ВИСШЕ СТРОИТЕЛНО УЧИЛИЩЕ
"ЛЮБЕН КАРАВЕЛОВ"
СОФИЯ

UNIVERSITY OF STRUCTURAL ENGINEERING
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Д О К Л А Д И

XIV МЕЖДУНАРОДНА НАУЧНА КОНФЕРЕНЦИЯ ВСУ'2014
5 – 6 юни 2014 г, София, България

ТОМ I

VOLUME I

P R O C E E D I N G S

14th INTERNATIONAL SCIENTIFIC CONFERENCE VSU'2014
5 – 6 June 2014, Sofia, Bulgaria

София / Sofia
2014

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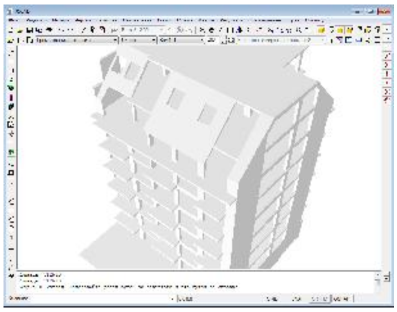

Proektsoft was found in 2008 by MSc Eng. Nedelcho Ganchovski. Main company activities are focused on the development of structural design software. Most structural engineers prefer our products PSCAD and Design Expert because they are practical, reliable and easy to use. We have over 500 users in Bulgaria like Lukoil, Argogroup, Markan, EQE Bulgaria, Niproruda etc. Since 2012, the English version is distributed in different countries in Europe, Africa and Asia, thanks to our international partners. On the other hand, Proektsoft distribute other CAD systems in Bulgaria for architectural, mechanical, electrical and HVAC and piping design.

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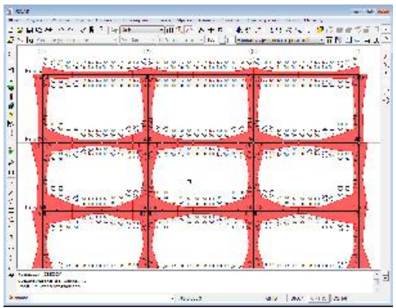

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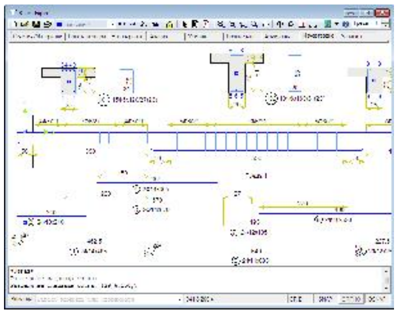

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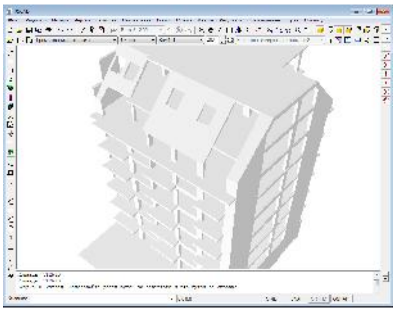

Проектсофт ЕООД е основана през 2008 г. от инж. Неделчо Ганчовски, с основна дейност - разработване на софтуер за проектиране на строителни конструкции. Нашите продукти PSCAD и Design Expert са предпочитани сред българските проектанти заради тяхната практическа насоченост, лекота на работа и високо качество. Към настоящия момент, програмите се използват от над 500 проектантски бюра и фирми, между които Лукойл, Аргогруп, Маркан, ИКюИ България, Нипроруда, Мостконсулт, БИАС-М и др. През 2012 година, софтуерът е преведен на английски език и се разпространява в редица държави от Европа, Азия и Африка, благодарение на нашите чуждестранни партньори. Проектсофт е дистрибутор и на други CAD системи за базово и специализирано проектиране в области като архитектура, машиностроене, ел. инсталации, ВиК, ОВК и др.

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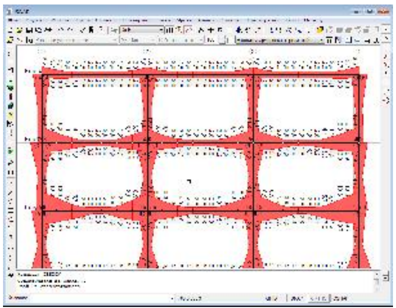
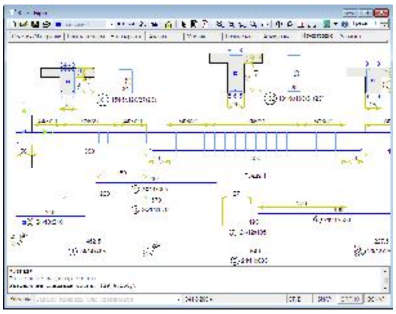
PSCAD и Design Expert са предназначени за цялостно проектиране на Ст.Б. и стоманени конструкции в съответствие с Еврокод. Програмите обхващат всички етапи от процеса на проектиране:



- Изграждане на пространствен геометричен модел на сградата чрез параметрични обекти;
- Автоматизирано генериране на кофражни и монтажни планове, разрези и изгледи, включващи необходимите оси, размери и коти;
- Генериране на мрежа крайни елементи и статико-динамически анализ на конструкцията по МКЕ;
  Отпечатване на подробни изчислителни записки на български език, съдържащи всички необходими проверки;
- Оразмеряване на конструктивните елементи в съответствие с Еврокод и изискванията за капацитивно проектиране;
- Автоматизирано конструиране и изчертаване на армировките. Генериране на фигурни спецификации и количествени сметки за стоманата, бетона и кофража.

Проектсофт предоставя на своите клиенти безплатно обучение и техническа поддръжка за използваните софтуерни продукти. Програмите могат да се ползват безплатно от ученици, студенти и преподаватели в учебни заведения в рамките на учебния процес.



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I. ARCHITECTURE.
URBAN PLANNING AND URBANISM.
ARTS AND CONSERVATION OF
ARCHITECTURAL HERITAGE

THIRD GENERATION IN PLANNING THE CULTURAL HERITAGE FUTURE

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Abstract*: Experience has shown that spatial and urban plans effectively preserve characteristics of land use - providing space for built and natural heritage, but do not foster their development role. In practice, conservation planning reflects views of experts and it is not always in accord with values and interests of a local community and economic development imperatives. Serious inclusion of immovable heritage studies in urban and spatial plans emerged in the 1970s, but the problem of abstracting social role and economic feasibility of heritage preservation remained. This approach generated the first generation of plans. The second generation of plans has taken into account social significance, focusing on urban renewal with a heritage component. Using investments in immovable cultural property, as catalysts for economic development of the wider area, has been applied in the third generation of plans. This approach implies that management planning shares equal responsibility with spatial and town planning in developing full economic potential of the area. The third generation of management plans is necessary for operationalizing objectives of spatial and urban planning for communities willing to live in accordance with the requirements of our time.*

Key words*: heritage, management, planning, development, cultural heritage*

1. Introduction

A heritage management plan is obligatory for every heritage site nominated for the World Heritage List. Cultural heritage management plans are the management plans used to secure preservation of values which originally defined the asset as a cultural heritage site. Management plans are not used for cultural heritage only; they are used for natural and mixed heritage sites, as well.

Numerous terms are used to mark the same or similar plans, according to legislation of the country or province of origin: Heritage Management Plan (HMP), Conservation Management Plan (CMP), Heritage Management Strategy (HMS), Master Conservation plan (MCP). Term „Conservation Management Plan" is used by the World Bank Global Heritage Fund and it is an exception from the rule. GHF also uses name „Master Conservation Plan", for the document which includes both Conservation plan and Management plan. Strategies are used when input data is not complete, as well as in the cases when it is required to define rules for several similar sites, or when a site has local

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significance, or has national significance but small interventions are required, or for a bridging period until the standard plan is completed. Heritage site management strategy is a shorter version of the plan, created to provide a general overview of an approach to preservation and management in a particular case.

The intention is to provide a brief insight in the following issues of heritage management planning: its use for the cultural heritage sites with less than „outstanding universal value", place of the third generation management plan in the planning process and the key advantages of the third generation heritage management plans for the society..

2. History

World Heritage List (WHL) has been established by the World heritage Convention (1972), which has received the widest support of UN member states, proving worldwide confirmation of its role in preservation of world heritage. The Convention is considered to be a turning point in the international practice of protection of cultural and natural heritage, as it provides a legal framework for launching international campaign for the protection of heritage, pointing out the problem of preserving a built heritage resource to the worldwide public. If heritage site is inscribed in the World Heritage List (see figure 3), the World Heritage Committee has the legitimacy to undertake an emergency response for the protection of the heritage site, which in some cases is crucial for its preservation. Designating a site as the world heritage, in most cases enables its efficient protection. Registering in the national or local heritage lists of immovable cultural and natural resources has a similar effect. That same year, when the World heritage Convention was announced, UNESCO adopted Recommendation on the protection of cultural and natural heritage, and it emphasized that every heritage site on the List must have an adequate management system and management plan. "The purpose of a management system is to ensure the effective protection of nominated property for present and future generation". [9] UNESCO Recommendation refers to the natural and cultural heritage, as well as mixed heritage [10].

Considering that management plan is obligatory for nomination of heritage sites for World Heritage List (WHL), according to the World Heritage Convention (1972), UNESCO offered many publications about this subject (see Fig. 1.).

Management plan: Contents
– Purpose
– Process (how it was prepared and who was involved), including a decision-making process diagram
– Property description
– Significance (with OUV for World Heritage sites)
– Identification of key issues
– A Vision Statement/guiding principles, policies/objectives
– Actions to meet policies/objectives (including timing, priorities, resources and indicators)
– Implementation plan; annual work plan, project formulation, indication of resources
– Monitoring plan
– Timetable for review

Fig. 1. Standard Management plan content for single heritage site [11]

2. WHL and Non-WHL Cultural Heritage Management Plans

According to Operational guidelines of World heritage convention (2013), it is left to the nominating country to offer management plan or equivalent plan, or strategy, as evidence that outstanding universal value (OUV) will be preserved. Value is the central issue of any management plan (see Fig. 4.), and in case of cultural heritage, it may be of local, national or international significance. Three pillars of recognizing and claiming OUV means that property meets (1) one or more World heritage criteria (see Fig. 2.), condition of integrity and authenticity if relevant, requirements for protection and management[5]. Significance of heritage site corresponds with the hierarchical competency of a particular conservation service, and the scope of those involved in the process. Understanding and defining OUV is a prerequisite for achieving a cultural impact on the international public in accordance with the objective significance. Similarly, value for the local community is the subject of analysis and a precondition of achieving a cultural impact, in line with the potential.

Extract from the *Operational Guidelines*

77 The Committee considers a property as having Outstanding Universal Value (see paragraphs 49-53) if the property meets one or more of the following criteria. Nominated properties shall therefore :

(i) represent a masterpiece of human creative genius;
(ii) exhibit an important interchange of human values, over a span of time or within a cultural area of the world, on developments in architecture or technology, monumental arts, town-planning or landscape design;
(iii) bear a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or which has disappeared;
(iv) be an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history;
(v) be an outstanding example of a traditional human settlement, land-use, or sea-use which is representative of a culture (or cultures), or human interaction with the environment especially when it has become vulnerable under the impact of irreversible change;
(vi) be directly or tangibly associated with events or living traditions, with ideas, or with beliefs, with artistic and literary works of outstanding universal significance. (The Committee considers that this criterion should preferably be used in conjunction with other criteria) ;
(vii) contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance;
(viii) be outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features;
(ix) be outstanding examples representing significant ongoing ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals;
(x) contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of Outstanding Universal Value from the point of view of science or conservation.

Fig. 2. WHL Criteria [9] [11]

Possibility to use an alternative plan for WHL site, which formally, but not essentially, replaces a heritage management plan, was offered to align UNESCO requirements with existing legislative framework of state party, which appears useful in practice. However, in some countries, heritage management plans have much broader use. They are applied for all cultural heritage sites of national, sub-national and local significance, and may be applied whenever cultural values should be preserved and integrated into the social and economic flows, even if an asset is not designated as a heritage site.

In favor of broader use of heritage management plans, important initiatives came from Australian branch of ICCOMOS, following the Burra charter [2]. After that, the concept was accepted among other members of the Commonwealth and in the USA. Most importantly, the novelty included a more thorough research of value, and its meaning for a local community. 'Conservation Management plan' appeared in the Australian legislation, based on the revised Burra Charter from 1999 [1]. The Burra Charters (original and revised) gave priority to the process of decision making over the application of formal rules, thus setting value in the centre of the conservation process. Subsequently, founded on the Charter principles, James Kerr wrote a practical guide for conservation management planning in Australia, which led towards its being well accepted in practice [2]. That document defines what is important at the site, and therefore, sets policy which is convenient to be applied for preservation of what is important for the future use and development [2].

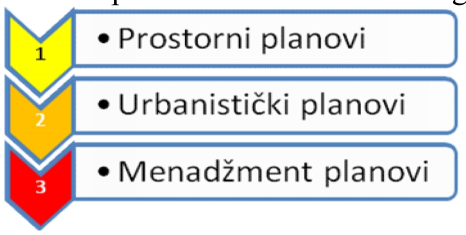
Fig. 3. Areas where Heritage management plans are obligatory (states are marked dark blue and World Heritage Sites as grey dots) [2] (alternations by authors)

4. Place of the third generation management plan in planning process

In the Recommendations [10], it is stated that management plans as well as conservation plans should be harmonized with regional and town plans, by heritage preservation authority. Any work that might result in changing the existing state of the buildings within a protected area should be subject to prior authorization by the town and country planning authorities, relaying on the expertise of the specialized services, responsible for the protection of the cultural and natural heritage. "Management systems may incorporate traditional practices, existing urban and regional planning instruments, and other planning control mechanisms, both formal and informal" [9].

Experience has shown that the regional and town plans are effective in preserving land use - providing space for immovable cultural heritage, but not for fostering their development role. The management plans are an essential step in the operationalization of the objectives of regional and town planning.

TARGET: Sustainable preservation of built heritage



Operationalization

Fig.4. Planning process

Role of management plans has evolved and expectations significantly increased since1970s. The first generation of heritage projects focused on urgent preservation, disregarding costs and community demands. Management plans focused on single heritage sites, though they were expected to be consistent with regional and town plans. Despite inclusion of immovable heritage studies in the regional and town plans, the problem of taking into account demands of different stakeholders remained. In practice, conservation planning reflected the attitude of experts, which often was not aligned with the values and interests of the local community or interests of economic development. Therefore, the second generation of plans, being influenced by collaborative planning and embracing social significance of the issue, has focused on urban renewal with respect to cultural monuments preservation and presentation, as its component. Simultaneously, after 1980s, global economical issues raised awareness about economic feasibility of cultural heritage projects. In time, this disclosed the economic potential of the cultural heritage projects, which was originally considered less important. The third generation investment in immovable cultural property is considered to be a catalyst of economic development of a wider area. Such goals have been achieved by the third generation of plans, which imply management planning that shares equal responsibility with regional and town planning. The number of the third generation cultural preservation projects has increased rapidly in the XXI century. The Chinese experience serves as a good example of it. From 1993 till 2013 the government of China initiated investment of 1.323 billion US$ in 12 heritage projects. Those projects included all three generations of approach (3 projects belong to the first generation of projects, with focus on urgent preservation, 3 projects belong to the second generation of projects of urban renewal with a cultural component, and 6, created after 2004, belong to the third generation of projects). They reflect an integrated and broad-based approach which "addresses (1) broader urban and regional environment of historic cities and sites (2) province-wide cultural heritage conservation and tourism development that involve multiple sites, and (3) strengthen links between heritage conservation and local economic development" [3]. Actual challenges of economic development include actions "to: a. Maximize economic benefits of heritage conservation b. Leverage traditional knowledge for smart growth and energy conservation c. Strengthen the integration of cultural heritage conservation and tourism development (and) d. Recognize the cultural heritage conservation as an asset for creative industries" [3].

The analysis of Serbian heritage management system, regarding planning process, reveals the following. In Serbia, management plans must be made for cultural heritage sites accepted on UNESCO World Heritage List, as well as for those which are relevant for regional and European common heritage, which arises from the membership of Serbia in the UN, the Council of Europe and from other international commitments. There are four heritage sites from the territory of Serbia on the WHL: Old Ras and Sopoćani, Studenica monastery, Palace of Galerius - Gamzigrad / Romuliana and The medieval monuments in Kosovo (inscribed on "red list" of endangered cultural heritage, in accordance with Article 11 (4) of the World Heritage Convention (Paris, 1972 17:10 to 21:11), as well as 11 sites at the provisional list, (until the last revision 07/05/2011): Caričin grad - Iustiniana Prima, Djerdap National Park, Fortified Monastery Manasija, Historical city of Bač and its surrounding, National park Tara with Canyon of Drina, Negotin breweries, Smederevo fortress, Stećak medieval tombstones, Deliblato Sands Special Natural Reserve, Đavolja varoš. In Serbia, built heritage planning is based, on one hand, on consideration of the immovable cultural and natural heritage site land use demands, at all levels of regional and town planning, and on the other hand, on the detailed planning of conservation interventions, including the preparation of conservation plans. The regional and town plans are well established in the Serbian legislation since 1970s (currently by Law on Planning and Construction of the Republic of Serbia adopted in 2011), while conservation plans are mostly considered professional necessity, which do not require particular definition by law. However, management plans (should) contain additional regulations, not enclosed in the previously mentioned plans, for example some regulations at the level of town planning (those related to cultural heritage outside protected area) and urban design, as well as thorough economic feasibility features, among others. Management plans bridge the gap between regional/town planning and preservation of the architectural heritage, in terms of economic development. The reason for this is that economic sustainability cannot be achieved at the heritage site itself and over 90% of income has to be collected in the surroundings of the protected area.

5. Concluding remarks: The key advantages of third generation management plans for the society

The conservation service generally determines the cultural value of heritage, but rarely estimates the value of the public "benefit", educational value and the measure of utilitarian value for society. Since the 1990s, evaluation of built heritage sites is analyzed in a framework of economic theory, in order to determine the economic potential and investments required for presentation, interpretation and maintenance of the site. The problem belongs to the field of culture economics, which takes advantage of numerous methods, originally developed for natural resource management [8] [9]. The economic evaluation has been fully supported by Faro Convention (2005) [5], which framed European policy for cultural heritage, based on positive benefits accumulated from use of heritage as the cultural capital. This document has given full legitimacy to the economic revitalization of cultural heritage, without degrading other values of importance to the society. Economic evaluation of built heritage as the cultural capital continues to occupy an important place in urban development, and in the international doctrine of cultural heritage. The cultural heritage management plans are important not only for the heritage sites of international significance, but for those relevant for national and sub-national level and whenever sustainable development is required. Furthermore, heritage management planning of the third generation provides so far, only, an internationally accepted methodological, institutional and legislative framework for treating built heritage as catalyst for socio - economic development.

Acknowledgement

This paper has been undertaken after part of the Project 36042 supported by Ministry of Education, Science and Technological Development of Serbia.

REFERENCES

[1] The Burra Charter, The Australia ICOMOS Charter for Places of Cultural Significance, 1999, retrieved from: http://www.heritage.tas.gov.au/media/pdf/The%20Burra%20Charter%201999adopted.pdf on April 4. 2014

[2] Clark K, Value-Led Planning for Cultural Heritage Sites, The GCI Newsletter, Volume 16, Number 3., 2011 pp 7-10

[3] Ebbe, Licciardi et Baeumler, Conserving the past as a foundation for the future, China-World Bank Partnership on Cultural Heritage Conservation, 2011

[4] Faro Convention - Framework Convention on the Value of Cultural Heritage for Society, 2005, retrieved from: http://www.coe.int/t/dg4/cultureheritage/heritage/identities/Faro-brochure_en.PDF on April 4. 2014.

[5] Heritage conservation management plan, retrieved from: http://whc.unesco.org/archive/opguide13-en.pdf on April 4. 2014.

[6] IUCN, Management planning for Natural World heritage Properties. A Resource Manual for practitioners. Gland, Switzerland, IUCN Programme on Protected Areas (IUCN World Heritage Studies 5.), 2008. retrieved from: http://cmsdata.iucn.org/downloads/whmanagement.pdf on April 4. 2014.

[7] Kerr, J Conservation plan. A guide to the Preparation of Conservation Plans for Places of European Cultural Significance, 7th edition, 2013. ICOMOS Australia

[8] Nijkamp P., The Economics of Uniqueness, Investing in Historic City Cores and Cultural Heritage Assets fpor Sustainable Development, Licciardi Guido i Amirtahmasebi Rana (ed), 2012, p97

[9] Operational guidelines of World heritage convention, retrieved from: http://whc.unesco.org/archive/opguide13-en.pdf on April 4. 2014.

[10] Pagiola S, Economic Analysis of Investments in Cultural Heritage: Insights from Environmental Economics, Environment department, World Bank, June 1996.

[11] Wijesuriya et al. Managing Cultural World Heritage, ICCCROM, ICOMOS, IUCN, UNESCO WHC, Rome, Paris

INTERVENTION METHODS ON RESTORATION OF WOODEN CHURCHES. CASE STUDY – THE "ST. NICHOLAS" WOODEN CHURCH FROM PRISACANI, BOTOSANI COUNTRY AND THE "ST. GEORGE" WOODEN CHURCH FROM VOROVESTI, IASI COUNTY

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***Abstract**: Being seen as having a temporal dimension, historical monuments represents certain traits of a society: accumulation and economic development, political stability, high level of creativity and cultural dialog. The purpose of the study is to analyze and to establish types of possible intervention on wooden churches from the perspective of protecting its historic values. This study uses as case studies two wooden churches situated in North East Romania: "St. Nicholas" wooden Church from Prisacani, Botosani County and "St. George" wooden Church from Vorovesti village, Miroslava commune.*

***Key words**: monuments, wooden church, cultural heritage, restoration*

1. Introduction

Being seen as having a temporal dimension, historical monuments represents certain traits of a society: accumulation and economic development, political stability, high level of creativity and cultural dialog.

The purpose of this study is to analyse and to establish types of possible intervention on wooden churches from the perspective of protecting its historic values.

According to the Historical Monuments List for Botosani County, "St. Nicholas" wooden Church from Prisacani is situated at no. 457, code BT-II-m-B-02006 and "St. George" wooden Church from Vorovesti village, Miroslava commune, is situated at no. 1537, code OS-II-m-B-04270, according to the Historical Monuments List for Iasi county.

2. A Brief History

The church from Prisacani was built in 1656 by Nicolai Stratulat, who, in those times, was the owner of the Prisacani village and estate. Initially it was built from logs and covered with reed and straws. Falling into ruins in 1861, the priest from that time repaired it and covered it with shingle. The next thorough repair job was made in the year 1881 on the expense of the parish, according to the inscription from the icon to the left of the imperial doors.

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The Vorovesti hermitage is believed to be established in the mid XVII century. In the year 1768, as the inscription from the gateway at the entrance attests, the village priest builds the „St. George" Wooden Church, in modest proportions due to the relatively small number of villagers.

3. The Architecture of the Churches

3.1. The Architecture of the Church from Prisacani

The church preserved *a basilica plan* consisting from a single large nave, with an eastern apse. The access is situated on the southern side in a exonarthex of oak forks with plank walls. The motivation for building the exonarthex consists in protecting the access in the church, creating a buffer space protected against weather. Thus conditioned the veranda is situated on the southern side generating a rectangular shaped plan. Above the exonarthex the belfry is located, having a rectangular shape and covered by a dome roof.

The nave, in a rectangular shape, is lit by two windows placed right by the stalls.

The altar is separated from the nave by a lime wood iconostasis consisting of three rows of icons.

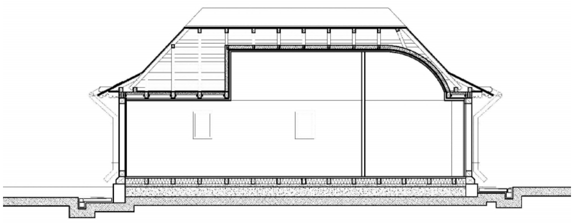
The arch that covers *the altar* is shaped as a spherical cap padded with planks. The rest of the wooden slab is horizontally padded with fir planks (deals).

The wooden church has small, rectangular *windows. The construction technique of the church walls* is similar to the one of the wooden houses. The walls are made of beams, round or carved, attached in "*loops*" or in "*swallow tail*", the clamping system being unitary at the scale of the entire monument.

a)

b)

Fig. 1 a) Prisacani Church ; b) East façade of Prisacani Church;
(photo and drawing by A. Cehan)



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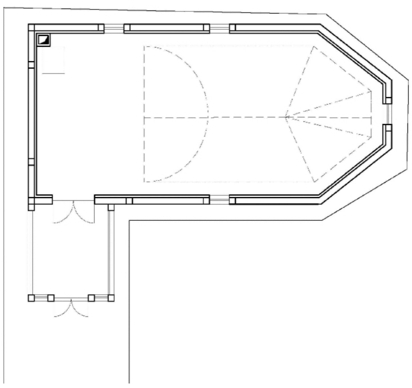


b)

Fig. 2 a) Section through Prisacani Church; b) Plan of Prisacani Church;
(drawings by A. Cehan)

So in the case of the churches built on levelled ground, but mostly in the case of the ones built on more or less uneven terrain, a stone base was built on *which the sole of the church* sits, a massive beam which exceeds two times the thickness of the construction material from the walls. This sole is continuous only along each wall and has a bevelled outer edge.

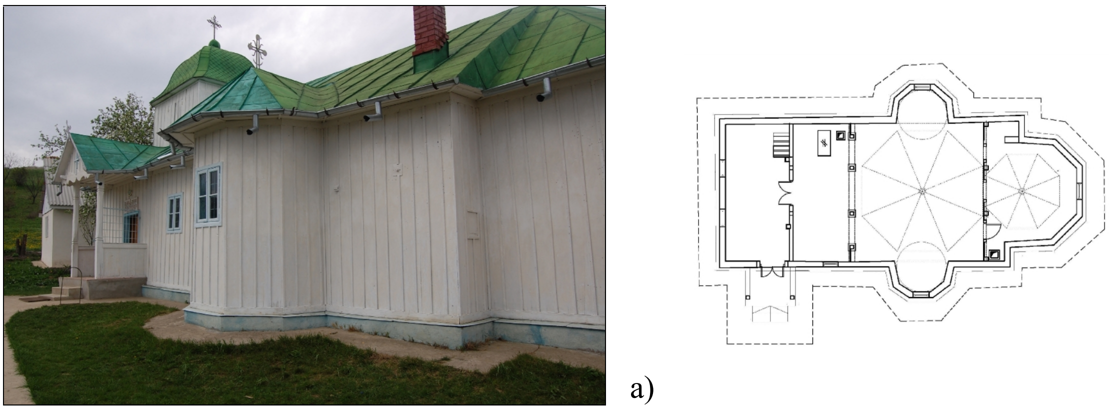
In Prisacani church case a combined covering system of the space was realized, in the same affirmed intention of restoring spatiality and grandeur to the interior through increasing the verticality, using skillfully the *wooden vaults*.

The straight ceiling is found on small areas, like the ones from the entrance area and from the intersection areas between the vaults and the walls. Also areas with straight ceiling can be found in the areas between the compartments making connection among the various structural elements.

The vault is the original system of church covering. It is born on a polygonal contour and it is being used especially in the spaces of the altar and the nave that have almost a square shape. The arched vault constructively imposes the presence of the support arches; depending on the angle of the arching, it comes close to the shape of spherical calotte. The closing of the semicylinder to the east and west is made by using some curved strips.

The church never had mural paintings in the interior. The walls are covered with Rabitz plastering and painted in colors with whitewash.

3.2. The Architecture of the Church from Vorovesti



a) b)

Fig. 3 a) Vorovesti Church b) Plan of the Vorovesti Church
(photo and drawing by A. Cehan)

The church conserved a triconic plan with polygonal apses, the access being performed on the southern side through the exonarthex. Well-proportioned altogether, the church distinguishes through a rigorous symmetry.

In the side apses and in the apse of the altar similar windows with reduced dimensions can be found, the altar gaining space by the advanced arrangement of the iconostasis from the limit of the apses.

The nave, in a square shape, is widened to the north and south through two symmetrical polygonal apses, which have a window on the direction of the axes.

The narthex is separated from the nave through 4 pillars on which a beautifully crafted in local motives wide beam sits.

Through a crossing opening, one might enter the closed exonarthex which has two windows on the western side. The exonarthex holds the access to the belfry.

The access in the church is made on the south side through a gateway crowned with an inscription and surrounded by an open exonarthex.

The wooden church of the XVIII century has small, rectangular shaped windows. The beams ensure with their length, the walls between alignment variations. The alignment variations are made from short, rounded or carved beams attached in "loops" or in "swallow tail", the clamping system being unitary at the scale of the entire monument. The trefoil plan of the church generated an expansion of the nave, and on the other hand the possibility of growing in length through the accentuation of the rectangular shape of the construction. The interruption of the walls through the side apses lessened the burden of the builder regarding establishing the dimensions of the building material. The polygonal contour of the side apses offers the possibility of adjusting the space according to the length of the segments, proportional to the segments of the altars apse and the rectangular nave.

The stone socle on which the sole of the church sits is a massive beam. This sole is continuous only along each wall and rarely does it have a rounded or bevelled outer edge, sometimes with clippings or decorative elements.

In contrast to the sole, which runs only up to the place of the intersection of the walls, the beam and console package of the purlin take over beyond the functional burden, and generate different areas of decorative volumes where cuts in the retraction, simple or double articulations, surface decorations in incisions or polychrome handling can be found.

In the case of wooden churches, unlike the Romanian traditional houses, a combined covering system of the space was realized, in the same affirmed intention of restoring spatiality and grandeur to the interior through increasing the verticality, using skillfully wooden vaults in the attic. The straight ceiling is found on small areas, like the ones from the entrance area, in the areas connecting the vaults to the walls. Also, a straight ceiling can be found in the areas between the compartments making the connection among the various structural elements.

The narthex and the side apses do not have a vault but a straight ceiling made of painted planks.

The vault is the original system of church covering. This is born on a polygonal contour, overlapping to the interior, in equal withdrawal beam successions with bevelled heads, to the realization of the keystones. It is practiced especially in the near square shape spaces of the altar and of the nave. The arched vault imposes constructively the presence of the support arches; depending on the angle of the arching, it comes close to the shape of spherical calotte.

4. The conservation state – causes of the degradation

The integrity and the structure of churches, regardless of their nature, can be affected over time by various environmental factors, reason why one of the important functions is conserving and restoring them, preventive activities trying to shelter cultural assets.

Among the risk factors that can cause damage must be mentioned: the human factor, biological factors, physical-chemical factors, natural disasters. All these factors influence in a different manner the integrity of the construction materials, the most sensitive being the ones which have an organic nature, like wood.

The human factor is, most of the times, the main cause of the degradation of the cultural heritage.

The biological factors that can affect, especially the organic materials, are fungi (mould, for example), rodents and insects. Mould exists everywhere in nature, but it develops especially in humid, warm, dark and unventilated environments. It's the reason why the humidity and temperature of interior spaces must be controlled permanently.

The physic-chemical factors of the environment which can influence the health state of objects are: temperature, humidity, light, air, oxygen, wind, salinity and pollution. All these act greater on parts that are exposed outdoors. Humidity affects most of all, especially wooden objects and paintings. Stone and metals are affected at a much smaller extent. The term "microclimate" is often used in the language of conservation, and represents the totality of the temperature and humidity conditions of an area or of a space. What is very interesting is the fact that buildings adapt to the microclimate, and their extraction from the environment with which they are used to, can be dangerous for their health.

Unfortunately uncontrollable, being able to damage seriously cultural goods, are natural disasters (earthquakes, floods, hurricanes) with everything they entail. Although these catastrophes are uncontrollable, some preventive measures that mitigate their effect can be taken. Earthquakes can affect the integrity of some fragile cultural goods.

4. Intervention works

When restoring there are some basic rules, generally valid, regardless the material the object is made of: the original parts are fully preserved, even if they are damaged; the new parts added to complete the object must be made of materials compatible with the original ones; the materials used in restoration must be *reversible*, therefore to permit the return to the original form or a new restoration; completions are not made when more than 50% of the object is missing; restoration tries to bring the object to a state that expresses functionality.

The first stage through which the piece goes through is the physical-chemical and biological investigation which aims to establish when and why the church was damaged. Subsequently the restoration methods are established.

We must specify that the principle which sits at the base of the entire conservation and restoration activity is the recovery of as many original elements as possible from the church with the condition that the ones that have a structural role to be viable, therefor capable to keep the edifice standing.

As is well known, in the case of wooden churches, and especially that of representative monuments, constituent elements are also structural.

This aspect makes the restoration process very difficult, any substitution or omission being completely excluded. In other words, the whole church is a structure. The only elements that escape the physical rigors of gravity are ornamental elements. Even though in terms of symbolic meaning they are integrated in the ensemble.

Applying the above principle, we looked to apply solutions that permitted the use as a material for the restoration of the pieces that needed only partial replacements or consolidations of some fragments of the historic wood that remained from the original pieces, totally structurally compromised. Thus the transversal beam of the altar was strengthened and recovered; the ribs (arches) of the vault of the nave which were found in situ were broken. Of course, many beams in which were found caverns, were restored and strengthened by replacing the compromised material with a good one, without changing in any way the original appearance.

The roofs frameworks of the churches were made more recently, thus the complete replacement was necessary, also the shape and the covering sheet metal.

The roof structure won't have a master-beam or any other intermediate support beams. The northern and southern rafters, two by two, have been placed on the interior side of the roof structure and then fixed with wooden nails to the roof ridge and wind-braces in the upper third, resulting in an A-shaped ensemble. The reinforcing of the structures was made through combining in the same point (the crest) the rafters from the east with the first pair of the ones from the north and south. An additional reinforcing element is constituted by the wide laths which bind horizontally the rafters to each other and on which the shingle will be fixed.

It must be noted that it was closely followed that, both to the realization of the pieces that have been replaced and, in general, in the reassembling process of the edifice were used only original techniques and methods, in other words, it has been operated in an age-appropriate spirit. Thus, only oak and acacia wood nails were used for joints, the iron ones with which the unprofessional interventions from the last decades were made being eliminated.

One of the difficult problems of church restoration was the restoration of *the oak soles* of the churches. A restoration of the soles and their joint system was made after studying other monuments and consultations with the traditional craftsman working today. Only such we manage to figure out an essential aspect regarding the joints system of the soles: the connection between them was not made using straight blending, but in the "swallow tail" system, the double inclination of the cutting ensuring the contraction of the flaring tendency of the inferior part of the construction. This was especially relevant as should be considered the poor quality of the foundations made in ancient times only from river rocks or masonry dried stones.

REFERENCES

[1] Sandu I., G. Ioan, Aspecte privind conservarea bunurilor culturale, Nomenclatura, tipologii si cauzistici, Ed. Performantica, Iasi 2005 (in Romanian)
[2] Sulea M., O. Carabele (editors), 60 biserici de lemn. Stramutarea bisericii din Pojogeni, Editura Simetria, 2009 (in Romanian)
[3] Godea I. ,Biserici de lemn din Europa, Ed. CD Press, Bucuresti 2008 (in Romanian)
[4] Bals G., Bisericile si minastirile moldovenesti din veacurile al XVII-lea si al XVIII-lea, Bucuresti, 1933 (in Romanian)
[5] Ionescu G., Istoria arhitecturii romanesti, Bucuresti, 1937 (in Romanian)
[6] Bals G., Bisericile lui Stefan cel Mare, BCMI, XVIII, 1925 (in Romanian)
[7] Brandi C,. Teoria restaurarii, Ed. Meridiane, Bucuresti, 1996 (in Romanian)

CONSOLIDATION – RESTORATION OF THE STONE CHURCH DEDICATED TO "THE ANNUNCIATION", CORNESTI VILLAGE, IASI COUNTY

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Abstract: *Historical monuments are a temporal dimension; numerically and in value they represent certain traits of a society: accumulation and economic development, political stability, high level of creativity and cultural dialog. Attested by history, monuments overlap different eras, assuming objective interventions determined by positive or negative events and conducted by more or less skilled people.*
The purpose of the study is analyzing and establishing a series of possible interventions concerning the Stone Church from Cornesti Village, Miroslava Commune, Iasi County dedicated to "The Annunciation" and "Saint Vasile the Great" from the point of view of architectural values.

Key words: *monuments, stone church, cultural heritage*

1. Introduction

Historical monuments are a temporal dimension; numerically and in value they represent certain traits of a society: accumulation and economic development, political stability, high level of creativity and cultural dialog. Attested by history, monuments overlap different eras, assuming objective interventions determined by positive or negative events and conducted by more or less skilled people.

The purpose of the study is to analyse the potential of the intervention concerning the Stone Church from Cornesti Village, Miroslava Commune, Iasi County dedicated to "The Annunciation" and "Saint Vasile the Great" from the point of view of architectural values.

According to the Historical Monument List for Iasi County, the Stone Church from Cornesti Village dedicated to "The Annunciation" and "Saint Vasile the Great" can be found at no 1348, code IS-II-m-B-04130**.**

The Cornesti Village is situated on the valley between two hills, 10 km to the West of the city Iasi. This village was founded at the beginning of the 19th century, when Constantine Anghel, father of the writer Dimitrie Anghel, brought peasants from Italy to do farm-work on his estate from Cornesti. From these peasants remained the name of one hill situated on the outskirts of the village – "Taliens". In this village, the Archbishop Filaret Beldiman built in 1833 a church made of stone and brick dedicated to "The Annunciation" and "Saint Vasile the Great".

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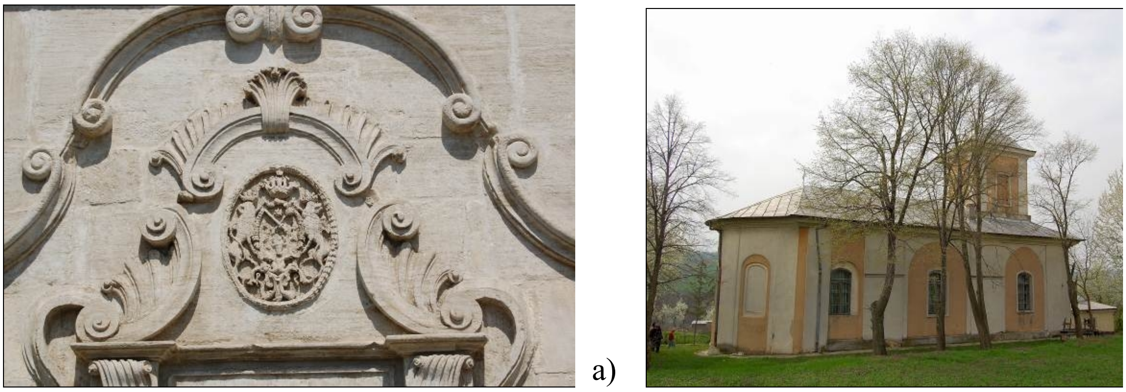
In 1836, the church was consecrated by the Bishop Filaret Beldiman with the blessing in commemoration to the Metropolitan Veniamin Costache. Between the years 1911-1913, the church was repaired radically and got today's shape, by the endeavour of the trustee and caretaker of those times, Lazar Condrea. In 1956 repairing works were conducted again, renewing the foundation and the interior of the church. Towards the end of 2007, a new steeple was built outside the church, diagonally to the Holy Shrine.



a) b)

Fig. 1. a) the inscription above the church's entrance ; b) The Stone Church Dedicated to "The Annunciation", Cornesti Village; (photo by A. Cehan)

2. The Structure of the Church.

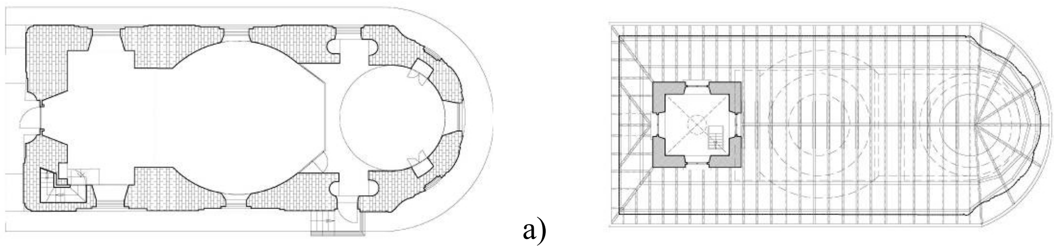
2.1. The Inner Shapes

The church consists *of naos, narthex* and *altar* and has been built after a *basilica plan* which is slightly larger in the sinus area (Fig. 2).

The semi-circular *altar* is covered with a hemispherical vault supported by pillars. Here, on the east axis, there is a single circular window, the other two being false and only visible on the outside. Also in the altar there are two large niches, one being the Prothesis apse and the other one the Diaconicon apse. The altar is separated from the nave by a transverse arch in which the iconostasis is mounted.

The nave, a square prolonged with lateral springs, is covered with a simple dome vault, supported by pendentives, arches and pillars placed in the walls. In the axis of the side apses there are two windows. The nave is separated from the narthex by a transverse arch and by attached pilasters (Fig. 2).

The narthex is vaulted with a half cylinder from south to north.



a) b)

Fig. 2. a) plan of Cornesti Church; b) Roof plan (Belfry); (drawings by A. Cehan)

The belfry (Fig. 2) is above the narthex. The current layout of these towers comprises a short partition - a low height room - at the first cat, lit by narrow little windows like ramparts. This chamber serves as a hideout, as a safe place for church vestments and as a chamber for defence. Above comes the bells bower which is covered only by the roof framing.

From the staircase there are entries in the attic of the church that also could be used as a hideaway if necessary. The belfry is built out of bricks, with open windows which follows the Byzantine style.

2.2. The Exterior Shape

The entrance into the church (Fig. 1 a) is directly in the narthex through a door onto the west wall. The door is made of built oak and iron plate and framed with iron. From the outside the geometry of the plan of the church is very simple, variating only by the apse of the altar.

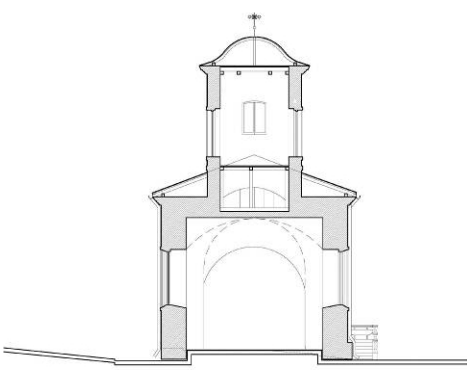
As features of the 17th and 18th centuries are those little protrusions, too small to play the role of buttresses, compensating their presence only by thickening the inner carving of the lateral apses, rising up to the eaves.

The outer clothing of the church hides the side apses of the interior, but they are marked onto façades by vertical registers (Fig. 1 b).

The roof has double roof framing with galvanized roofing sheet. The church is surrounded by a cornice made of several mouldings rows.

The socle is made of stone and pillars attached to the wall rest on it. The windows are surrounded by embossed frames made of plaster.

On the exterior the whole church is plastered and tinned with lime.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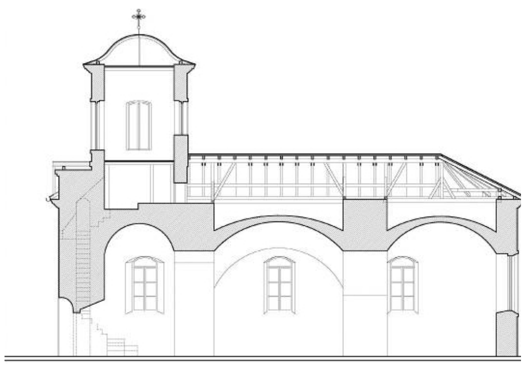
b)

Fig. 3. a) Cross section; b) Longitudinal section; (drawings by A. Cehan)

After a technical expertise of the current state of the building was found that **the church** showed degradation and damage to the structural system consisting in fissures, cracks and tears in the interior and exterior structural walls, respectively:

- cracks along the axis of the church (one along the longitudinal axis altar-narthex and one along the transversal axis defined by the two apsides);
- cracks in the nave;
- cracks on the entire height of the building;
- cracks developed over and under windows and openings;
- vertical and inclined cracks in the walls of the south façade;
- the run-out of interior and exterior plaster on the facade;
- fissures and cracks of the socle.

The vaulting system (arches, pendant, and vaults) of the church shows run-out and cracked plaster both on the interior and exterior. Cracks are also visible into the structural elements of the vaulting system.

Degradation and damage to the foundation system consists of fissures and cracks in the stone socle. The facades are damaged due to moisture which is concentrated at the bottom of the socle and also due to the narrow and non-operating pavement which is broken due to improper execution. Special degradation are concentrated in the structural voids of the walls. On the north façade the entrance level (establish as ground ±0.00) was lifted with approx. 1.00 m to the initial ground thus generating damages into the socle of the church and allowing surface water to enter the base and elevation of the structural brick walls.

The roof structure is made of rounded fir wood of recent date, but poorly implemented according to current requirements and regulations.

Remarkable thick plaster layers arranged in time and series of interventions for pointing the masonry of the socle with cement mortar are to be noticed.

The water spouts are inadequate or missing.

The steeple (belfry) shows serious degradations and damages over the entire surface of the brick masonry structural walls: developed cross cracks all over the walls; cracks in all of the flaring edges of the walls.

a) b) c)

Fig. 4. Photos during the physical study of the church (photo by A. Cehan):
a) serious degradation caused by multiple factors; b) the church with the plaster removed – masonry detail; c) the church with the plaster removed entrance detail

Probably after one of the last earthquake, the one in 1977, the tower bells were cast away and iron tie rods were built at the top of the bell tower, reinforcing steel metal bars, which currently are not strained anymore and do not satisfy the original purpose of providing mechanical strength and structural stability of the entire belfry height. The technical condition of the belfry requires emergency maintenance interventions to be carried out in order to strengthen, rehabilitate and repair the tower.

The causes of damages:

The damages of the structure resulted largely from three main causes:

- the structural strength was affected by several earthquakes that caused degradation of structural walls and the appearance of cracks in the transverse and longitudinal arches and dome;
- the quality of materials used for building the church;
- degradation produced by wear, weather, duration of exploitation general and local conformation, external actions and the nature of the foundation soil.

The roof and the rainwater collecting system are inadequate because the water system is poorly maintained and using downspouts throwers the water is discharged at the base of the building. The concrete pavement and the covered with cement plaster socle promotes capillary moisture. It affects the monument on all sides up to the height of 0.10 m ÷ 1.00 m.

On the exterior there is a noticeable evaporating salt efflorescence strip at the mentioned quota. Moisture infiltration was favored by the degradation of the roof. The water infiltrated and reached the pictorial layer and gave rise to numerous scraps and salt efflorescence. The lack of ventilation of the air during and after church officiating services promotes moisture condensation.

Improper interventions carried out over time have caused several degradations. The successive earthquakes caused severe damage to the church, and thus on the painting (bricklayers dislocations, cracks).

The degradation of masonry walls were visualized after removing the exterior plasters.

It has also been revealed the following:

- local degradation of finishing and exterior plasters due to excess moisture;
- water infiltrations through the roof;
- ceilings deterioration;
- local deterioration of finishes and interior plaster due to excess moisture;
- floors deterioration;
- damage and degradation of woodwork;
- the lack of accessories for both roofs: discharge channels, downspouts and gutters to collect water from precipitation;
- the lack of adequate vertical systematization for collection and removal of rainfall.

The implementation defects consist of the following:

- the use of improper wood elements in building the roof structure;
- usage of materials (brick and mortar) with low physical - mechanical characteristics for building brick masonry structural walls and floors; these materials were appropriate for the stages of building and then for execution of rehabilitation works carried out for repairing the damages caused by earthquakes.

At the same time, the following have been observed in wood floors and roof:

- the wooden floor beams are elastic, causing a feeling of insecurity on moving;
- in certain areas the wooden beams of the ceiling show higher deterioration due to rotting;
- the roof structure has been modified and improper interventions that have reduced the resilience and stability of it were made.

The roof no longer meet the special conditions of sustainability (for moisture, corrosion, biological action of microorganisms) because it separate two different environments inside and outside which have climatic variables.

3. Intervention works suggested in order bringing the building on normal operating parameters

The substantiation and intervention measures are divided into three categories:

a) Repairing measures for structural elements, which consist of remedying damages, so the items will be brought to at least their initial state (before the earthquakes occurred). These works do not significantly alter the strength, stiffness and ductility of the structure.
b) Rehabilitation and strengthening measures of structural elements and/or structural assemble by increasing the overall structural strength, stiffness and ductility of structural elements and/or by introducing of new structural elements;

c) recovery measures of non-structural components due to existing damages.

Measures of intervention consisting in repair and strengthening works on structural elements were finalized only after removing the plaster and viewing the existing degradations and failures (Fig. 4 a, b, c). Technical solutions were consistent with the state of degradation of these elements.

4. Conclusions. Measures for consolidating the structural and/or structural assembly, consisting of the following:

- repairing the deteriorated structural masonry walls by:
- local repairing works by rebuilding the brickwork in field and intersections with bricks and mortar;
- injecting cracks with cement paste or/and fluid mortar;
- possible reparation works of masonry walls with degradation: repairing cracks and dislocations in walls by rebuilding with brick and mortar and by providing concrete belts with concrete cores, if it is found that there are no possible links to poles in adjacent areas. This solution was also applied to the areas where inappropriate previous intervention works have been performed;
- some local concrete cladding, symmetrically placed have been provided so that the structural masonry brick walls would be dressed up, and a layer of the initial masonry have been removed so that the initial wall thickness remain;
- the doors and windows openings have been reframed with reinforced concrete frames
- tensioning the existent iron rods of the belfry and revising its anchor elements;
- repairing cracks and dislocations in masonry arches and spherical caps by injecting fissures and cracks with cement paste and fluid mortar;
- repairing and restoring the wooden floors of the belfry, if they can be repaired properly after removing the wooden skeleton of the bells;
- reconstruction of the roof framing by replacing the damaged elements and provision new ones (collar-beams, cross-bars, etc..), ensuring proper anchoring and support of structural elements proposed in the attic height, if they can be properly repaired in order to ensure stability and mechanical strength;
- repairing and rebuilding works of the parament of elevations in order to be similar to the original one. On the north façade the dressing soil has been scoured to a depth of approx. 1.00 m, and adequate sidewalks and rainwater harvesting gutters have been provided.

REFERENCES

[1] Sandu I. and Ioan G. Aspecte privind conservarea bunurilor culturale, Nomenclatura, tipologii si cauzistici, Ed. Performantica, Iasi 2005 (in Romanian)
[2] Sulea M. and Carabele O. editors. 60 biserici de lemn.Stramutarea bisericii din Pojogeni, Editura Simetria, 2009 (in Romanian)
[3] Godea I. Biserici de lemn din Europa, Ed. CD Press, Bucuresti 2008 (in Romanian)
[4] Bals G. Bisericile si minastirile moldovenesti din veacurile al XVII-lea si al XVIII-lea, Bucuresti, 1933 (in Romanian)
[5] Ionescu G. Istoria arhitecturii romanesti, Bucuresti, 1937 (in Romanian)
[6] Bals G. Bisericile lui Stefan cel Mare, BCMI, XVIII, 1925 (in Romanian)
[7] Brandi C. Teoria restaurarii, Ed. Meridiane, Bucuresti, 1996 (in Romanian)

ROMANESQUE CHURCHES AS A PART OF ROMANIAN ARCHITECTURAL HERITAGE

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Abstract: *The Romanesque architectural style is considered the first European integrated architectural style that left us valuable historical buildings. Looking through the historical connotations, artistic and technical aspects, historical monuments are also valuable documents and real testimonies of a period. It helps us and our future generations to memorise and understand the "concepts, social values" of our ancestors and the development of human society.*
Related to the complex problem of architectural heritage conservation, the study of Romanesque architecture represent the starting point for preservation of historic buildings. Therefore, this paper focus on the conception, materials and technologies used to build Romanian churches of 13th century, also the integration of main characteristics, decorations and aesthetic aspects of our architectural heritage.
The final aim is to determine the origins, originality and formation of the medieval Romanesque style in our country on the one hand. The actual state of the conservation of built heritage in Romania on the other hand.

Key words: *Romanesque architecture, historic building, built heritage, state of conservation, preservation*

Introduction

Romanesque architectural style developed in the first period of Middle Ages, and spread over the whole Catholic Europe between 9th and 13th centuries. Romanesque style presents significant regional variations because of the availability of materials, technologies and the aesthetic tastes. Therefore it became the first international ecclesiastical architectural style.

Romanesque churches give a general impression of simplicity and massive quality. They followed the basilica plan, often with three naves, characterized by thick walls, round arches, generally small and semicircular arc frames windows, sturdy piers and decorative arcading. The builders adopted the Roman building principles and methods in order to revive the Roman Empire and its culture, along with the integration of Carolingian and Byzantine elements. But the builders' problems were in providing a larger space for pilgrims and acoustics and fire resistance.

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To understand the origin and the formation of the Romanesque architecture in the Carpathian-Danubian territory, a look back to the historical and political events of the period that followed the withdrawal of Roman legions to south Danube (3th century) and the formation of Romanian Principalities (between the 12th and 14th century), has to be made. On the other hand the study of construction conception and architectural features of Romanesque churches in Romania is a very important aspect for the complex problem of architectural heritage conservation.

1. Historical and social context

Before 11th century, and because of constant warfare and poor economic conditions, significant buildings "except of monasteries and churches" were not built. By the 11th century Romania was divided into three distinct regions: Transylvania, Wallachia and Moldavia. Large parts were under the Hungarian rule of King Stephen I, whose control was largely established over the region of Transylvania. The expansion of the Hungarian feudal state in Transylvania and the persistence of various foreign rulers influenced the medieval fine arts and contributed to the evolution of architecture.

Romanian architecture presented a complex configuration due to penetration of Western trends combined with both Byzantine architectural elements and local tradition. The western trend (catholic) had a stronger influence in Transylvania than in Moldavia, while Wallachia was influenced by the Byzantine (orthodox) trend that came from the Balkans. [1]

Romanesque architecture was mostly developed in Transylvania, with a delay from the West, in the 13th century. It spread through Benedictine construction sites; the Saxon colonists brought from Germany for strengthen the power domination of Hungarian kingdom, the Teutonic Knights and religious orders. In a region constantly under the threat of the Ottoman Empire the fortifications became a necessity. Whereas the most important towns were fully fortified, the smaller Saxon villages were typically organized around a fortified church often with a defensive tower and storehouse.

2. Romanesque architecture in Romania

Based on the research made by specialists about Romanian churches and the general considerations of cultural and economical situation of our ancestors until 13th century, we deduce that, before the foundation of the principalities, Romanians did not have buildings made out of brick or stone. [2] Building activity was limited to wooden churches or monasteries. Most of the old edifices have not made it to present, being destroyed by the invasions of migratory populations.

Romanesque style across Europe was developed starting before the 10th century and many Romanesque buildings were expanded with new Gothic features in the 12th century, while across the old region of Romania, the style was adopted later in the 12th century and the beginning of the 13th century.

At this time in Romania can be found around 110 buildings from 13th century as it is listed on the Historic Monuments List, and drafted by the Ministry of Culture and National Heritage, from 2010. Most of the monuments of 13th century are part of ecclesiastical architecture. Thus, about 90 Romanesque churches were built in that period, not even 10 of them has kept the entirely originality and the features of the Romanesque style. Most of them "around 80 churches" have undergone to additions or changes made in the following centuries. Moreover, across Transylvania we can find today the ruins of eight churches and 7 fortresses from civil or military buildings, built in the 13th century, under the Romanesque mark.

3. Concepts

The Saxons and Szekler colonists had brought from Germany for strengthen the power domination of Hungarian Kingdom over Transylvania contributed to develop the architecture. Architecture in Saxons' regions followed the Eastern Bavarian monuments shapes as well as the Austrian, Moravian and Bohemian ones at the beginning of the 13th century. This may be due to the neighboring origin of master builders that manage the first building sites. [3]

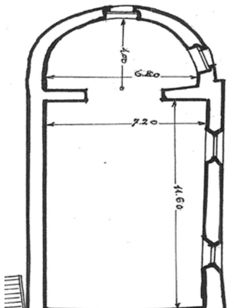
The monuments of this period bear a sober and modest look in appearance, but with specific morphological elements of style. The Saxon churches are characterized by massive solidity and strength, modest heights, horizontal lines, multiple units. The load bearing structural elements are thick walls and section of walls called piers, round arches, barrel vaults and groin vaults. The exteriors were very simple, and several geometric forms often made up the building, rather than one large space.

3.1 Plan and section

Romanesque churches have clearly defined forms, frequently with symmetrical plan. In the Saxon churches that followed the basilica plan, usually the central nave is higher than the collateral ones with small and narrow windows placed over the roof of the lateral naves. Some churches have the central nave longer than the lateral ones, with three apses on the eastern wing. This is the case of St. Nicholas church in Cisnădioara citadel, the most representative historic monument of First Romanesque architecture, reflecting the Cistercian influence. (Fig.3, Fig.7, Fig. 14)

Building stone basilica with three naves, with roofs within each room, semicircular arches, narrow windows and a square choir placed between the central apse and the main nave are found at Ocna Sibiului, Cisnădie and the very well preserved churches from Guşteriţa, Turnişor and Vurpăr. This case of churches form Ocna Sibiului at Cisnădie or Guşteriţa was built under Renan influence. [2]

In North Transylvania the Benedictine sites, inspired the churches of the period through the influence of late Romanesque in Hungary. The reformed church in Acâs and the evangelical church in Herina (Fig. 2, Fig. 15) belong to the category of churches with three naves and two towers on the west bay in the lateral naves that border a tribune at the top floor crossing the central nave This building type is frequent in Transylvania as well as the evangelical churches in Sebeş, Cincu, Drăuşeni, Hărman. [2]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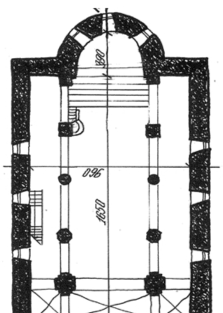
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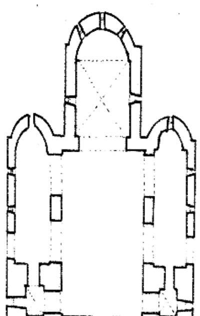
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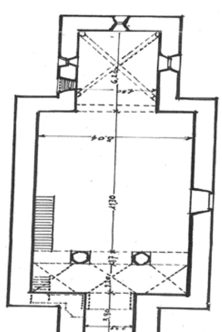
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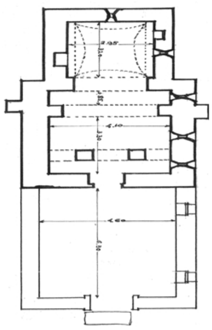


Fig. 5.

Short rectangular basilica without towers can be found in Sibiu county at Roşia.

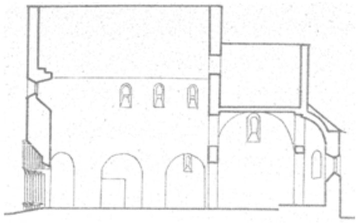
Another type of churches plan is hall church, usually small churches with one nave, carved out of raw stone, as the reformed church in Sântămarie-Orlea (Fig.4, Fig. 11, Fig. 13), the orthodox church in Strei (Fig. 5, Fig. 12) and the reformed church in Şieu-Odorhei.

From their planimetric, volumetric and artistic characteristics, churches can be inscribed into the following categories:

- Circular plan- Pelişor (Sibiu), Geoagiu de Sus (Alba), Mănăştur (Cluj).
- Rectangular plan churches called hall-church
- Three ships plan churches without tower
- Three ships plan church with one or two towers

Small proportions and simple execution but a great diversity and a tinting of proportions can be seen at Bonţida, Luncani, Nima (Fig. 8), Nireş (Fig. 9).

Fig. 6.



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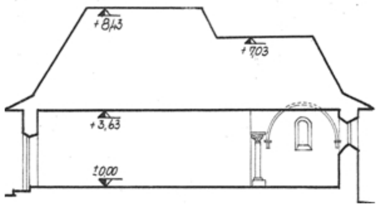

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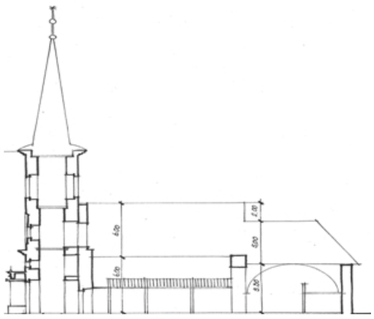

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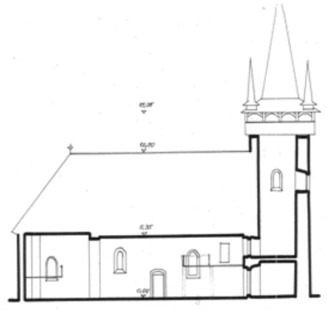

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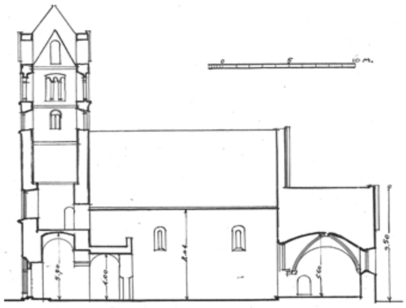

Fig. 11.

3.2 Techniques

Regarding the construction techniques used to build the Romanian churches of 13th century, we can note the using of raw stone masonry, coming from quarry stone or river, which tied with mortar. The artisans have used for facings, biggest stone blocks with regular surfaces, placed in horizontal rows or by simply matching. The wall interior was composed of smaller stones, sometimes were thrown randomly and bonded with mortar. Such masonry fortresses could be seen at Tăuţi, Piatra Craivii and Vurpăr.

3.3 Materials

Before the 13th century, the main building materials were wood. But in the period of Tartar invasion and the Ottoman attacks, the use of stone or brick increased. That led wood to be replaced in the most of important buildings.

Stone has local origin. Raw stone was brought from the Roman ruins from Haţeg and Mureş county. Raw or carved stones were used for masonry paramount and the carved stones were used for elements such as pillars, columns, arches, buttresses, pavements. Traditional stone masonry has often plastered facings made by different stones sizes, bound with lime mortar hydraulic and grained sand.

Bricks were used in the areas where there were lacks of good building stone. For example, the churches from Cetatea de Baltă, Bistriţa, Bihor, Someş, Herina, Acâş. Sometimes masonry is mixed: stone and brick, raw stone and carved stone. The using stones were limestone or siliceous stone.

In the walls of Tăuţi fortress there are fragments of carved stone and bricks stamped by Legion 13 Gemina. At Cetatea de Colţ, Mălăieşti and Subcetate-Haţeg fortresses the using materials were brought from nearby Roman ruins or Sarmisegetuza. At the Cathedral church from Alba Iulia, the additions and repairs of the fortress "in the 13th and 14th century " were made of carved stone taken from the Roman ruins.[4]

Most of the Romanian churches kept their wooden ceiling and roofs.

3.4 Facades and external decoration

Romanesque churches facades are usually symmetrical. The common decorative feature is arcading. The west end of the building has a central portal. Cisnadioara church has one of the most representative portals in Transylvania (Fig. 21). Smaller churches as the church from Strei (Fig. 12) and Sântămarie-Orlea (Fig.13) often have a single tower that is placed in the western end, following the French or England model. Arcades with round arches accent facades and towers.

Fig. 12.

Fig. 13.

Fig. 13.

Fig. 14.

3.5 Interiors

The structures of the churches developed over the centuries but some characteristics are common: round arches and arcades support by rectangular piers as at Vurpăr church (Fig. 18). Some churches have the central nave distinguished by huge circular columns like the Romanesque churches from France built in early Romanesque period. The roof varied from open timber roof or wooden ceilings to simple barrel vault or groin vault. Chapels and towers have conical or pyramidal roofs. Sometimes the main nave has kept the wooden ceiling, while the lateral naves are covered by stone vaulting.

Fig. 16.

Fig. 17.

3.6 Typical Romanesque architectural forms

Fig. 18.

Fig. 19.

Fig. 20.

Fig. 21.

Churches built in late Romanesque style showing the transition between Romanesque and Gothic are found at Cricău, Reghin, Mureş as well at Prejmer, Hărman, Feldrioara with Cistercian influences. The most important building site was the reconstruction around 1246 of the old Romanesque cathedral in Alba Iulia, destroyed by Tartars.

Others buildings include civil and military architecture were built after the Tartar invasion in 1241-1242. Therefore house-towers can be found at: Gârbova (Alba county); Cheresig (Bihar county) and fortresses at Deva (Hunedoara), Colţeşti and Câlnic (Alba). This fortress is inscribed on the World heritage List (Fig.1, Fig. 6). Donjons built out of stone can be found at Gârbova, Tăuţi, Piatra Craivii (Alba county), Viscri (Braşov county), Ruja and Axente Sever in Sibiu county.

Conclusion

So far the greatest number of surviving Romanesque buildings are churches. Romanesque style was introduced to Transylvania from Hungary in the 12th and 13th century. The influence on architectural style was initially from Hungary and Germany, and later from France and Italy. Romanian Romanesque churches are generally small and modest churches, compared with the following Gothic churches. While a small number remain substantially intact, many churches were sympathetically restored, being extended and altered in different styles. The examples above are demonstrating the form, character and decoration of Romanesque church architecture.

REFERENCES

[1] Draguţ V. Encyclopedic dictionary of Romanian medieval art, 1976 (in Romanian)
[2] Iorga N. Romanian church History, Bucuresti, 1979 (in Romanian)
[3] Pro-exemplaria. Preliminary study of built heritage in Romania, 2011, part 1
[4] Fabini H. The universe of fortified churches in Transylvania, Sibiu, 2009 (in Romanian)

THE INFLUENCE OF ROMANESQUE STRUCTURAL ELEMENTS OVER THE DEVELOPMENT OF ARCHITECTURE

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Abstract: *Is it reasonable to invest time and effort searching on Romanesque architecture? How could be not when ancient Rome achieved many great accomplishments that have influenced numerous structural and architectural patterns. Especially when they created an arch that could support huge amounts of weight. The arch led architects to explore different and larger structures as aqueducts or massive Romanesque churches.*
This paper looking into structural details and their influence on the mechanical behaviour and structural stability of Romanesque buildings is giving an overview over structural conception of elements such as: arches, vaults, columns, piers and thick walls. On the other hand, the outward and thrust stresses created by the barrel and groin vaulting have led to structural requirements, as thick walls and columns. Thus this paper will take into account the implications of structural elements, in a Romanesque church, for the further structural development. At the same time the main points of the constructional concept of that period will be revealed.
Despite the lack of engineering knowledge, the builders could create rigid, stable structures and less vulnerable that has kept their load bearing capacity for years.

Key words: *Romanesque church, structural conception, arch, outward and thrust stresses, stable structure, structural development*

1. Introduction

Historic building in general and their load bearing structure in particular are a significant part of built environment and built heritage of a country. Even if a Romanesque building has many architectural features that can be easily distinguished, it cannot be fully understood without an analyze over its structural elements that sustain it.

During the medieval period the two Architectural styles of Romanesque and Gothic were created and used in great success in the forms of large cathedrals. The Romanesque period flourished from the 10th to the 12th century and the successor to this was the Gothic movement which lasted from the 12th to the 16th century. There were great technological advances during this time to spread the loads and forces of the building, through the walls down to the ground, which in turn meant that the Architects could create dramatic, large, spacious buildings [1].

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A short analyze on the conception of the Romanesque structural elements reveals new knowledge about the construction concepts and methods in the Early Middle Ages. It also demonstrates that the mature Romanesque of the 13th century continues many of the applications created and perfected over the previous years and it is showing its implications for the development of architecture into the subsequent Gothic style.

2. Historical context

Romanesque style is the first integrated architectural style that spread across Catholic Europe between the 6th and 12th centuries. It developed in the Gothic style in the 12th- 16th century within regional variations.

After the disintegration of Roman Empire in the 5th century and up to the 11th century, significant buildings are rare because of the poor economical and political Europe situation. The 11th and 12th centuries of the Romanesque period are a turning point in Western Europe. Feudalism continue dominating society, while individual nations struggle to rise. The expansion of towns, commerce, industry and populations creates a building boom. Catholic church provides stability and unity. The monasteries and churches became the most important medieval institutions in preserving knowledge and culture and supporting intellectual and artistic expression.

In order to respond to functional needs as larger stable churches for pilgrims, acoustic and fire resistance, the builders of the period adopted the Roman principles and methods. The reuse of the arch and the arcaded system, the stress on individual parts to create unity, maintaining the stability of massive and solid buildings are aspects that need to be solved under the first integrated style defined as Romanesque.[2]

The numerous regional variations led to structural development such as rib vault that will be carried further in the subsequent Gothic style.

3. Structural elements

The main problem for the builders of the Romanesque churches was to equilibrate the downward push of weight of the stone in order to maintain the stability of the building. The massive quality of a Romanesque church is defined by thick walls made by stone, sometimes brick, sturdy piers, semicircular arches and the barrel and groin vaults.

The immensity and massiveness of the structure is created by repeating shapes of the arches that defines the naves as well by the large arcades of the ground level made up of bulky piers or columns. Pursuing the height of the building the mass is reduced by diminution of the structural elements. The arcaded system developed a logical system of stresses and buttressing.

Unlike some other materials, working with stone is more difficult because does not change shape, stretch or get squeezed smaller. The concerning aspect about stone is its heavy that produce compression force through the downward push of the stone and every weight above it.

3.1 The arch

The arch consists of two supports, called piers, each topped by a platform called an impost. Angled blocks of brick or stone, called voussoirs [voo-swars’], are placed on the imposts in an arched, curved pattern that is capped by the central block of the arch called the keystone. A row of arches is called an arcade. Arches allowed the Romans to create wider, taller, and lighter structures.[3] They also learned that they if they built arches entirely inside the walls of their buildings that this would make the walls even stronger (Fig.1).

Arches enable builders to maximize the space volume of the building more than in a simple beam construction. Arches develop two basic forces: downward and outward. For the stability of the arches and columns these combined forces must to be balanced and counteracted. To counterbalance an arches' force is very important the height of columns and walls, therefore it appear the development of the columns into the buttress, pointed arch and pinnacle. To build higher buildings the columns need to be stabilized.

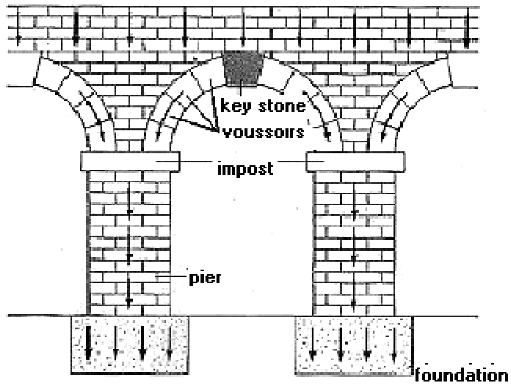

Fig. 1

3.2 Vaulting system

Vaults are extended arches and the Romanesque builders used them to create large open rooms and high[4]. The ceilings and roofs developed from the ones made of wood to barrel vaulting (simple semicircular roof vaults) or later to groin vaulting. The stone barrel vault construction system provides excellent acoustic and reduced fire danger. The vault creates outward pressure all along the walls that support it. Therefore it is need extra thick walls and small and few windows. Larger windows could bring the building collapse.

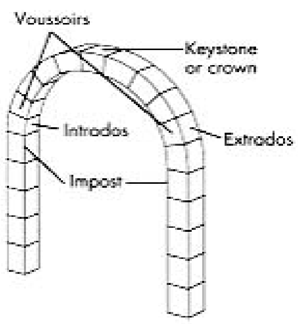

Fig. 2. Arch

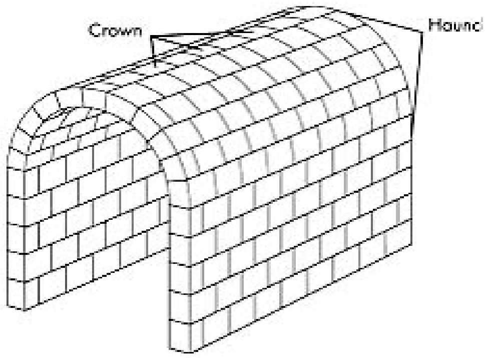

Fig. 3. Barrel vault

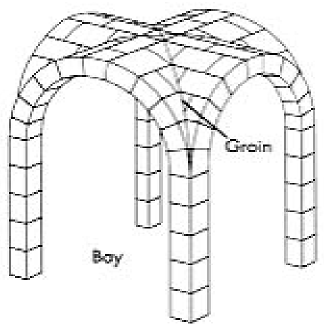

Fig. 4. Grain vault

For many centuries the builders were hampered by a lack of the excellent concrete which Roman builders had used in imperial times. Unable to construct vaults of concrete as the Romans had done, the early Romanesque builders construct semicircular barrel vaulting, developing the science of vaulting.The barrel vault (Fig. 3) was generally semi-cylindrical in section. The groined vault is formed by the intersection of two barrel-vaults (Fig. 4). When several compartiments of groined vaulting are placed together over an oblong plan, a double advantage is secured. Lateral windows can be carried up to the full height of the vaulting instead of being stopped below its springing; and the weight and thrust of the vaulting are concentrated upon a number of isolated points instead of being exerted along the whole extent of the side walls, as with the barrel-vault.

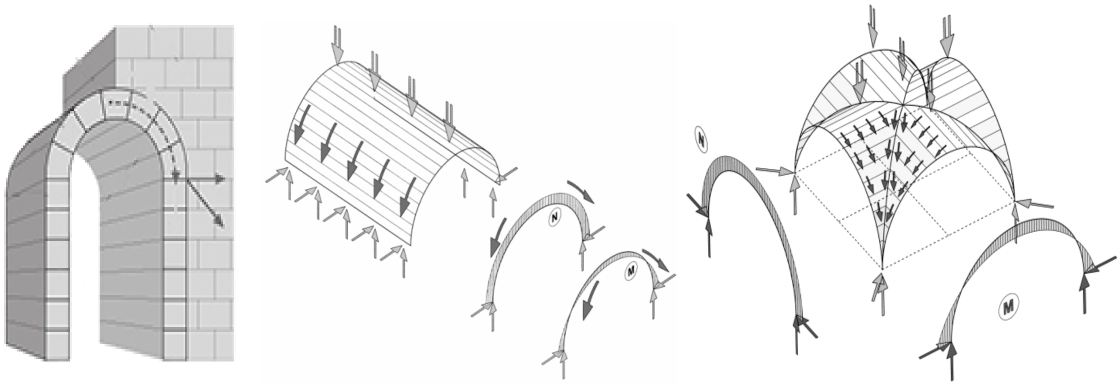

Fig. 5. The thrusts of a barrel vault and a groin vault [5]

Vaults constructed of numerous blocks of material pressing against one another exert not only the accumulated downward weight of the material and of any superimposed load but also a side thrust or tendency to spread. To avoid collapse, adequate resistance against this thrust must thus be concentrated at the haunches (lower portions) of the vault. The resistance may take the form of thickened walls at the haunches; of buttress placed at points of concentrated thrust as in Romanesque and Gothic architecture; or of vaults so placed that their thrusts oppose and counteract. This necessity has controlled the evolution of masonry vaulting and its use in buildings.

3.3 Walls

The walls are one of the most important component for the load-bearing structure of a building. The thick walls used in the Romanesque architecture bears a load resting upon it by conducting its weight to the foundation. They normally consist of a layered stone exterior and rubble infill. The thickness of the walls allows to carry the weight above them, the weight of the vaults. Otherwise, the wall could became unstable if the loads exceeds the strength of the stone, causing structural collapse.

Regarding the innovations that led from the Romanesque style it is worth to mention that the thick Romanesque walls developed into the flying buttress of the Gothic period. Thus, the weight was transferred to the buttress instead to the bearing walls.

3.4 Piers and columns

The piers have the role to support arches. Their section is square or rectangular, generally with a horizontal molding called capital at the intersection with the arch. They are built of masonry. Columns together with the walls are a very important structural feature of Romanesque architecture, their use is also for decoration.

Alternation of piers and columns are a common characteristic for a Romanesque building. Complex piers and columns emphasis bays and articulate the interior (Fig. 6).

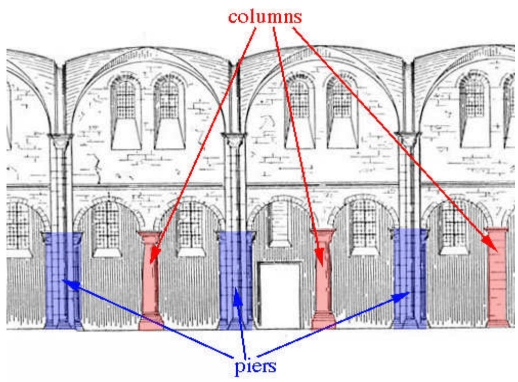

Fig. 6.

4. Advantages and disadvantages

4.1 Advantages

Stone masonry and brick masonry increase the thermal mass of a building. Also, does not requires painting, like it can be seen at most of the Romanesque churches' facades, therefore the life cycle cost is reduced.

Stone masonry structures built in compression with mortar have a longer useful life compare with the structure of steel or reinforced concrete.

The stone barrel vault construction system provides excellent acoustic and reduce fire danger. In the case of a pointed arch the destabilizing sideways forces is less than with a round arch.

4.2 Disadvantages

The Romanesque style of church had many failures. They were rather dark on the inside because the high walls would not support large openings for windows. The walls were very thick. The arches were rounded and as such would not tolerate a lot of weight without crumbling.

Rounded stone limit the potential size of a building. The material and the technique do not permit the construction of structures larger than a village church for static reasons. The monumental constructions only became possible through the growing use and perfection of brick buildings.

The degradation of masonry wall surfaces under the influence of extreme weather and the resistance of water penetration.

While the compressive load (vertical load) is higher, the tensile strength (twisting or stretching) is lower.

5. Developments

The major development that marked the beginning of the Gothic style was the ability to support heavy stone on much thinner walls. This problem was solved through the use of buttresses at exterior of the building, and columns in interior and the pointed arch.

Pointed arches, ribbed vaults, the triforium and clerestory windows begin to dematerialize the thick Romanesque walls. Gothic innovations will complete the process. When the problem of ribbed vaulting was solved the Romanesque builders had prepared the triumphs of Gothic.

The later developments of Romanesque provide the opportunity for large glass windows with stained glass, larger cathedrals filled with light to represent heaven. The thick walls were no longer needed, therefore they use thinner walls and pillars and generally more delicate and more vertical architecture. The ground plan in Gothic was different, but the Latin cross shape was still use. The east ends were polygonal, not semicircular, the central nave much higher and wider than the side aisles.[1]

The first flying buttress for example, is said to debut in the Cathedral of Notre Dame, Paris and the statue column in the royal abbey at Saint Denis. It is known that in Paris masons invented the Gothic style by combining the pointed arch from Burgundy with the rib vault from Normandy. Whether true or not this theory about the sources of Gothic architecture, is still not known where was first used the pointed arch and vault.[6]

The builders of Romanesque made of the vault something more than a mere constructive device. It became in their hands an element of interior effect at least equally important with the arch and column. No style of architecture has ever evolved nobler forms of ceiling than the groined vault and the dome. Moreover, the use of vaulting made possible effects of unencumbered spaciousness and amplitude which could never be compassed by any combination of piers and columns. It also assured to the Romanesque monuments a duration and a freedom from danger of destruction by fire impossible with any wooden-roofed architecture, however noble its form or careful its execution. [6]

Conclusion

The Roman arch also caused the Romans themselves to make further architectural developments. They combined arches to form ceilings or roofs called vaults. The Roman arch solved an important problem by being able to support a large amount of weight. As a result, it enabled people to build larger and more varied buildings. The spread of the Roman arch and its cousins, the vault and dome, has had a lasting impact on architecture throughout the world.

While in the Romanesque the load-bearing structural elements are the walls and sections of walls called piers, the development consist in a rational distribution of the material in the weaknesses. Thus, the walls become thinner, along with the buttresses ensured a better bearing capacity of the structure and the load-bearing structural elements in the Gothic architecture are columns, pilasters and buttress. Unlike Romanesque buildings, in which a continuous mass of wall is necessary to sustain the load, the Gothic structure is a skeletal system that transfers roof loads down to the ground at discrete points, thereby freeing large expanses of wall to be opened for windows.

The Romanesque structure proves to be a model for these later developments.

Because the creative process of Romanesque churches in Romania is essentially undocumented I will try in a next approach to answer to casual questions by examining the remaining physical evidence "the consistencies or inconsistencies of masonry, the building process, the integration of the vault into a sophisticated system of structure", exemplified by Romanian churches built in the Romanesque period and those which are showing the transition to the Gothic architecture. The study will be based on the structural developments which were revealed in this paper.

REFERENCES

[1] Briana Y. Romanesque and Gothic Art and Architecture, Fulbright ETA
[2] Edison Armi C. Design and construction in Romanesque Architecture
[3] Ward-Perkins, John B. Roman Imperial Architecture, Harmondsworth, 1981
[4] Clarence W. Medieval church vaulting, Princeton University Press, 1915
[5] Szabo B. Draying of Historic Structures -Vaults
[6] Rabun T. Roman builders A study in architectural process, Harvard University

ARCHITECTURAL SPACE AND MEMORY: THE HERITAGE OF HOTEL "UNION" IN PRISTINA

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Abstract: *This paper discusses the architectural heritage of the hotel "Union" in the context of social changes in Pristina. Built in 1927. this hotel was a symbol of cultural and public life of the city. The memory of this place was changed by the memory of the social community and first of all it was primarily caused by the ruling ideology and the politics which managed the city. From being a city hotel and tavern, through the post office and shelters for refugees, to being recognized as a historic monument, its significance for society was changed. The hotel existed for a long time, with a touch of sentiment, as an unattractive building at the end of the Korzo promenade, and in 2009. the hotel, as it used to be, finally disappeared. The Union's existence was the measure of its presence in the collective memory and the hotel was defined by it. The aim of this paper is to perceive these parallels through the existence of this building.*

Key words: *hotel Union, Pristina, collective memory, architectural heritage, social history*

1. Introduction

The development of every-built area is conditioned by the different processes that take place in it. Changes in the structure of society visibly trigger changes in the use of natural and built environment, respectively, the changes in its structure. Strongly influenced by a variety of social events and processes in the return are coupled with changes in the urban structure of the city. This process is not always possible to identify and locate because they have been recognized in the "direct and indirect action of various factors and actors with different levels of power and decision-making."[1]

What concerns the professional public in recent years is clearly changing the structure of Pristina for the benefit of modern buildings, at the expense of the city heritage. Contemporariness should not be repressed past, but rather revive it. The past is concretized in the present, and the present indicates future. Memorizing the present, we associated past with the future, and therein is created future vision.[2] If the works of the past has the potential to create a better future, do we know how to properly recognize the value of the past for the values of our time? Shall consider the heritage integrity, integrate the past into the present and use the maximum of its potential [2].

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[2] See: Kuljić, T. Kultura sećanja, Čigoja, Beograd, 2006, p.66.

An example of inheritance that heritage inside different stories and spaces is the subject of this paper and the reason for discussion of the ways of understanding and preservation of heritage.

2. Hotel Union and its values

2.1. Architectural and aesthetic values

Hotel Union is located in the center of Pristina, which is the area of cultural and historical heritage of the city. It was built back in 1927. with elements of neo-Renaissance, neo-Baroque and Art Nouveau, presented one of the few examples of architecture that brought to Pristina new influences from western Europe. Republic Institute for Protection of Cultural Monuments, when declaring the hotel as a cultural monument, about architectural values of the hotel it tells: "The building was designed by the concept of epoch post-Academism, with a choice of details and decorative elements in an eclectic style. This monument is the most representative example of urban architecture of the first half of the twentieth century in Pristina, which took place in significant cultural events that enhance public life in the interwar." [3]

Fig. 1. Hotel Union: Viewing a location of the object

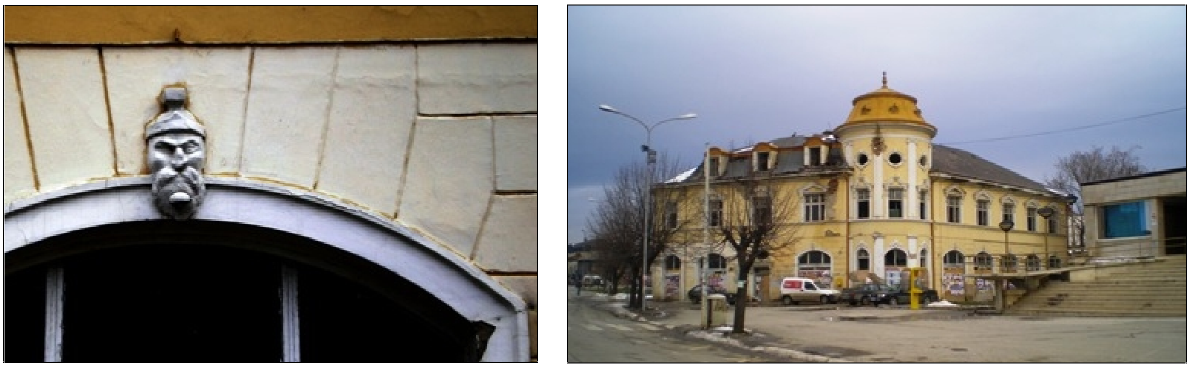
The composition of the building is asymmetrical, L-shaped, in a manner typical of the Art Nouveau style. (Fig. 1) The corner of the building is accentuated by a circular tower that rises above the surrounding rooftops. The ground floor occupies an area of 500m2: the building has a basement, two floors and a mansard roof on the west wing.

2.2. Intangible values

Investor and first owner was Zafir Jorgić, Pristina merchant. Creator of this building is considered to be Andreja Kremer3, Austrian engineer who was at that time living and working in Pristina.[4] As soon as it was built, the hotel is given on lease, called the Nacional and since its opening it became the center of intense life of the city: there have been organized balls, entertainments, toured the traveling theaters and artists. Skenderbeg monument, which stands opposed to the hotel building was built in 2001. For many years in the restaurant Union was working a café - remembered as Skenderbeg café, a term used

[3] According to professional research that was conducted by Biljana Vranići, manuscript.

during World War II, when Kosovo was under Italian occupation. It was believed that the sculptural decoration on the facade of the building in the form of male-specific expression face looks like the face of Skenderbeg. (Fig. 2a) After the war, the hotel was renamed in the New Yugoslavia (Нова Југославија). In 1948. by the decision on the nationalization, the hotel is owned by the State. Than in 1961., the hotel became property of the company Sloga, keeping purposes. From its beginning until in 1997., the building functioned as a hotel, and is remembered as the Union Hotel.



a) b)

Fig. 2. Appearance of the hotel Union: a) decorative element above the window opening on the ground floor b) hotel Union in 2008. (photo by M. Pavlicic)

In the nineties hotel has been used as a home for displaced persons after 1999. In the ground floor was located a post office. After privatization in 2007., the situation is unchanged. Protected monument, a symbol of the cultural life of the city changes and gets a new meanings. (Fig. 2b)

3. Hotel Union at the beginning of 21st century

After 1999. Republic of Serbia does not have institutional authority over state property in Kosovo and Metohija and it begins a period of management of Pristina institutions as autonomous, independent bodies.

Technical assessment of the hotel's condition was completed in July 2000th by the Bureau Action Civile-Militaire, which was part of the International Military Mission in Kosovo and Metohija (KFOR), on demand of UNMIK.[4] Costs are estimated at around 549,000 euros for major restoration works. The report of the feasibility study for the renovation and repair of buildings with a total cost estimated at 2,327,786 euros. In the segment concerning the property, says that the building is leased to the company PTK (Post Telecom Kosovo) by KHT (Kosovo Hotel and Tourism Company), and it is currently "an empty, abandoned and barred."

In the summary of report, the Ministry of Culture proposes that the object, given its importance and central location in the city, should be dedicated to creating a cultural center, to attract the various artistic groups of Kosovo's artistic community, and to provide a gallery that can be used for exhibitions of domestic and international works. Restoration of this building, with the characteristics of city symbols (as stated), will contribute to the revitalization of artistic life in Pristina and make this space, which is close to the National Theatre, a gathering place for all artists.

3.1. Assessment, risks and proposals for measures of protection

In the last decade of hotel Union's existence, the temporary occupation of the building, together with the inadequate use of space and poor maintenance are the main risks for its survival. Due to the architectural characteristics of the building, its location in the city, the current state of the building and lack of maintenance, there is an urgent need to undertake a process of restoration. Regional Programme for Cultural and Natural Heritage in South East Europe under the leadership of the Council of Europe has realized the project plan for the rehabilitation of the architectural and archaeological heritage which refers to Kosovo and Metohija. A preliminary assessment has been prepared by local experts in cooperation with the international expert group. In this document, "building of the former hotel Union" is categorized as a monument of regional importance, described as "the most prominent example of the Austro-Hungarian architectural style." It is located in the main street, in a very important place for the urban city development, especially after its reconstruction to the only pedestrian street in Pristina.[4] Vicinity of the theater, which is located near the hotel, close to the monumental square, the closure of the pedestrian zone and important streets that surround it, increases the semantic dimension of the object.

Inadequate use of the object, disrepair, leaking roof, illegally constructed buildings in the immediate neighborhood, it is described as "alarming condition" with high priority of intervention.

Fig. 3. Alarming condition: visible damages on façades a year before the fire (photo by M. Pavlicic)

Parts of the decoration on the façades were damaged, but the greater part is in good condition. All windows and doors were heavily damaged. (Fig. 3) . The building wasn’t damaged in the last war, but nothing is remained of the original inventory, furniture and interior decoration.

3.2. The fire

The last architectural, cultural, social symbol of old Pristina's up in flames one August night in 2009. (Fig. 4) The fire has caused considerable damage to the building, its unique values and everything it’s presented. The news agencies reported on fire in the context of the events that preceded it: the privatization of hotel in 2007, the sale, the investor's plans to demolish the building and so on. Even about the protest of the most respectable and most significant artists of Kosovo and Metohija, who have consistently demanded that this unique architectural work must be, at any cost, put under protection.

[4] The main sources of documentation are from the Institute for Protection of Cultural Monuments and the Regional Museum of Pristina. Significant literature hasn’t been found.

4. Word of the authorities

Next year, in the June 2010., Pristina Mayor has decided to withdraw the permission for renovations. This decision was based on reports from experts in the field of Cultural Heritage under the Ministry of Culture, Youth and Sports, which concluded that the building in a fire suffered 80 percent damage. In this way, it closed the door to any kind of protection, preservation, revival of of the past. In the report of KTA (Kosovo Trust Agency) from the 2005th about Union condition says that it is the oldest building in Pristina and the only one that is a cultural and historical monument.[6] Since the building is located in the main street, which is partly a pedestrian street, her destiny is largely affected by the urban development of Pristina.[5]

Fig. 4. The fire: hotel Union in flames, 22nd August 2009.

"In order to preserve the architectural value of the building, the project of restoration and reconstruction must be initiated immediately," says according to in the UNMIK report from 2006. Organization OSCE (Mission in Kosovo) in the report from May 2010. expressed concern about the continuing destruction and threats to the cultural heritage of the old part of the town. [7] They criticize the institutions responsible for the protection of cultural heritage and their big failure in the implementation of the rights and ensuring the safety of goods. The organization calls the institutions to increased coordination in order to avoid more such cases in the future and immediate action for the implementation of the Law of cultural heritage.

Conclusion

Transformation processes that affected the socio-economic life in Kosovo and Metohija, imposed a radical change in the ownership structure, which could not pass without a deep disorder and conflict in the constructed space. As an integral part of the area and the general perspective of the city of Pristina, hotel Union realized the relationship with surrounding space and citizens. The sacrifice of a protected space for profit, caused the situation we have today. Some values are preserved in the collective memory of the city, but the question is whether they are sufficient to make up for all that is completely lost. Demolition must be understood as a syndrome inherited from the past, which is a kind of cultural and political vandalism, especially now, in the 21st century.

[5] KPA, established in 2002, is tasked to privatize socially owned enterprises in Kosovo, urging investors to buy through open competitive tender . Since 2008. KPA does not exist in this form, but transformed into the Kosovo Privatization Agency.

Mutual tolerance and co-existence of old and new, instead of winning the progressive over reactionary is urban formula in which must be based current and future urban planning practice. The ruling ideology has always been conditioned by the character of the memory the social community. Authorities, experts, community and urban context are factors that can not work separately What happened to the building of hotel Union, sadly not unique, but certainly is the most tragic event that can happen to the architectural heritage.

REFERENCES

[1] Стојков, Б. ed. Обнова Приштине у условима одрживог развоја. Институт за архитектуру и урбанизам Србије, Београд, 1996, p.135.
[2] Булатовић, Д. Баштина као brand или музеј као економија жеље. Да ли робна марка улази у музеј или је из њега произашла? *Гласник за друштвену историју* (2-3), 2004, p.145
[3] Службени гласник РС бр. 27 од 26.јуна 1997.г. Одлука о утврђивању зграде "Унион" у Приштини за споменик културе, бр. 649. (Решење о проглашењу споменика бр. 633-2231/97-007 од 18. јуна 1997.)
[4] Тодић-Вулићевић, Р. Приштина, Приштевци и време, Матица српска, Нови Сад, 1999, p.41
[5] http://www.coe.int/t/dg4/cultureheritage
[6] http://www.kta-kosovo.org
[7] http://www.osce.org/kosovo/69303

A VIEW ON SPATIAL CHANGES IN KOSOVSKA MITROVICA DURING THE LAST DECADE

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Abstract*: After the war activities ended in 1999, territorial, physical and functional divisions occurred in Kosovska Mitrovica, and the Ibar river became a natural border between the two divided parts of a formerly comprehensive city organism. This paper talks about the necessity of structural changes that were made in the accelerated creation of new functional entities, converting the existing spatial structure into the new one, meeting new needs of the (newly-formed) city and the society within it. The aim of this study is to point out that, despite the fact that the urban spatial structures are developing analogously to the changes in the way of life of its inhabitants, sudden changes in society did not result in corresponding developments in the public space that would fulfill new needs of the city.*

Key words*: spatial structure, public space, Kosovska Mitrovica, urban transformation, postwar period*

1. Introduction

The question of transformation of the public space and multiple spatial changes in the architecture of Kosovska Mitrovica have been actualized during the period that followed the end of the war activities, i.e. after 1999., when the city was physically divided into two unequal parts: north and south. In the process of creating the current architectural and urban physiognomy of this region, a major influence were social and political developments that had produced a clear division by sudden population movements and changing its structure and size, followed by changes in the functional structure of the city and ways of communication, all in the context of the heritage of this city. Of course, it is assumed that the architecture of an urban area is a result of the natural characteristics of the environment in which it occurs, the socio-economic relations, the existing tradition of the area, but also of ongoing cultural processes.

The changes about which we are talking are, primarily, a part of socio-political events and applicable for a specific urban phenomenon of the divided city which has affected the wider context of the development of the social community.

The subject of this paper is the transformation of the concept of public space in the city of post-conflict period in the example of Kosovska Mitrovica, by implementing new

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and modifying existing functions, and then physical structures, observed through development and change of the city's priorities. Reducing the number of public spaces in urban centers in general, and particularly in Kosovska Mitrovica, encourages the development of new, more functional models of communication and the need for preservation and transformation of existing models, and, at the same time, preserving the identity of the place. Observing the city space as a manifestation of the changes in society and urban life culture, this research is based on the following assumptions:

- Changes in the value system and way of life of the residents caused the transformation of the public space
- Spatial structures generate further development of the city, while preserving the identity of inherited space
- Transformed urban space is a result of numerous attempts at a reconciliation of inherited and contemporary needs and values that dictate the direction of the development of the city urbanity.

This paper uses an analytical method of research, the methods of observation, abstraction and systematization of the results.

2. About the phenomenon of urban public space

Ever since the earliest grounding of the city as a social phenomenon, differed indoor and outdoor, public and private spaces of the city. The public space was a forum, a square, a place where meetings and conversations took place. It's not just "a space within the maze of streets"[1], but is a kind of visualization of life that occurs there, and defines it. The urban area is such an essential place of discovery — an ambience of opportunities.

Norberg-Schulz[2] interprets public space in terms of aesthetics, but without omitting its functional and sociological dimensions. A relationship between urban space and the character of the city life is inevitable. People and their needs dictating city development, so the urban space is not just a collection of individual architectural forms, but also represents a generated *humanscale* space that man uses, in which it manifests its purposes, activities and perceives opportunities

Key characteristics of urban public spaces are:

1) physical characteristics,
2) functional characteristics,
3) identity.

The complexity of the urban area of Kosovska Mitrovica is in the emergence of a large number of constant activities and communication that only adds to its significance. Speaking about the transformation of the urban area of Kosovska Mitrovica with architectural and urban points of view, these three characteristics are important parameters in analyzing upon certain examples.

3. Characteristics of the Public Space in Kosovska Mitrovica

3.1. Physical characteristics

Radović[3] in his analysis of the physical structure of space he describes the concept of the built environment as the actual physical space of human existence, the framework of existence and development, history and future. So, we are talking about an artificially created environment in which we clearly recognize human intervention. Any intervention in the life environment implies a transformation of the social backgrounds through a various number and composition of users, their needs, experiences, activities, actions. Form follows function, and is in relation with other forms, symbols, existing matrices, and of course, ideology. However, the architectural values exist independently of any ideology.

Today's physical space of Kosovska Mitrovica is built by opposing terms: big-little, narrow-wide, public-private, high-low, open-closed, peripherals-center. All of which indicate the complexity of activities that take place in it. Every urban space, especially that of Kosovska Mitrovica, is a complex and integral process, a set of complex relationships, not just the aesthetic experience. The physical division of the city caused the necessary and rapid relocation of certain institutions and primary urban functions to meet the increased and increasing needs of the citizens, and therefore followed the "relocation" of people. This movement was carried out in the direction of north-south, meaning that the northern part of the city is the area that has endured the most significant changes that we are examining in this paper. Free space and well-planned communication are the resources that ensure a successful planning undertaking. However, the urgency of the post-war situation resulted in the predominance of space over time in relation to space-time. This imbalance implies a specific city life from that point on and it is contained in every change that has occurred in its physical structure.

Fig. 1. The object of a new student dormitory in the final phase of construction: positioned "just" along the existing (photo by M. Pavlicic)

The physical potential of the urban area of Kosovska Mitrovica can be achieved through the implementation of the following concepts: the diversity of content and experiences, the formation of new micro-environments, the readability of space, the variability of the intensity of space use. In almost all of these approaches it is impossible to escape the tight connection between the ground and the built environment. The lack of free (or of reclaimed) space that would allow a freer approach to solving a problem of the oversaturation of the physical structure in Kosovska Mitrovica contributes to the reduction of the quality of city public spaces and the unconvincing acceptance of its user as such.

Fig. 2. City centre: the variability the physical structure of the city is moving towards increasing the level of development (photo by M. Pavlicic)

3.2. Functional characteristics

In the particular physical surroundings, there are human needs forming values as part of the culture from which objectives — sum of actions — are derived. The architectural program is the design of content, and their formation is conditioned by the needs and interests of the groups. On the example of Kosovska Mitrovica, new human needs have been created in the particular circumstances, and spatial specificity involves selecting only the relevant needs for further functioning of the city as a new organism. The need for an increase of the city's territory along with the extinction of certain functions (for example industrial production), the growing of other functions (trade, education, services, recreation), the need for storage capacity, are some of the main reasons for the new changes.

However, the inherited areas of the city where quality functioning of social relationships among users is not satisfactory demand proper spatial interventions that will improve them. Kosovska Mitrovica is being developed along with the increase in the number and needs of the population, and these needs will have as a consequence the development of functions. In this sense, the variety and variability of the main advantages that public spaces need to possess.

3.3. Identity

Except the utilitarian function, a new urban transformation of Kosovska Mitrovica shaped the multicultural nature of the change in the identity of the micro-ambient and macro space, caused by the different way of life of the local community and brought the emergence of new models of culture. The identity of a place is driven by the way of life of its inhabitants, and is inversely proportional to the development of the city's urban tissue. Norberg-Schulz[4] defined a concept of "place" as "the structure plus action" versus "space" that was only "structure". Consequently "the place is a space with a certain character." The combination of physical structures (and interpersonal relationships) and dynamic activities that determine the residents of the city, giving the city area a unique identity.

Lynch[5] considers identity a fundamental component of the overall picture of the environment. The identity, as he defines it, is close to the "recognition" of a specific place and its readability.

Fig. 3. The use of color: objects of similar shape and dimensions, gained their identities by using colors on the wall (photo by M. Pavlicic)

A cultural dimension causes mode of space forms communication and controls the level of expression of content. Color as one of the most obvious characteristics of architectural form, is seen as a secondary architectural tool, emphasizing composition, volume or detail.

The newly designed colored spatial structures like an urban artistic expression may offer a compactness of structure, the kind of cultural transformation, and indirectly provide the identity of the city. The basis of the emergence of color in the public space is a historical architectural polichromy. In Kosovska Mitrovica the entire street fronts received a new look with the use of colors on the walls, reviving public space that contains them. On the other hand, the increased level of construction of one part of the city increases the degree of urbanity of the city space, but uniformity threatens his reading and reconditioning. Therefore, they turned to the simplest, i.e. the fastest solution to the problem: using color as the architectural asset that will contribute to a more dynamic character of the street as a public space.

The assignment of the architectural science and profession is to examine ways of planning city-coloring with the help of the interplay between color (light) and the immediate environment in setting the direction for the identity development of the city. Improving the quality of public space of Kosovska Mitrovica must be a condition of every architectural action. Successful implementation of project the architectural is the product of detailed analysis and multidisciplinary work, without which public areas of the city suffered the greatest damage.

Fig. 4. Multiculturalism: an affirmative value and need of the city (photo by M. Pavlicic)

4. Altered Concept of Urban Activities and Spatial Implications

Urban areas are recognized as functional places inhabited by people who are participants in public life, and physically as places inhabited by buildings that, with their physical prevalence, establish a relationship with the environment. Ways of behavior of people who use the public space of this city is conditioned by existing cultural patterns that can be seen through the territory occupancy of some sort of use — walking, working, resting, playing, entertainment, socializing, moving from point A to point B. However, the changes of urban functions in Kosovska Mitrovica caused, above all, the transformation of the urban morphology of the city, the changes in social trends, in the age structure of the population and in the cultural patterns, changing the identity of the city.

Objects characterized by a certain concept of human activity as a goal of moving, hence the necessary condition for the life of urban public spaces whose "nature of public is prevalently perceived through their use"[6]. When we talk about Kosovska Mitrovica those are: university institutions, dormitories, schools, banks, health care facilities, and also, indirectly, restaurants, bars, parks, playgrounds, shops, kiosks, fast food. Therefore, such facilities must be promoted and contextualized in space in order to provide further living spaces of the city. Thus, the architecture mimics the order which its society puts in.

However, "if architecture can not find an order that it can imitate and follow, or if it can not imitate an existing one, can it create a new one, whether it's a world or society?"[7]. In this case the architecture becomes dominant, favoring the idea of the material. This treatment is applicable to the urban areas of Kosovska Mitrovica where there are clear and thoughtful vision of the future genesis of the city in the context of preserving the legacy and promoting the new values of the society.

Conclusion

The sudden historical changes in Kosovo and Metohija had a strong influence on the overall development of the urban environment. Striving to improve the quality of life in Kosovska Mitrovica is one of the key requirements of activity in the urban area, with a certain level of complexity of the functional requirements and cultural identity. This paper talks about the necessity of structural changes that are comprised in the accelerated creation of new functional units converting existing spatial structures into new ones to meet the new needs of the city. Influence of space-time relations in the example of of Kosovska Mitrovica especially is amplified by the characteristics that carries a single location, historical and political context, space limitations and the structure of the city's inhabitants. It brought to the city a new cultural recognition that becomes part of the heritage.

The aim of this study is to point out that, despite the fact that the urban spatial structures evolve along with changes in the lifestyle of the inhabitants of the city, sudden changes in the society, however, did not lead to corresponding changes in the public space that fulfilled the changing needs of the city. It is up to us to, by changing the city, with specific relation of space-time, our actions seek to cherish those spatial and cultural elements that directly liaise with the past and adapt them to the new needs of the city.

REFERENCES

[1] Zucker, P. Town and Square: From the agora to the Vilage Green, Columbia University Press, NY, 1959, p.5.
[2] Norberg-Schulz, C. Existence, Space & Architecture, Studio Vista, London, 1971, p.81.
[3] Radović, R. Fizička struktura grada, Institut za arhitekturu i urbanizam, Beograd, 1972, p.13.
[4] Norberg-Schulz, C. Genius Loci, towards a Phenomenology of Architecture, Rizzoli, New York, 1979, p.5.
[5] Lynch, K. Good City Form, MIT Press, Cambridge, 1981, p.131.
[6] Herzberger, H. Lessons for students in architecture, Uitgeverij 010 publishers, Rotterdam, 1993, p.16.
[7] Tschumi, B. Architecture and Disjunction, The MIT Press Cambridge, Massachusetts, 1996. p.38.

DEMOGRAPHIC FACTORS, URBANIZATION AND URBAN SPRAWL IN SOFIA, ROME AND BELGRADE

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Abstract: *There is a clear relationship between the population growth, population density, growth of the urban areas and the processes of Sprawl. As urban Sprawl does, the urban growth also usually leads to an expansive enlargement of the urban areas. The essential difference is that the general growth of the city is the reason for the increase in the density of occupation, while Sprawl is characterized by decreasing density. Therefore, for this study is particularly important to investigate two of the major factors related to the processes of growth and / or Sprawl in Sofia, Belgrade and Rome: first, the growth of the urban area and second, the changes in the density of habitation.*

Key words: *urban sprawl, drivers of urban sprawl, urbanization, population growth, population density*

1. Introduction

Globally population of the major cities, agglomerations and especially their capitals is constantly growing, and this process occurs at different rates in different parts of the world[1]. Urban population growth leads to an urban increase and a spatial restructuring of the urban areas, showing as a change in the environment, living conditions, infrastructure, distribution of the social - utilities and the functional zoning.

Europe is not staying behind the common global trends, moreover historically it has always been a highly urbanized continent. The ever increasing per capita consumption of urban land is putting a high development pressures for urbanization of the suburban areas. In its report of 2006 EEA published data for more than a double difference in urban (78%) and population (33%) growth in Europe from the 1950s to around 1990 [2]. Over the last 20 years the trend is maintained, and according to Jansson et al. 2009, cited by Ravetz et al 2013, it is mainly as a result of increased numbers of households and the reduction of their size. These facts are showing a trend towards continued de-concentration and urban sprawl, which in the form of low density, discontinuous and dispersed urban development is now a common phenomenon throughout Europe [2].

Many researchers (Ravbar, 1997; Timár and Váradi, 2001; Brown and Schafft, 2002; Tammaru et al., 2004; Sýkora and Novák, 2007), cited by Krisjane, Z. and Berzins, M. (2010) [3], have claimed that suburbanisation in central and eastern Europe (CEE) at the end of the 20th century and the beginning of 21st century was one of the most visible processes of socio-spatial restructuring. The process is mainly described with the suburban

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and hinterlands growth of big cities and capitals as a result of population migration from the compact city, and often from other settlements.

Suburbanisation is mostly evident in the suburbs of capital cities and centers of economic activity and is one of the many reasons for uncontrolled expansion of the urban areas, defined as urban sprawl. Issues concerning urban sprawl are considered in a significant amount of literature, but still it can not be claimed that there is a uniform definition for the process. However, from all the definitions perhaps the most - short is that of Brueckner (2000) [4], who argues that sprawl can be characterized as "excessive spatial growth of cities". Of course this definition is too general, as sprawl is a multifactorial phenomenon (Galster et al, Malpezzi, Torrens and Alberti, Ewing et al, Brueckner и др.). For the needs of this study, urban sprawl needs to be examined in the aspect of demographic processes, as part of the socio - economic factors driving sprawl. And as Ewing et al (2002) [5] concluded for the presence of sprawl can be claimed when the urban growth rate significantly exceeds the population growth rate.

Suburbanisation and urban sprawl as its negative trend can be mainly divided into two patterns [6], occuring most frequently:

- Western type, characterized mostly with processes of intra - urban migration led by upper- and upper-middle-class population, searching for a better living standart in sparsely inhabitated areas adjacent to natural environment, and
- Eastern type, characterized mostly with processes of rural-to-urban migration, in search for a better job and salary.

2. Object and subject of the research

For object of the current research are selected three capital cities - Sofia, Belgrade and Rome. Subject of the research are the demographic and urbanization processes that took place there during the 2001-2011 period. This period was chosen deliberately so, because of its coinciding with cycles of the official national censuses. The analysis of these processes is intended to show to what extent one can speak of suburbanization with patterns of urban sprawl in the peripheral areas of the examined cities. This will be done in terms of the most - widely spread and known indicator for the presence of sprawl - the population density (Ewing et al 2002) [5]. During the study of demographic and urbanization dynamics will be made an attempt to determine the type of suburbanisation – eastern or western.

3. Specifics in the historical development and the administrative structure of Sofia, Belgrade and Rome

Historicaly the development of former socislist countries differs substantially from that of the capitalist countries. As a result of the lack of a free market and the presence of a centralized planning (Pichler-Milanovic, 2009) [7] Sofia and Belgrade till 1990 grew much more compact from the capitalist Rome. That's why during the communist period, the process of suburbanisation has not been so significant in Bulgaria and Serbia. But with the collapse of the socialist system and the creation of new capitalist societies countries of the Eastern bloc faced the negative effects of the loss of certain markets, an increase in interior and exterior migration and the impoverishment of significant parts of the society.

As very important factors, heavily interrupting the development of former Yugoslavia and having serious consequences on the development of Belgrade between 1990 and 2000 must be considered the division of the country, the subsequent military conflicts and the embargo imposed by NATO. At the same time Bulgaria experienced some periods of high inflation and a severe economic crisis, which also slowed its development and caused significant demographic changes. Sofia, as the capital of Bulgaria, due to these reasons, in the transition period experienced a population decline and decrease in its economic development . With respect to Rome at this stage of the research this was not studied.

In terms of their administrative structure it is difficult to identify interdependencies for the three cities, although in terms of administrative - spatial division all the three capitals are classified into NUTS3 territorial level. In fact, in all the three Countries under review, considering the administrative units, we have subdivisions extremely varied: both as regards the areas of jurisdiction, both in the number of administrative levels. It is therefore hard to draw clear interconnections and relationships between the capitals Sofia, Belgrade and Rome based on administrative - spatial characteristics.

4. Analysis of the population and urban growth dynamics in Sofia, Belgrade and Rome during the 2001-2011 period

There is a clear relationship between the population growth and density, the urban growth and the processes of sprawl. Usually urban growth is manifested by uniformity and simultaneousness in the territory and density increase, while sprawl trends towards anticipating growth of the urban areas compared to population growth rates, which leads to a low population density. Therefore, for the present research is essential to study two major factors related to the processes of growth and/or sprawl in Sofia, Belgrade and Rome:

- First, the changes in the density, and
- Second, the growth of the urban area.

According to MOLAND [8] data, between 2000 and 2006, the total urbanized area in all the three agglomerations reviewed grew as also their population did. This indicates that Sofia, Belgrade and Rome are indeed growing. For the period from 2000 to 2006 the urban territory of Sofia region increased by 2.2%, while for the same period the population grew by almost 6%. For Rome the figures are almost 5% average growth of urbanized areas and only 0.36% population growth. For Belgrade the data is still not full.

Considering the facts available they didn't show any evidence of sprawl for the region of Sofia. On the contrary is the municipality of Rome, where the urban growth outpaces 14 times the population growth which is an indication of city sprawling.

The analysis in this section focuses initially on the quantitative indicators concerning the population dynamics in the examined different areas of the case study cities. Demographic characteristics and assessments of the demographic status of Sofia, Belgrade and Rome are based on analyzes of certain number of demographic indicators – population growth, population density and migration. To outline certain demographic trends, the course of demographic processes over the last 10 years (2001 – 2011) is monitored in the present paper. The data shows processes of uniformly population distribution over the period in Sofia- city and Sofia region, while the processes in Belgrade and especially in Rome are towards greater increase in the region than in the compact city.

4.1 Sofia

In contrast to the situation between 1991 and 2000 (From 1,190,126 people in 1992, the population of Sofia-city dropped to 1,170,842 in 2001) during the last decade in the demographic development of the city, continuing positive trends are observed [9]. The mechanical movement of the population (internal migration) strongly influences on its number and structure in Sofia, especially given the enduring trend for negative levels of natural population growth throughout the period. Over the past ten years, the mechanical movement in the area remained relatively the same, without substantial deviations observed – newcomers are always more than the leaving ones. The amount of the positive mechanical growth is quite large, which is explainable by the fact that the capital city is an attractive place for living mainly due to the significantly better, compared to other areas, economic conditions.

The demographic development of the different districts of Sofia is not uniform and, in fact, considerable differences might be observed that reflect, above all, the trends of suburbanization. Suburban districts of Sofia, according to their level of influence on the distribution of population in the area can be combined into two main groups:

- Northern comprising Vrabnitsa, Novi Iskar and Kremikovtsi, and
- Southern, comprising Vitosha, Ovcha kupel and Pancherevo.

Northern suburban areas show an average population and density change at the rate of 4.1%, which is two times lower than the average for the urban areas. At the same time for the southern suburban areas the average rate gains 26.5 percent, equal to more than six times the average growth in the northern regions and three times the average for the compact city [9]. And it is clear that the processes of inter-urban and intra-urban migration in the metropolis of Sofia Municipality, during the considered decade have been obviously focused mostly on the southern suburban areas, near Vitosha mountain, and not to the northern territories of Sofia. These facts are evidence of serious investment interests namely to the southern territories, and it is reasonable to suggest that right there may eventually be sought a faster land urbanization, which is a precondition to talk about suburbanization with urban sprawl.

4.2 Belgrade

During the considered ten-year period, between the last censuses, the population of Belgrade grew by nearly 8%. Given the fact that from the 1992 Census until now the city recorded a constant negative natural growth, it can certainly be claimed that population increase in the region is entirely due to mechanical growth [10]. A major share in it, during the nineties of the twentieth century have war refugees in the former Yugoslav republics, and later settlers from Kosovo and Metohija. Certainly part of the immigrants come from other parts of Serbia, but all have one in common - the search for a better socio-economic conditions for living.

Suburban territories of Belgrade, as these in Sofia, do not develop equally. There are significant demographic differences between them, primarily reflecting trends towards suburbanisation. According to their degree of impact on the allocation of population into the area, as well as according to their geographical location two main groups can be determined:

- Suburban 1(S1), located in a direct contact with the compact city, to the north of it and including: Barajevo, Grocka and Surčin and
- Suburban 2(S2), located in the southern part of the municipality and including: Lazarevac, Mladenovac, Obrenovac and Sopot.

The three areas of S1 group, during the period of 2001-2011, averaged a population and density of occupation change at 11.4%, which is more than ten points higher compared to the average for the S2 group (0.93%) [10]. It can be clearly seen that the processes of inter- and intra-urban migration in the Belgrade municipality during the analysed decade were mainly focused on the suburban areas from the first group, but not to the southern, end areas of the second group. But also it is of great importance to note the strong trend of depopulation in the central areas where the historical center lost between 8 and 15 per cent of its population.

4.3 Rome

For a period of twenty years between the censuses of 1981 and 2001, the population of Rome was steadily decreasing but from 2001 to 2011 there is a slight increase in the compact city and almost a triple in the greater province of Rome. Having regard the data from the "Annuario Statistico 2011, Roma" [11], it can be clearly seen that during that period the number of registered foreigners in Rome increased a lot. Therefore, from 18.3% population growth in suburban areas of Rome, more than one third is due to the settlement of foreign nationals. Considering these data and the data for the “ Municipios ” in urban core it can be concluded that there is not enough evidence for significant processes of migration from central to suburban areas of Rome, and the growth in suburban areas is mainly due to inter-urban migration wave of immigrants.

Various suburban areas of Rome as well as those of Sofia and Belgrade, demographically also do not grow in a uniform pattern. Among them there are substantial differences, some of which reflect the trends towards suburbanization. After a thorough review of "Annuario Statistico 2011, Roma", it turned out that the suburban areas that registered the highest growth during the period are actually the ones with the youngest population and the greatest percentage of foreigners. Based on these indications were established two basic groups of suburban areas:

- Suburban 1 (S1), including municipios VIII, XII, XIII and XX, and
- Suburban 2 (S2), including municipios IV, IX and XIX.

S1 group areas, for the period between 2001-st and 2011-th, averaged a population and density of occupation change at 25.7%, which is three times higher - than the average for urban and S2 areas. Meanwhile for the last the average rate is 8.9%, which is comparable to that achieved for the compact city [11].

It is absolutely clear that the processes of inter and intra-urban migration in Roma Capitale, during the analyzed decade obviously have been focused mainly on the suburban areas of S1 group. These facts lead to the assumption that there is a strong interest faced to these particular areas, so it is reasonable to suggest that right there may eventually be sought an anticipative urbanization of land, which is a precondition to speak of suburbanization with urban sprawl.

Conclusion

All three cities, object of the research, recorded an overall increase of the population and the urban territory during the examined period. Although the demographic development of Sofia, Belgrade and Rome, to varying degrees, shows a trend of negative natural growth. They all marked a population increase but while in Belgrade the rate change in the compact city and the peripheral areas are comparable in Rome and Sofia the population growth in the periphery outpaces the increase in the compact city. The data themselves are certainly a strong evidence of significant suburbanization. And since all three cities recorded a negative natural and positive mechanical growth in the period considered, it can be certainly argued that the population growth is due to their mechanical growth owed to the different migration processes.

However because at this stage of the research there is no suficient data available for the urbanized area of each of the municipalities of Sofia, Belgrade and Rome throughout the given period, and though the significant population growth in most of the suburban areas it can only be suggested for processes of urban sprawl and their intensity. Despite this, the three capital cities can be treated as comparatively compact urban forms, with high densities in the compact city – something very common for South-eastern and Southern Europe.

Acknowledgement

This paper is a result of the research carried out within the scientific project "Transition towards Urban Resilience and Sustainability" (TURAS) funded by the Seventh Framework Programme of the EC.

REFERENCES

[1] United Nations,Department of Economic and Social Affairs, PopulationDivision. http://www.un.org/en/development/desa/population/theme/urbanization/index
[2] EEA (2006) Urban sprawl in Europe: the ignored challenge. European Environment Agency, Copenhagen, 10/2006
[3] Krisjane, Z. and Berzins, M., 2010. Post-socialist Urban Trends: New Patterns and Motivations for Migration in the Suburban Areas of Rıga, Latvia
[4] Brueckner, J.K., 2000a. Urban sprawl: Diagnosis and remedies. International Regional Science Review 23, 160-171
[5] Ewing, R., Pendall R., Chen, D. (2002), Measuring Sprawl and its Impact, Volume 1 (Technical Report), Washington D.C.: Smart Growth America, www.smartgrowthamerica.org
[6] Hirt,S., 2007a. Suburbanizing Sofia: characteris¬tics of post-socialist peri-urban change, Urban Geography, 28(8), pp 755–780
[7] Pichler-Milanovich, N., 2009. The process and pattern(s) of residential sprawl in post-socialist cities: a story of Leipzig-Ljubljana-Warsaw, Studia universitatis Babeş-Bolyai, sociologia, liv, 1, 2009
[8] http://moland.jrc.ec.europa.eu/index.htm
[9] National Statistical Institute, 2012a. Census 2011, Sofia (Capital). Sofia, Bulgaria
[10] Statistical Office of the Republic of Serbia, 2011 Census of Population, Households and Dwellings in the Republic of Serbia, Belgrade 2012
[11] Annuario Statistico 2011, Roma, dicembre 2011, U.O. Statistica e Censimento Sistema Statistico Nazionale

ARCHITECTURAL FORM OF THE CONTEMPORARY RAILWAY STATIONS

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Abstract: *This paper will focus on the architectural form of the contemporary railway stations.*
Nowadays railway stations are undergoing changes in order to become transportation hubs where different means of transport are located. Stations in the city centres are perfect places for situating next to them other buildings such as shopping centres and office buildings. Very often all of the functions are located within one multi-functional complex or building. Functional complexity of the railway station buildings has influence on their architectural form. Main types of the railway stations will be distinguished depending on the form and location of the reception building and the train shed. The typology based on the representative examples of railway station architecture in Europe will be created.

Key words*: contemporary architecture, railway station*

1. Introduction

First railway stations were built in the XIXth century in Liverpool and Manchester. It was necessary to create new building type which had new architectural form: the reception building and the train shed. Some of the stations used to have full train shed, the others just partial covering of the tracks [1].

Nowadays different architectural forms of the stations could be distinguished. Some stations are very monumental and have very representative forms. The period in which the station was designed and built has influence on the form of the building.

2. Extensions of the existing railway stations

Existing railway stations could be extended with new functions located inside the existing building or next to them.

Amsterdam Centraal station, designed by architect P.J.H. Cuypers and A.L. van Gendt, was opened in 1889. At the end of the XXth century it was necessary to transform the existing railway station and its surroundings into an attractive transport hub which would become a gateway to the city. The masterplan was designed by Benthem Crouwel Architekten and Merckx + Girod [2]. The railway station was extended with the bus station located on the north side of the station at the level of the train tracks. The bus station will

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be covered by a steel structure (360 meters in lenght) which consists of steel arches every 12,5 m (spanning 65 meters) and cold bent laminated glass panes (3 m x 1.1 m) [3].

Fig. 1. New bus station (author)

On the level under the bus station the IJhal of the Amsterdam Central Station will be built. The IJhal, designed by Wiel Arets Architects, will become a place with catering, service and leisure facilities [4]. On the north side of the IJhal the ferry terminal with the waterside plaza will be created.

Other station which was extended with new functions is Leipzig Hauptbahnhof - a terminus train station [5] designed by prof. William Lossow and Max Hans Kuhne. The modernization works of the station (built in 1915) at the end of the XX century were finished and the shopping mall „Promenaden" on the underground levels of the reception building was opened [6]. There is 30 000 m2 of retail at the station.

Fig. 2. Interior of the shopping centre Promenaden Leipzig Hauptbahnhof (author)

In 2007 the construction of the 2 kilometer-long tunnel, designed by HPP Hentrich-Petschnigg & Partner, Schleich Wunderling, Max Dudler and Peter Kulka, started. The CityTunnel Leipzig, which will become a connection line between Leipzig Hauptbahnhof and Bayerischer Bahnhof station, is situated 22m under the ground [7].

Construction works at the existing stations which have historical value, usually does not influence the form of the existing buildings. Extensions are usually realized as and additions to the existing structure (situated next to them or located on the underground levels).

3. Newly designed railway stations

New railway stations could be built in the new or old locations. Usually at the new stations which are built in the old locations, the level of the train tracks does not change. It is important that trains run normally through the stations during the construction works.

One of the new stations in the old location is Rotterdam Centraal. The new station was designed by a group: Benthem Crouwel Architekten BV bna, Meyer en van Schooten Architecten bv, West 8 urban design & landscape architecture bv [8]. The construction works started in 2007. The reception building is situated on the south side of the train tracks. In front of the entrance to the building there is a big cantilevered roof which creates covered plaza. The reception hall is connected with the shopping passage (49meters width) under the train tracks (on the level +1). From the hall there is also an entrance to the underground metro station. The platforms are covered by a glass roof (28 800 m²) [9]. In front of the station on the south side there is a square where tram and bus stops are located. There are also entrances to the metro station. On the other side of the station, at the Provenirsplein, there is a taxi rank and a bike park [10].

Kraków Nowy Główny is the new railway station built on level -1 [11]. The reception building opened on the 15.02.2014 and is located entirely below the existing platforms. The new complex became a multifunctional transport hub. In 2005 on the east side of the train tracks the new bus station was opened. On the level -2 (below the reception hall of the station) there is a fast tram stop. On the deck above the train tracks car park is situated. On the west side of the station there is a shopping centre [12,13]. The station does not have a traditional for railway architecture form. The reception building is not visible from the outside.

Some of the newly designed stations have very sculptural and representative forms. Those designed by Santiago Caltrava are usually becoming the landmarks of the cities or districts. That happened to the Oriente Station in Lisbon which was opened before the Expo exhibition in 1998. There is no traditional reception building in front of the station. That role has, placed on the level +1, an open public area with free standing volumes (in which waiting rooms, ticket offices, small gastro and toilets are located). The ornamental roofing structure (above the train tracks) made of glass and steel has very representative form.

Fig. 3. Roofing above the train platforms – Oriente Station (author)

In the newly designed stations traditional forms could be noticed as well. Berlin Hauptbahnhof was designed by Meinhard von Gerkan and was opened in 2006. The new station has an arch shaped glass train shed, which is a traditional form. The main entrance to the station is located between two tower office buildings [14, 15].

Conclusion

Nowadays different types of the forms of the railway stations could be distinguished. Traditionally railway stations were free standing buildings which had representative role in the cities. The traditional forms are the reception building and the train shed. The historical buildings during the modernization works usually keep their form. The new functions are added in a way which does not influence the form of the buildings and respects the existing structure and its historical an architectonical value. Some of the new stations have traditional forms (reception building and train shed). The form of some of the stations are very monumental and sculptural (Santiago Calatrava - Oriente and Liege). Not all of the new designs respect the tradition of the representative form of the stations. Some of them could be located on the underground levels and be invisible from the level of the ground.

REFERENCES

[1] Meeks L. V. C. The Railroad Station: An Architectural History. Yale University Press., New Haven, 1956.
[2] http://www.benthemcrouwel.nl/portal_presentation/transport/amsterdam-cs
[3] Excerpts from De Ingenieur 10/11. Buigbaar busstation. De Ingenieur, 5 June 2005
[4] http://www.wielaretsarchitects.nl/
[5] Niedenthal C., Bahnhöfe in Deutschland/Stations in Germany: Moderne städtische Zentren-Modern Urban Centers, Jovis 2008
[6] http://www.ece.de/en/geschaeftsfelder/shopping/listedershoppingprojekte/center/phl/
[7] Niedenthal C., Bahnhöfe in Deutschland/Stations in Germany: Moderne städtische Zentren-Modern Urban Centers, Jovis 2008
[8] http://www.west8.nl/projects/rotterdam_centraal_station/
[9] Benthem Crouwel Architekten, Schipper K. BC AD Benthem Crouwel 1979-2009: 2010
[10] http://www.rotterdamcentraal.nl
[11] Ogrodnik D., Krakowskie Centrum Komunikacyjne a problemy kształtowania przestrzeni publicznych w otoczeniu dworców kolejowych, Urbanista 12/2004, Urbanista, Warszawa 2004
[12] Małecka D., Dworce kolejowe – teraźniejszość i przyszłość [w:] D. Załuski, Dworzec kolejowy w strukturze miasta, Biblioteka Urbanisty t. VIII, Urbanista, Warszawa 2006
[13] http://krakownowyglowny.pl
[14] http://www.mev-lehrte.de/download/Bahn_Lehrter_Bahnhof.pdf
[15] www.bahn.de

ART AT THE CONTEMPORARY RAILWAY STATIONS

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Abstract: *This paper will focus on the art at the contemporary railway stations. Nowadays railway stations are becoming more and more complex: within them different functions (transport, commercial, and public) are located. Railway stations are perfect to place public art inside them. The main function of public art is to amuse passengers while they are waiting for trains at the platforms and inside the station halls. Introducing public art could also be useful in building the image of the railway company and helping passengers to orientate/navigate inside the stations. Usually the sculptures, paintings and art installations have monumental forms and are easily visible from different parts of the stations. Railway stations are also perfect places to organize temporary exhibitions and events as they attract different people.*
Art could be also integrated in the structure of the building, as it happens at the stations designed by Santiago Calatrava (Oriente Station in Lisbon, Liege Guillemins Station in Belgium), which have organic forms.

Key words*: art, railway station, contemporary architecture*

1. Introduction

One of the first railway stations were built in 1830 in Manchester and Liverpool. Both of them had very simple architectural forms. Invention of the new mean of transport resulted in creating new building type. With the growth of the importance of the rail transport, it was necessary to look for more representative forms of the railway stations and train sheds [1]. With time the stations became landmarks and gateways to the cities. Their facades had more and more details and ornaments. It could be said that art has been always present at the railway stations. From the beginning the art at the stations was supposed to amuse people and to show the significance and importance of the station.

2. Art at the stations

Art could be incorporated in the structure of the station buildings and train sheds.

The stations designed by Santiago Calatrava have very sculptural organic forms. Among them are stations in Liege (Liege Guillemins Station), Zurich (Stadelhofen Station) and Lisbon (Oriente Station). Each of the stations is a masterpiece, where Calatrava confirms his talent as an architect and engineer.

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The station in Zurich was the first important project in career of Santiago Calatrava. The construction of the extension of the Stedelhofen station finished in 1990. The station is built on different levels. The lowest level has the most massive form, while the uppest one – very light. On the underground level there is a shopping centre, while on the ground floor – railway tracks. At the level +2 there is a footpath which connects the station with the other part of the city. Calatrava used different materials: concrete, steel and glass. Even though those materials might be considered as rough the organic ornamental forms make the whole structure very monumental and fluent [2].

Another station designed by Calatrava is Oriente in Lisbon - a transportation hub where each mean of transport (train, bus, metro) is located on another level. The station was opened before the exhibition Expo in 1998. It has very representative form, as it was designed to become a gate to the whole district. The most sculptural element of the structure is ornamental roofing (above the train tracks) made of glass and steel.

Fig. 1. Roofing above the train platforms – Oriente Station (author)

Liege Guillemins (construction: 2000-2009) is another station which was built according to the project of Calatrava. The structure of the station at the level of the ground is made of concrete. The train tracks and platforms (level +1) are covered by a copula (200x73m), made of glass and steel, composed of 39 arches [3].

Fig. 2. Liege Guillemins Station – main entrance (author)

Art located at the stations could also be very characteristic and make reference to the tradition of the region it serves [4]. The façade of the reception building at the railway station in Aveiro is covered with traditional Portuguese painted ceramic tilework called *azulejos*. They are also placed in the interior of the reception building of the main railway station in Porto.

Fig. 3. Façade of the railway station in Aveiro, Portugal (author)

Public art could be celebration of a person or event (like a statue on London St Pancras Station) or might be designed for a practical purpose (for example murals ate the underground stations). Free standing statues and sculptures inside the reception halls have also important role in helping passengers to recognize where they are. They also act as a focal points and meeting places for people [5]. At the new railway station in Kraków inside the reception building (on the underground level) there is a sculpture "The Globe" which is a meeting point and helps passengers to orientate where they are.

3. Art events and installations at the stations

Railway stations and terminals, as well as many other transit venues, are places where people watch and wait – perfect for art installations.

In 2013, because of the centennial celebrations of Grand Central Terminal, MTA Arts for Transit organized events during the whole year. One of the projects organized for the celebrations was "Grand Central Light" [6]. During the event, which took place on the evening of 100th birthday, 135 participants (From Improv Everywhere group) suddenly appeared in the windows of the terminal. They stood on the 3 levels of the windows and while using flashlights and camera flashes, created a shower of light for people below in the main concourse. The performers were just told to bring with them a flashlight and a camera. The more precise instructions were given to them just before the performance. The "Grand Central Light" performance was produced and created by Charlie Todd, who is the founder of Improv Everywhere. In 2008 the group performed Frozen Grand Central when 200 Improv Everywhere Agents unexpectedly stopped moving for a while.

The presence of art at the station could also play an important role in revitalization of the station and its surroundings. Revitalisation of the Eichbaum station is an example of bringing new life to the old structure. Eichbaum station is on the interurban metro system of the metropolitan area of the Ruhr. Located in the difficult unpleasant setting between 2 motorways and accessible by tunnels it became insecure area with a lot of vandalism. In 2006 a group of architects and urban planners came up with an idea of giving the station an atypical function. They thought that it could transform the area of the station into the safe place and change people's attitude to that area. The idea was to convert station into the opera house with help of the main theatres in the region. On the upper level of the station, a pavilion constructed of recycled containers was built. The whole process was done in order to present the new type of opera. In 2009 between the railway tracks the temporary seating for 200 people and a stage were constructed. After the opera season, the pavilion remained on the upper level as a proof of the previous events. The project confirms that organizing collective events at the run-down public areas might significantly improve the quality of those areas [7].

Conclusion

The art at the railway stations play very important role: not only from the point of view of aesthetics, but also from practical reasons. Pieces of art could be located at the station as a decorative elements added to their structure or incorporated in it. It could also help people to recognize where they are and give a sense of place to the transit areas. Organising events and performances at the stations might enhance the public domain at the stations and encourage people to use rail transport. Presence of art might also limit vandalism and improve the passenger experience.

REFERENCES

[1] Meeks L. V. C. The Railroad Station: An Architectural History. Yale University Press., New Haven, 1956.
[2] Ferrarini A., Railway stations : from the Gare de l'Est to Penn Station : Aix-en-Provence, Arnhem, Berlin, Florence, Frankfurt-am-Main, Kyoto, Lyons, London, New York, Paris, Singapore, Seville, Zurich, Phaidon Press 2005
[3] Lewandowski M., Dworzec kolejowy (Liège-Guillemins TGV Station). Architektura-murator 11/2010, Warszawa 2010
[4] Edwards B. The Modern Station: New Approaches to Railway Architecture, London : E and Fn Spon 1997
[5] Ross J., Railway Stations: Planning, Design and Management, Architectural Press, 2001
[6] http://improveverywhere.com/2013/02/05/grand-central-lights/ (posted on February 5, 2013 by Charlie Todd)
[7] http://www.publicspace.org/en/works/f030-eichbaumoper/results:2010

ВЛИЯНИЕ НА ЯПОНСКИТЕ ТЕНДЕНЦИИ ВЪРХУ КОНЦЕПЦИЯТА ЗА МИНИМАЛИСТИЧНИ ГРАДИНИ

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INFLUENCE OF JAPANESE TRENDS ON THE CONCEPT FOR MINIMALIST GARDENS

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***Abstract**: Strong influence on traditional Japanese design and the minimalism concept ZEN philosophy that believes that simplicity is not just aesthetic value and moral perception which analyzes the nature of truth and reveals the inner qualities and essence of the material and facilities. Minimalism is characterized by large expanses with minimal use of industrial materials, tones that are reduced to monochrome range with emphasis on neutral earth tones. The whole concept is based on precise geometry that makes clean horizontal lines, low elements of urban equipment. Lighting also uses basic geometric shapes as own contour combined with dim light and clean form of coatings that also contribute to the beauty of the structure. The main goal of elaboration will be the composition, color materials in creating minimalist garden design supported by the Japanese.*

***Key words**: garden, composition, vegetation, landscape*

1. Въведение

Минимализмът възниква в Америка през 1960 или началото на 70 години като реакция на абстрактният експресионизъм, той се фокусира върху простота, която произтича от редуциране на елементите на по-малко елементи като цвят, линия, материали и тяхната текстура.

Минимализмът се характеризира с големи пространства с минимална употреба на промишлени материали, тонове, които са сведени до монохромна гама с акцент върху неутрални земни тонове. Цялата концепция се основава на прецизна геометрия, които правят чисти хоризонтални линии, ниски архитектурни елементи с напълно изчистена линия. Осветлението също използва основни геометрични форми като собствен контур в комбинация с замъглена светлина и чисти покрития на

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формата, които също допринасят за красотата на самата структура. Тя е силно вдъхновена от японският традиционен дизайн и концепция на Зен философията.

Фиг. 1. Зен концепт

Концепцията и елементите от дизайна се основават на използването на красивите естествени текстури от пейзажа, дърветата, камъка, които определят структурата на минималистичните градини.

2. Композиция на японските градини

Трудно е да се разбере символиката на японските градини. Възхищението на днешния човек се ражда от изобилието на информация от получените ефекти, живописно разполагане на мовчетата, стълбите, фенерите, кладенци и др. Всички тези елементи не са случайно - те имат символично значение и подчертават добра картина по отношение на японците.

Японците проявяват особено възхищение към каскадите – основният елемент в пейзажа. Има десет вида японски каскади. Когато нямат течаща вода, японските специалисти показват нейно присъствие с оригинални решения. По това отношение въображението им е безгранично. Езерата също са основен композиционен елемент на градините. В градинските езера се виждат и острови, които разполагат с различни форми - например, костенурка.

Каменните пътеки от плочи с неправилни форми, са изградени, за да влиза в градината стъпка по стъпка.

Жестокият начин на живот и будизма са причината японците да обичат простотата на формите. Религиозните доктрини, философски теории и народните вярвания я плетат идеята основа на японското градинско изкуство. Законите за добро поведение, постулатите за хармонията, принципите на активното и пасивното, светлината и сянката, мъжкото и женското, както и деветте духове на будистката пантеон действат директно на разположението на градините.

Традиционно японския градинар прави дизайна на мястото така, че да бъде в хармония с всичко, което го заобикаля. Ако в близост има хълмове или в далечината се виждат планини, той включва в структурата с помощта на древната техника шакеј. Това приблизително би означавало "пейзаж на заем". Ако наоколо има вода, градинарят строи нещо като малка каскада или езера. Той подрежда камъни, прокопава вади, вдига малки хълмове, прави стъпаловидни тераси. Всичко това се постига с една единствена цел - градината да бъде място за размисъл, наслада и успокоение за погледа и душата.

Фиг.2. Композиция на японската градина

Фиг. 3. Въздействия от японската традиция

Концепцията на минимализма е да се отнеме от елементи което се свежда до негово основно качество и да се постигне простота. Идеята не е пълна без украса, но те треба да са съвсем малко. Съображенията за "есенции" са лесни, форма, детайли на материала, пространство, място и човешкото състояние. Ландшафтните дизайнери минималисти търсят дълбоко духовно измерение обръщат вниманието на детайли, пространството, природа и съвременни материали, който разкриват абстрактното качество на нещо, което е невидимо и търсят същността на тези невидими качества. Като естествена светлина, небето, земята и въздуха. Освен това, те започват диалог с околната среда, с цел да се реши един от най-важните материали за създаване, съответно на растенията и да се създаде отношения между растенията, релефа и архитектурните елементи.

В минималистичните градини, елементите на дизайна пренасят съобщение на простота. Основните геометрични форми, елементи без украса, прости материали и повторения на структурите представляват усещане за цел и качество.

3. Концепция за развитието на минималистичните градини

Минималистичните градини не са специфичен стил на градинарство, а естетически принцип върз основа на перспектива, че по-малко е повече. В тези градини, растенията са внимателно подбрани и необикновените материали са интегрирани в растителността.

Фиг. 4. Минималистична градина

В съвременната градини, често се намират предмети, като например от неръждаема стомана и стъкло. Може да се намери съвременно изкуство в градините като дом с високо иновативен дизайн, и където дворовете сами по себе си изящни галерии на открито. Водни елементи в тези пейзажи, често се използват за надграждане усещането за контраст с благотворно или спокойно чувство.

Минималистичен дизайн на градината, с баланс на прости форми е отдавна на мода. Много култури намесват с тенденции за по-малък или по-голям достъп за редактиране, за да изразят специфични ценности и традиции, напоследък, минимализма има разширение от популярност и се прехвърля леко към модерната съвременна градина. Геометрия е по-важна от когато и да е в минималистичния дизайн за тези и много други причини. Това е една връзка между това, което остана от органичния свят, архитектурата на ландшафта и непознатите параметри на човешкия ум. За разлика от своите класически еквиваленти, тези градини и паркове направиха повече, отколкото просто имат силен опит да контролират и да ограничат естествен прираст. Те активно търсят да заменят естествените елементи с неорганични структури като архитектурните елементи, стълби, чакъл и изкуство на открито. Това води до чувство на зрителя на ред и реалност и силите на зрителя да се направят изводи за изключително субективна основа за откриване на ценни качества.

Фиг. 5. Геометрия

Фиг. 6. Геометрични форми во пространство

Заключение

Минимализмът не е уникален стил това е естетически подход към дизайна на градината. Всяко обзавеждане може да има полза от минималистичните градини до известна степен.

Това, което "по-малко е повече" наистина се отнася за внимателен баланс на отделните елементи, които са толкова контролирани, че нито един елемент не доминира в цялото.

В официални градини, това изисква експертни познания на ботаническата науката.

В съвременната градини, тя изисква математически точност и съзнание за това как да се използва нетипични елементи и уникални геометрични фигури на архитектурни елементи, за да се постигне уникален резултат.В резултат на това, математическите и научни аспекта сега са заменени органични и символични елементи на изкуството и духовността.

Едностадноставноста на линията, геометрията, прави перфектни линии пространство почистено от елементи, съвременни материали са компонентите, които дефинират минимализъм под силното влияние на съвършените композиции на японските градини.

ЛИТЕРАТУРА

[1] Фомина, Л. История и композиция, София 2003
[2] Сугерев Д. Проблеми на пейзажа, пространството и отдиха. София 1971
[3] Стойчев Л., Парково и ландшафтно устройство.София1960
[4] Betts H.E.Urban country style. 2007, ISBN 1-4236-0159-9
[5] Shepheard P., Modern Garden. London 2001
[6] Yglesias C., The Innovative Use of Materials in Architecture and Landscape Architecture: History, Theory and Performance 2014

ПРИЛАГАНЕ НА СТИЛА КЪНТРИ (STYLE COUNTRY) В СЪВРЕМЕННИЯ ИНТЕРИОР И ЕКСТЕРИОР

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APPLICATION COUNTRY STYLE IN MODERN INTERIOR AND EXTERIOR

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***Abstract**: Country style comes from a reputable English gardens in 1600. The main inspiration for the design and authentic rural life. Paints that sets the style starts from sky blue colors to the range of earth tones which nudge nature. Country gardens are modeled so not appear in the correct format, and as they have no specific design. Geometry does not belong in this style of editing. Focus more on colors and choice of plants contribute to a harmonious whole. Country interior delights with natural segments of nature that deploy in the modern style of life to give a picture of the relationship between man and nature lost in the urban city environment . This style has a deep charm and extraordinary character.*

***Key words**: style, interior, exterior, design development, nature*

1. Въведение

Какво е стил? В наше време понятието стил се приема в много широк смисъл, от общата характеристика на духовните постижения на дадена човешка общност в цели хилядолетия до конкретни особености на едни или други личности, колективни или дори модни творчески изяви.

В историята на изкуството, в който част попадат стилистични характеристики те се използват като сумарна характеристика на преобладаващите естетически възгледи през определени исторически периоди. За целта епохи се различават по време и характеристиките на израз, техните активи се характеризират с най-важните отличителни белези.

Послушанието в този смисъл на понятието стил ни помага, защото обхваща изобразителното заяви на всеки период като завършени естетически концепции, затворени в определени исторически граници. Но не заблуждава, че създава

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категорични разлики между видовете изяви характеристики на предишната и следващата епоха, при това ги омаловажава характеристиките на създаденото през много дълги периоди от неизбежното историческо преплетени.

Стил е исторически обусловено, единна система от художествени принципи и изразни средства със собствени свойства. Стил е единство на основните идеологически - художествени особености и характеристики.

Стилът като исторически обусловена система от изразни средства и художествени принципи, винаги с високо характерен и със собствени характерни черти. Определя се различни видове стилове, но ние в следващото изследване ще разгледаме стила кънтри, както в интериора, така и в екстериора.

Официално стил кънтри идва от Англия, както подсказва и името. Кънтри стил датира своето начало от XVII в. В него са се смесили народни елементи с различен произход. Той действия отпускащто. Синьото и зеленото го представуват спокојствието. При кънтри стила синьо изразява спокојствието, а зеленото природата. Всичко това е доста приятно и отпуска очите.

Стилът кънтри има много общо с различните етнически направления и въпреки това се счита, че е напълно самостоятелно творческо русло. Той се явява антипод на високите технологии, без да се конфронтира с тях.

Говорейки за характерните черти на кънтри стила, е необходимо да се спомене липсата на изтънчени и модерни елементи, което пък от своя страна се явява основният елемент за постигането на харизмата в този тип жилища. За да има настроение, не е необходимо да се следва стриктно всяка стъпка при проектирането на такъв интериор или екстериор от конкретната епоха. Една от най-важните особености при проектирането на кънтри е правилното съчетание на цвета. Балансът между всички детайли, мекотата, грубата текстура, семейните картини, реликвите от миналото и тъмните цветове са ядрото.

Най-важната особеност на този кънтри стил е използването на естествени материали в украсата.

2. Кънтри стил в екстериора

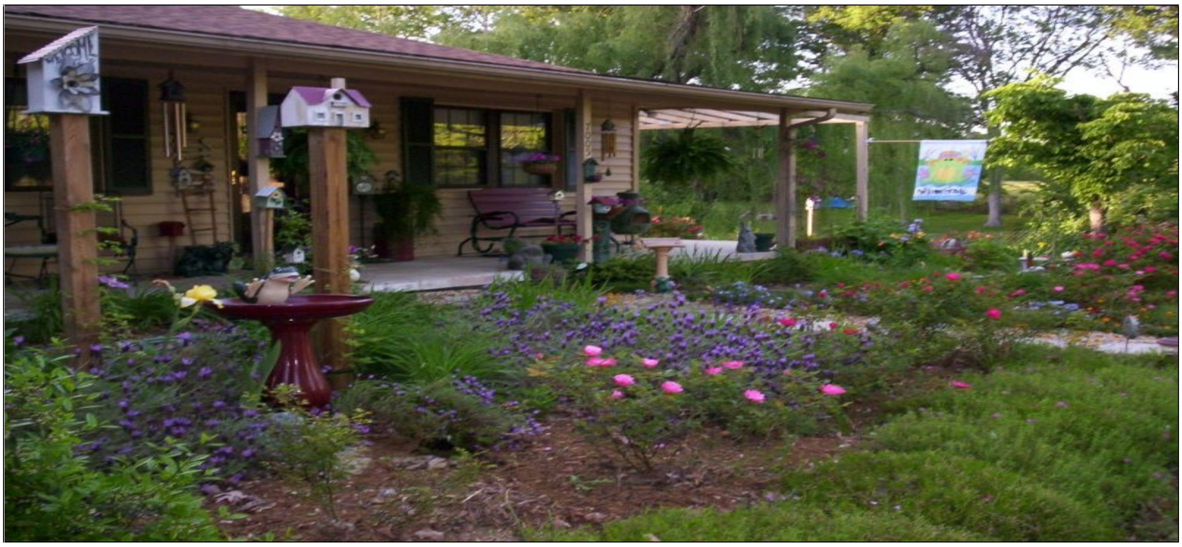
Кънтри стила е предпочитана от хората, уморени от строгия ред и правите линии, за нея няма твърди правила и установени рамки. За кънтри стила може да се каже, чт е градината на творческите предимно естествени елементи, които не са много привързани към модните тенденции и съвременния свят, но това е градината на тези, които пазят спомените от детството, и които са готови да вложат душа в дома.

Плодни дръвчета, пъстри цветни лехи, колело от каруца и тикви, висящи от оградата – стилът кънтри носи радост и безметежност, простотата и непретенциозността му го правят най-уютния и лесен за поддържане. Това е градината на творческите натури, които предпочитат да бъдат отвъд модните течения и рамките на скучния и правилно разграфен съвременен свят.

Това е ландшафтният стил, който дава най-голяма свобода при дизайна. От миниатюрните английски дворчета е наследил най-ценното си качество - дори да създадете кънтри градина на 100 кв. метра, тя пак няма да изглежда нелепо малка.

Елементи в кънтри градини:

- камък, тухла, чакъл или павета
- богато украсени чугунени пейки
- беседки
- къщички за птици
- антики



Фиг. 1. Кънтри стил. Старомоден, очарователен, и случайни, този стил се превръща в продължение на вашия дом.

Най-подходящите материали за кънтри градината са естествените - камък, дърво, за предпочитане не много обработени. Тук имат място и пътеките от дребни камъчета, и дървените пейки, и грубо скованата маса. Нито мебелите, нито перголата и беседката трябва да бъдат прецизно изработени - важното е в тях да е вложена душа. Ефектът ще бъде много по-голям, ако оградата е направена от дъски или от плет.

Фиг. 2. Материали за кънтри градината

Същността на стила кънтри е в аксесоарите. Не е задължително те да са много, но колкото по-стари и автентични са, толкова по-добре. Кладенецът, дори да не се използва по предназначение, има голяма декоративна стойност за този тип градина. Дворната чешма от чисто практичното кранче ще се превърне в украса - каменна, дървена или от ковано желязо - повечето варианти имат корени именно в старите селски дворове. Коритото й също е важен елемент - каменно или дървено, прескочило сякаш от времето преди век.

Фиг. 3. Стила кънтри – аксесоарите

Градината цъфти от ранна пролет до късна есен и през цялото време е наситена с ярки багри. За предпочитане е растенията да са традиционни. Изборът е голям - кокичета, минзухари, лалета и момина сълза през пролетта, божури, перуники, флокс, карамфили, петунии, рози, ароматен тютюн през лятото, та чак до далиите и димитровчетата през есента. Цветните лехи ще бъдат най-близо до желания резултат, ако в тях цари небрежно многообразие. На заден план са по-високите растения, пред тях - ниските.

Фиг. 4. Најчесто използвани растенија в стила кънтри

В стила кънтри тревната площ е трудно да се нарече морава. Но тя прелива от живот и цветове, както и всичко в този тип градина. Глухарчетата, лайката, детелината и паричките са желани обитатели на зеления килим. От декоративните храсти най-добре се вписват люляк и трендафил. Увивните растения също са желани - клематис, ароматен грах, грамофончета. Малините, къпините и дрянът изглеждат съвсем на мястото си в тази градина. Както и розовите храсти, те могат да оформят живите прегради вътре в двора, разделяйки го на части.

Градината в стил кънтри обикновено има зона със зеленчукови растения и това е не просто жертва в името на екологично чистата продукция, а част от цялостния облик на двора. Кънтри градината няма да е пълна без кътчета за отдих. Какви и колко зависи от размерите й. Пътеките са изградени от естествени материали. Ако участъците, засадени с дървета и храсти, се редуват с открити пространства и цветни лехи, ефектът ще бъде още по-голям.

Водните елементи сашто са значим фактор. Мостчето може да представлява прехвърлени над водата талпи или лека дървена конструкция.

2. Кънтри стил в интериора

Непринуденият художествен безпорядък и мебелите от натурално дърво са основните елементи на кънтри интериора. Специалистите са единодушни – това е стилът, който може да внесе идеално успокояваща атмосфера, уют и селска романтика във всяка къща.

Стилът кънтри е в състояние да пасне на всеки дом. Непринуден художествен безпорядък и мебелите от натурално дърво — са основният принцип, който е ключът към щастието в кънтри интериорите.

Фиг. 5. Кънтри стил кухня

Това е стилът, който може да пасне идеално при създаването на интериорът на една къща. Успокояваща атмосфера и уют.

4. Ключови особености

- В по-голямата си част са старинни дървени мебели със „странен" дизайн, рядко полирани антики от метал или декори от различни епохи.
- стари и недодялани мебели, за да постигнете истинския дух на кънтри стила. Не са уместни големите кухненски шкафове претрупани с модерна техника или сгъваемите модернистични трапезарни маси от стъкло.
- Задължително е присъствието на цветни материи и текстили, бъдейки в един тон със заобикалящата ги среда.
- Прости завеси и пердета без грандиозни детайли в меки и земни тонове от чисто натурални материали.
- Натурални текстури - от дървени и каменни облицовки по стените, до ръчно тъканите завивки и възглавници - цялостна комбинация за създаването на уютен, стар дом.
- Изложени и подредени домашни судове, декорации, лични вещи и снимки по стените, рафтовете, шкафовете и масите. Духът на обитателите се усеща из целия дом.

В този ред на мисли, основното в кънтри стилът при проектирането на интериори, се явява превъзходната възможност да се използват не само старинни мебели и дивани, но и ръчно изработените плетива.

Говорейки за характерните черти на кънтри стила е необходимо да спомена и подчертая липсата на изтънчени и модерни елементи, което пък от своя страна се явява основният елемент за постигането на харизмата в този тип жилища. За да постигнете настроението не е необходимо да следвате стриктно всяка стъпка при проектирането на такъв интериор от конкретната епоха. Старият сръдък с пораждясали обкови идеални би допълнил настроението за един идеален интериор.

Фиг. 6. Кънтри стил спална

Един от най важните особености при проектирането на кънтри е правилното съчетание на цветът на стените и мебелите. Балансът между всички детайли, мекотата, грубата текстура, семейните картини, реликвите от миналото и тъмните цветове са ядрото.

Що се отнася до окраската на интериора, стените трябва да са в многоцветен стил. Във всеки случай тоновете са меки и спокойни – може би бежово, зелено и сиво, което не пречи на отделни места да се направят елементи с по-ярки цветове. Има и друг подход – декоративна шпакловка или комбинация от облицовка с декоративни тухли и камък.

Заключение

Дървени конструкции или мебели в бяло, осигурява висок контраст с пъстри растения, използвани в Кънтри стила.

Всички предмети се характеризират с простота и практичност.

В Кънтри градини като че ли не съществува специфичен дизайн. Геометрия, прави перфектни линии, или точни криви не принадлежат в този стил на ландшафта. Съсредоточи повече върху цветовата схема, като се уверите, не само цвета на растенията, но и листата на всички да допринесе за хармонично съчетание.

Ключови особености на кантри стила в интериора са дървените планки на подовете, частично покрити с шарени килимчета, разнообразието по стените и таваните, нюансите на мебелите от череша, бук, бреза или ела са задължителни елементи. Характерна за вътрешното разпределение на помещенията е липсата на врати и преградни стени. Просторна всекидневна, в средата на която се намира голям диван, украсена камина, фотографии, стари снимки и други семейни реликви, които очевидно допринасят още повече за домашния уют висят по стените.

ЛИТЕРАТУРА

[1] Беджев И. В света на стиложите мебели. София 2000
[2] Стойчев Л., Парково и ландшафтно устройство.София1960
[3] Betts H.E.Urban country style. 2007, ISBN 1-4236-0159-9
[4] http://tallbox.org
[5] https://www.mug.mk/index.php?option=com_content&view=article&id=2484
[6] http://www.landscapingnetwork.com/

THEORY OF VIEW. METHOD OF CALCULATING THE MAXIMUM PERMISSIBLE HEIGHT OF VOLUMES CONTAINED IN THE VISUAL PROJECTION TO AN OBSERVED OBJECT WITH AN EYE ON PRESERVING THE VISUAL THREADS IN THE URBAN SETTING USING PETROV'S POLYHEDRON

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***Abstract**: The study aims to set the foundations of the theory of the view. It presents a method for calculating the maximum permissible height of volumes within the scope of the visual projection to the observed object in order to design and preserve visual connections in the urban environment using Petrov's polyhedron.*

***Key words:** theory review, environment message, benchmark, methodology, method, design and preservation of visual connections, vision point, vision field, blind point, blind field, visual projection, vision range, visual thread, Petrov's polyhedron*

1. Issues

Often, the organization of space, the configuration of volumes, their size, shape and outline, create a sense of environment as a monolith in which the components are obliterated due to careless selfishness in planning and volumes that destroy the possible perception of individual objects and their properties. This impersonal body of architectural matter rips non-matter and space, creating conflict in an environment that lacks its entirety and begins to exist in conflict with itself. Destroyed space cannot operate in favour of the volumes. This contradiction at the heart of the integrity is due to its incoherence and the resulting autonomy of the constituent parts. In the urban environment volumes seek expression mainly through their scale, multiplying and increasing the problem of the environment as a "unified" system.

2. Environment Message

Physical environment in which the society has developed has a deeper sense of simple configuration of volumes – a fact that should be taken into account in its design. It has an impact on people therefore the architectonic (or lack thereof) of the environment similarly to social contact builds the individual personality by means of suggestion and the emotional impact it creates. Just as an artist creates paintings and suggests ideas to contemplators, just as writers change the world of readers, thus urban designers educate residents to the fullest extent of material reality – shape, quality, scale, character and philosophical persuasions. In view of the fact that consciousness develops within the material environment as a reflection of reality, it is important to build a model of the environment which addresses the issue of architectonics and possibly – provide a solution.

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3. Benchmark - its evolution and meaning

A settlement has always had a cohesive role for the people who inhabit it. With its range, it encloses a community exceeding general kinship relations. There are many theories about when the first cities appeared, but in terms of visual perception this occurred when the boundaries of the settlement expanded so much that they went beyond the human gaze. At this point there came the need of a benchmark which united the areas located on the periphery of the settlement in a planned whole. Depending on the era and place of development benchmark had different functions – palaces, temples, military fortifications, etc. However, regardless of the type of benchmark, they always represented objects that brought community together and carried the identity of the place like a spatial anchor. Subsequently, the need for a particular feature of the benchmark was removed and the symbolic importance of the environment and its inhabitants became a sufficient prerequisite for its existence. This evolution of perception can be matched to a deeper sense of the material to which Hegel leads us to claim that "the appearance of the image by means of which the content becomes available to the eyes and the perception exists only for the realm of our soul and our spirit." It is important to note that the deliberate targeting of sight to a fixed location and building a benchmark subjected to the urban framework does not represent a cultus object, but emphasizes the importance of his message.

4. Theory of view

4.1. Mediation Meaning

An object of observation can be the bearer of philosophical, religious, symbolic, historical, triumphant and tragic, educational, aesthetic, ideological, political, propaganda, etc. provocative message. It is not exceptional that a benchmark could be saturated simultaneously with several semantic charges which enrich its visual message. This paper aims at presenting a methodology which is justified from an urban point of view, providing quality communication between the object carrier and its recipients by organizing an exhibition environment for the object. The meaning of visual communication should not be limited only to the attractiveness of the phenomenon, but also to incorporate an active connection to the everyday life of the target group.

4.2. Urban Meaning

The urban context of the proposed theory and outlined methodology build upon several components and can be viewed in two ways, depending on the activity – designing a new environment or one already in existence. In the first case the theory of visual communication can assist the designer in determining the spatial concept, linking it with the output of the main messages of the environment, so the developed methodology should be used as a precise and spatial based instrument for determining the height of volumes within the scope of the development. Similarly, when changing the existing environment a designer should evaluate the elements of the existing environment, comply with them and weave them with the necessary spatial fairness and objectivity in their vision. The urban context includes firstly the preservation of valuable visual links by protecting the integrity of the circuit, it is possible to implement visual communication with the observed object. This happens by means of modelling construction between the place and the object of observation. Here the main goal is to expose the value of the benchmark and link it with another part of the territory for the purpose of mutual understanding and quality supplement. In a broader sense, it is necessary not only to secure the establishment / preservation of the visual connection between the place and the object of observation, but also to secure the view in its entirety. In this case not only the benchmark is involved but also its framework – both anthropogenic and natural. Through the benchmark, the eyes may be involved in the perception of other elements of the urban environment which are generally ignored and invisible. Theory of view builds upon the idea of the semantic message of benchmarks and emphasises the need to build a complete, unique urban suggestion by linking individual visual connections and their messages into a single network. In this case, establishing and / or preserving not only by visual threads between the separate parts of the whole, but also achieves justification in selecting an approach to quantify the scale of the urban fabric and its development in height and thus attitudes towards the visual communication transform into attitudes to the size of the medium.

4.3. Exposure Meaning

In his "The Work of Art in the Age of Mechanical Reproduction" Walter Benjamin discusses the issues related to the evolution of exposure. The Essayist also discusses the issues related to the object, subject, message, method and purpose in opening the work to the contemplator. In an explicit and even radical manner he commented on the issue, which brings us to the conclusion that the perception of a message by a lot of people leads to the destruction of the sacred meaning of the object of observation. This absolutism of Benjamin's is due to his chosen concept that a work of art has a cult and exhibitor value that are mutually exclusive. The developed theory of view relies on the complementarity of the cult and exhibitor value and practically speaking its ultimate goal is to achieve a precise overlap between the two.

4.4. Humanistic Meaning

Venceslav Konstantinov [3] reflecting on the issues discussed by Benjamin points out that at first a work of art is something unfamiliar to people. It is designed for the deity. "Deer that Stone Age men portrayed on the walls of their caves were a magic tool. The artist really put them on display for his fellows, but the deer is intended primarily for the spirits. "In this sense, the message of the subject is taboo. In connection with the philosophical humanism, it is appropriate to assume that the universe is contained inside the human being and that our objects of worship are also inherently part of us. Therefore, we should not hide secrets from ourselves and everything sacred is intended for us. The message of the Forbidden City, passed in the past through the taboo now lives in the open gates. That is to say that here we do not mean to release the holder of a message from its sacredness and meaning in order to display it to a wider audience, but to deepen its function by shifting the educational potential towards something to be awakened. In this sense, understanding the visual connection, its design and preservation as a necessary element of the urban environment means to introduce a methodology of urban design serves as the bridge carrying the logic of humanism from the field of artistic essays and art into the realm of material reality which we face daily and which, as I said, is the main teacher of inner peace.

4.5. Philosophical Meaning

In 1924 essay "On View in Art" Jose Ortega y Gasset gave evidence for the existence of a general principle in the development of the understanding of the relationship between object and subject. He traces the evolution of perspective in European painting by displaying an undeniable trend – the perspective is amended – from near to far. It starts from the detail of the nearest object and passing through marginality of the remote object reaches the demand on the subject by accepting the message of the artist. Theory of view is a theory that moves away from the object of observation in relation to the overall sense of awareness and message. A look afar is a look inside. In relation to the problems of planning and design of the urban environment, this trend confirms the preservation of valuable visual connections like the withdrawal from the particular volumes that can digest it and unite fragmented parts of the environment in the holistic sense, building visual, functional and philosophical completeness to the whole.

5. Methodology for the Design and Preservation of Visual Connections

5.1. Terminology

The theory of view and survey methodology for its extraction from space, design and preservation as a characteristic value of the environment, incorporates specific phenomena to be introduced as terminology. A key element of the atomic level of vision is the visual thread that is a visual connection between the observed point and the vision point. The vision point is the point in space that is bound to that observed by optical fibre. One vision point may result not in one but in multiple threads to the observed object/s, in this case we talk about visual cluster of the vision point.The set of vision points to an object falling within the common polygon covering part of any surface in space is called a vision field. Each observed point can be linked to one or more vision points which resemble a set of visual fibres arising from the observed point and shaping its vision range. Despite being only a theoretical construction, there is also another crucial element that makes up the main operating system. The visual projection is a polygon which is constructed by connecting the two outermost points of the vision field with two outermost points of the observed object. Another important element of the theory is the blind vision point. It has no visual connection with the observed point and in the context of observable universe this is the antimatter. The blind field is a combination of blind points falling within the general range covering any part of the surface. Blind fields can be "transferred" or "absolute", depending on whether they are intersected by a visual projection or not. The transferred blind field is possible in three-dimensional space, where the configuration and size of the volume are creating conditions for the visual connection to be recovered after loss of contact. The essence of the methodology for the design of new and preservation of existing visual links is to assess the quality of the object of observation, its message, social and cultural context of the environment, the demand of the target group and not least in the establishment of a valid urban design method to determine a maximum height in the range of the visual projection. An important element of the methodology is a method for constructing a three-dimensional body whose size fits all objects that fall within the visual projection and which at the same time possess the height, shape and configuration that do not interfere with the visual contact between the vision field and the observed object. This volume is called the Petrov's polyhedron (Fig.1, Fig.2, Fig.3).

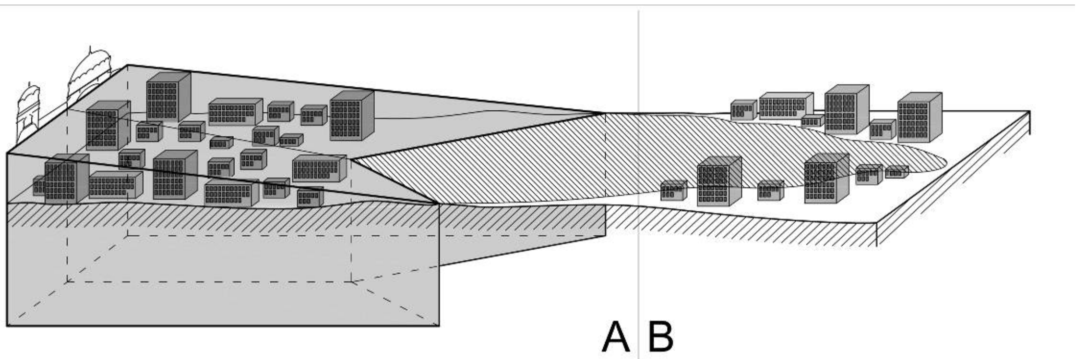

Fig. 1. Preserving the visual threads in the urban setting using Petrov's polyhedron (A and B)

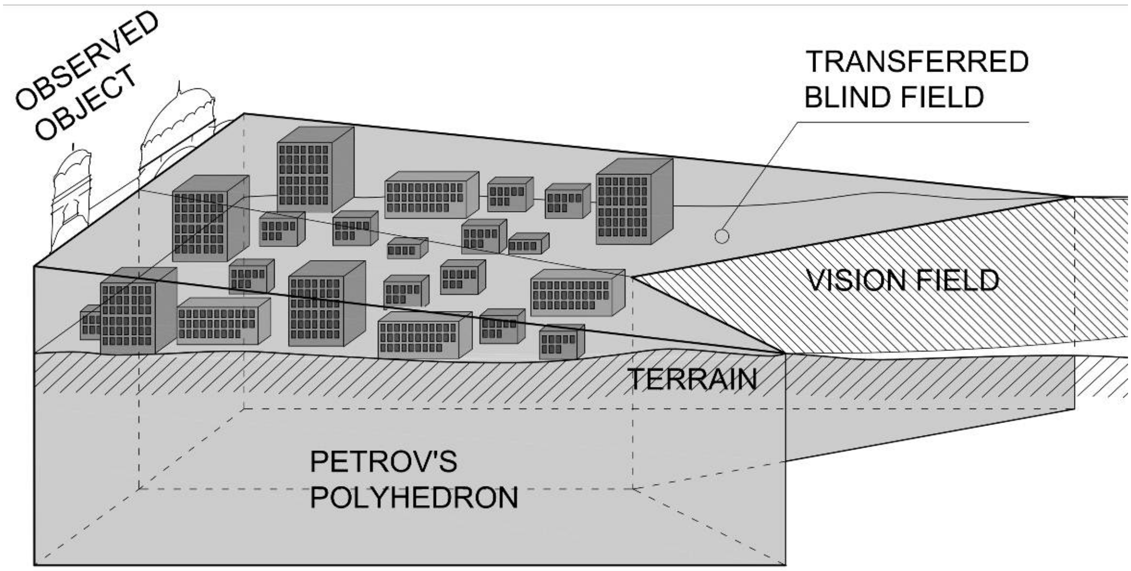

Fig. 2. Preserving the visual threads in the urban setting using Petrov's polyhedron (part A)

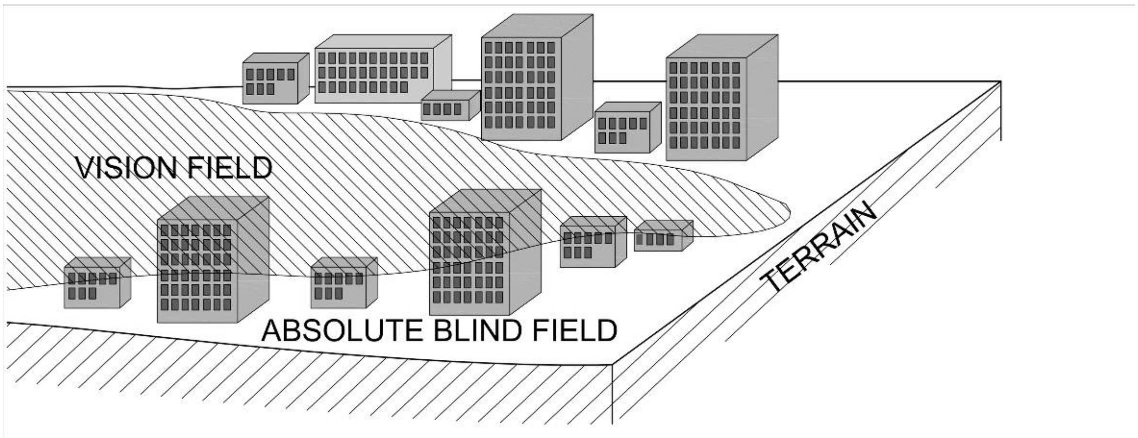

Fig. 3. Preserving the visual threads in the urban setting using Petrov's polyhedron (part B)

5.2. Method for construction Petrov's polyhedron

The article will present a simplified model of this three-dimensional body. Its construction requires surveying the object of observation in order to determine the altitude of the lowest observable point from the vision field, and the point coordinates in view of the projection defining characteristic points (it is appropriate to provide for indentation out of these points when constructing the visual projection to achieve quality within the site). Subsequent fieldwork aims to outline the boundaries of vision field. This step is crucial because the unusual shape of the polygon reflects the characteristics of the construction within the scope of the visual projection and appears a structural element in the construction of the polyhedron, and therefore needs to be approached with the necessary precision. Volume located between the point of observation and the observed object affects the shape of the vision field with its parameters and available space. This is due to the fact that if a barrier rises between the observer and the observed object, it is necessary to depart some distance, until it is resolved. The higher the barrier is, the more remote the point of recovery of the visual contact. The wider the barrier is, the more it consumes the vision field. The demarcation of this polygon which is specific to any eye contact should be done by a geodesic path (it is important to bring out the coordinates and elevation of all points describing the polygon). Connecting the points along the front of the vision field to those lying on the horizontal passing through the lowest observable point from the vision field builds the upper surface of the polyhedron. It should be limited by the boundaries of the visual projection. Depending on the location of points on the front of the vision field, the upper surface of the polyhedron has a characteristic slope in the direction of the observed object to the vision field and the side walls point towards the characteristic central section (in some cases the slope is reversed).

5.3. Method for Determining the Maximum Heights Within the Visual Projection Using Petrov's Polyhedrons

The ultimate goal of the construction of the polyhedron can be summarized as displaying the altitude of the projection of an arbitrary point on the terrain explored on the upper surface of the three-dimensional body. The simplified model for calculating its parameters involves the two side walls of the polyhedron and the longitudinal section passing through the point of the vision front which is closest to the observed object. Depending on the location within the polyhedron and on which side of the central section, the point for which we want to determine the maximum permissible height is influenced by the corresponding sidewall and the central longitudinal section. In this case the formula * for the maximum permissible height that may arise from any point studied in the visual projection without damaging the vision field reads as follows:

$$x = \frac{b\left(h - a.\mathrm{tg}\alpha\right) - a.b_1\left(\mathrm{tg}\beta - \mathrm{tg}\alpha\right)}{b}, \tag{1}$$

wherein x is the altitude of the projection of an arbitrary point of the terrain tested on the upper surface of the three-dimensional body, in other words – the maximum permissible height, which may arise from any sampled point within the visual projection without damaging the vision field, a is the distance from the object of observation to the test point, b is the distance measured horizontally between the central section and the corresponding side wall of the polyhedron determined at equal intervals "a" of the observed object, b_1 is the distance measured horizontally between the research point lying on the "b" and the point marking the intersection of the "b" with the central longitudinal section of the polyhedron, h is the altitude of the lowest observable point from the vision field, tgα is the tangent of the angle enclosed between the horizontal passing through the closest to the observed object point from the front of the vision field and visual thread between this point and its corresponding lowest observable point from the vision field (also lying on the longitudinal section), tgβ is the tangent of the angle between the horizontal passing through the vision point from the front field belonging to the sidewall of the polyhedron and the visual thread between this point and its corresponding lowest observable point from the vision field (characteristic point describing the boundary of the visual projection). The formula is different for the parts of the three-dimensional body which have a triangular section.

REFERENCES

[1] Schneider M.S., Constructing The Cosmological Circle, Symbol and Instrument for Universal Harmony, 2008, 115 p.
[2] Chouquer G., L'étude des paysages. Essais sur leurs formes et leur histoire, Paris, 2000, 208 p.
[3] Konstantinov V., Writers for creativity, Sofia, 2007, 27 p. (in Bulgarian)

INFLUENCE OF THE FAÇADE THERMAL ENVELOPE ON THE STUDENT HOSTELS ARCHITECURE

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Abstract: *From the standpoint of energy efficiency a non-transparent part of the façade thermal envelope represents one of the important elements that determine the total thermal losses of a building. A very large number of buildings that need energy efficiency reconstruction require detail analysis of the architectonic form of the façade planes. The question that arises is explicit: Can the most often used way of rehabilitation using the ETICS system be the simplest still an aesthetic standpoint. Therefore the reconstructed shape of the façade thermal envelope may represent a key functional factor influencing the experience of an urbarchitectonic physical structure in space. In this paper, the focus is on the student hostels and their esthetic appearances. This discursive analysis indicates the importance of selecting an application of ETICS on the façade of student hostels. It results in better aesthetic recognition of the campus environment and a new image of student dormitories.*

Key words: *Thermal envelope, student hostel, façade reshaping, visual-esthetic effect*

1. Introduction

The most frequent basic structure of the façade walls of the student hostels constructed in the second half of the last century is constituted by two typology groups, i.e. two structural compositions. The single-layer homogenous walls without thermal insulation belong to the first group, while double, triple and multi-layered walls with the layer of adequate thermal insulation belong to the second group which is designed and dimensioned according to the standards and regulations valid in this period.

Therefore, in general terms, there are at least two "thermal" reasons for structural, energy but also the aesthetic reformation of the façade, primarily of the external walls constituting the façade. One of the doubtlessly most prominent, and one could argue, most justifiable reasons, is the energy efficient buildings, which is particularly topical because of enactment of new regulations in this field. [1]

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Having adapted to the fast pace of life, we inadvertently adapted to fast style of buildings, primarily in terms of technology of restoration, reconstruction, adaptation and revitalization of buildings. Contemporary trends of conversion in architecture, irrespective if that comprises entire buildings of some of their parts, also generated adequate application of "fast food" construction method. Being aware of the fact that it is not worthwhile to resist application of new technologies, it will be sufficient to at least initiate a discursive analysis on the topic of sustainability of esthetic architectonic value.

2. General characteristics of the ETICS façade systems

In statistical terms, in the last several decades, the most frequent form of the designed and built structural composition of facade walls, has been a wall with thermal insulation lining commercially known „demit facade". A façade wall treated in this manner is essentially the system which has been defined in the international nomenclature as an external thermal insulation composite system with rendering. The most frequent acronyms of such systems are: WDVS; ETICS; EIFS; EWIS; FTIS, even though in literature one may encounter the term CONTACT FACADE. Hereinafter a short analysis and description of this system, primarily for the purpose of determining elements and criteria of esthetic evaluation will be presented.

The basic function of ETICS – façade thermal insulation composite systems is improvement of thermal protection properties of external walls of buildings. Such systems can be implemented both for the newly constructed buildings and for energy rehabilitation of existing buildings. In case of energy rehabilitation of buildings, ETICS thermal insulation systems, in terms of construction are ranked among the simplest and most frequently implemented systems.

In general, thermal protection efficiency and quality of thermal façade cladding directly depends on the structure, that is, thermal characteristics of the components, as well as the service conditions. In order to conduct the assumed initial analysis of the described systems, it is necessary to know all the previously listed dimensional-qualitative-quantitative properties of their constitutive elements. The first step is typification according to the structural composition and structure. According to this principle, the ETICS systems are classified as the following types:

- Bonded polystyrene systems,
- Bonded and anchored polystyrene systems,
- Bonded systems with mineral wool,
- Bonded and anchored systems with mineral wool and
- ETICS where the connection to the substrate is ensured by mechanical fixings.

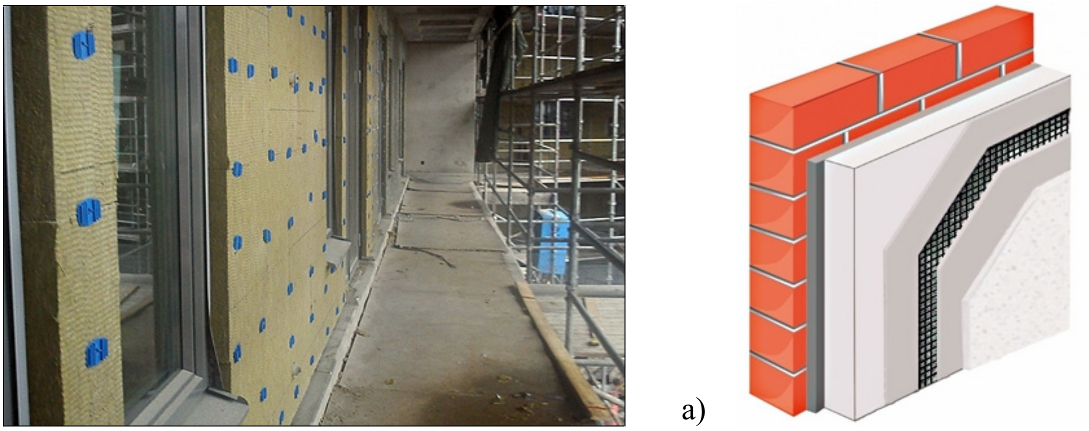
a) b)

Fig. 1. Examples of ETICS system: a) system with anchors; b) system without anchors (photo: http://www.sfsintec.biz/en/web/industry_solutions/construction/eis/ETICS.html)

At the first sight, it may be noticed that the installation of ETICS system basically comes down to two basic ways: and anchored systems and just bonded. On Fig.1a and 1b [2] show examples of these two ways of installing the façade thermal insulation composite systems In addition to the aforementioned, as well as a special type of facade thermal insulation composite systems are distinguished by a system that could be classified as a special construction ETICS, which is generally divided into:

- facade insulation system with ceramic coating and
- ventilated facade with a facade thermal insulation system.

2.1. Structural components of ETICS façade systems

The basic components of the structure of façade thermal insulation composite systems are four structural subsystems:

a) Rendering systems,
b) Thermal insulation material systems,
c) Anchoring systems for mechanical fixation and
d) Bonding systems.

a) Rendering systems of ETICS

The rendering systems consist of 2 layers: the bottom, primary rendering layer (the first layer which integrates the protective-reinforcement mesh) and the upper protective rendering layer. As opposed to the traditional renders, the ETICS rendering system is constructed as thin and thick rendering system.

The thin system of rendering can be:

- A system of artificial resin, thickness: d = 4- 6 mm,
- Modified mineral system of artificial coating, thickness d = 5- 10 mm,

The thick systems of rendering

- The thick rendering system is a mineral lightweight system, thickness: d = 8-16 mm.

b) Thermal insulation material systems in ETICS

The type of the structure of the façade thermal insulation composite system (type of ETICS) will determine the material used for making of thermal insulation layer (functional layer. ETICS defined in this way are classified as:

- Expanded polystyrene systems (EPS)
- Extruded polystyrene systems (XPS)
- Mineral fiber system – mineral wool panels (FS+)

c) Anchors – mechanical fixation system of ETICS

Anchors are a system element used for mechanical fixation of ETICS, by so called anchoring. They are produced in a variety of sizes and types. Selection of the applied anchor is performed on the basis of the static calculation, which determines adequate type, size and method of installation. In general terms, the anchors as system elements are fitted if their application is necessary according to the conditions of external conditions and static design. According to the method of fitting, fixation can be provided by:

- Insertion anchors and
- Screwing anchors.

d) Bonding System of ETICS

Adhesives represent materials for bonding of thermal insulation system with the basic structure – the wall. The characteristics of bonding material must conform to all the norms and standards, and the thickness of the adhesive layers is approximately d = 2–3 mm. The basic division of adhesives is based on the manufacturing technology, so that they are classified and manufactured as:

- Ready-made system for application (wet systems) and
- Powdery mixture, for application after mixing (dry systems).

3. Determination of elements for the assessment of ETICS façade systems

Analysis of the structure and components of such thermal insulation systems, presented by the previous chapter, is determined according to the position where ETICS is fitted into the external – façade thermal insulation systems (external side of the wall, Fig.2). Regarding such clearly defined position of the system, it is not difficult to conclude that they are very much exposed to, but also conditioned by the various external typical and atypical influences.

Apart from the effects of the basic structure, which are classified as conditional external influences, the systems are exposed to typical external influences such as: mechanical action, material ageing effects, wind action, solar radiation, atmospheric water and moisture generated by diffusion, i.e. air influence. Preventing the adverse effects of the listed typical influences can be seen as a primary designing and construction requirement. The criteria and conditions which must be fulfilled, according to these requirements, are in detail dealt with by the proposition of instructions and recommendations ETAG 004 (Edition March 2000; Amended February 2013), which was given by EOTA organization (European Organisation for Technical Approvals). This document describes in detail the guidelines for obtaining the European Technical Approval of compliance of ETICS (EXTERNAL THERMAL INSULATION COMPOSITE SYSTEMS WITH RENDERING). [3]

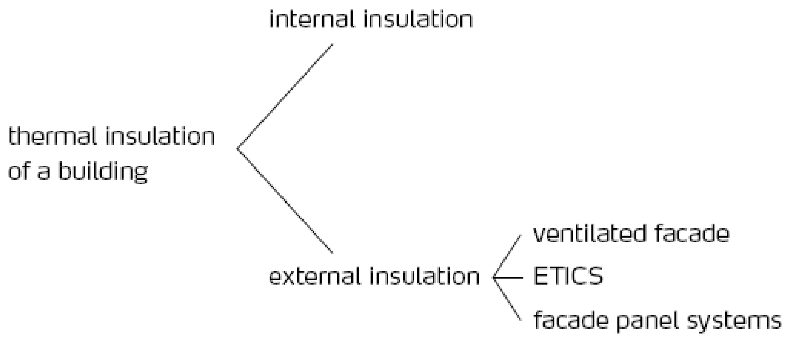

Fig. 2. Various ways of installing insulation in respect of its position in the structure (Catalog ROCKWOOL - External Wall Insulation) [4]

The second group of influences, potentially defined by this discursive analysis, are constituted by the atypical influences. They are characterized and directly determined by the impossibility to measure them. The relativistic approach has its materialistic basis, so that the components of the ETICS system structure representing indirect elements of the atypical influence are: thermal insulation material, and thin-layered external rendering. These two components of the system structure have the potential of the elements which determine and form visual, formal, coloration and esthetic urbarchitectonic potential of the facades constructed in ETICS.

The described and analyzed potential influences, provisionally termed as typical and atypical have an irrefutable and significant role in determining conditions which must be met by ETICS, as the most frequently implemented system of façade thermal cladding. The typical conditions (typical influences) are regulated by the afore mentioned recommendations given by the EOTA organization by the document ETAG 004. These recommendations should be implemented in the adequate regulations and legislations of all the countries using ETICS. One of the possible ways of implementation of legislative regulations is presented on the example of the Slovak Republic (Appendix 5 of the Act of the National Council of the Slovak Republic No. 25/2006), which was cited in a part of the paper [5] by Nada Antosova, stating:

The design of an ETICS system, especially the specific details, is coordinated by the manufacturer together with the project manager. The builder of an ETICS system builds the construction into the building. Such a person is required to have a professional qualification to do this activity (STN 73 2901). The owner, user, caretaker or facility manager oversees the maintenance of the ETICS system. A list of suggested tasks for cooperation and responsibility in creating a user manual for an ETICS system by each of the persons involved is presented in Table 1 below. The user manual must be understood as part of the documentation of the whole system of controlling the quality. In general, it should consist of four basic parts:

- Description of the actual status of the ETICS system – monitoring,
- Rules for using the ETICS system,
- Rules for checks–inspections and
- Rules for maintenance and repairs–database of operational and planned interventions.

The end result of the user manual must be a complex document–a guidebook for its users. It is clear from the required breadth and content of the manual, that it must be devised by the manufacturer, project manager, designer and caretaker of the ETICS system. The basic information is provided by the manufacturer, and then the project manager and designer must add rules for its use based on the actual status of the system. The caretaker will use the information and rules during the necessary interventions and repairs, and will update the information. With such feedback, the development of the components, status of its construction and the prolongation of its durability will be improved. [5]

Table 1. Cooperation and responsibility of persons when making an ETICS user manual.

Task	By			
	Project manager	Designer	Care taker	Manu facturer
Informing the users about the rules for using an ETICS system			●	
Determining the person responsible for using an ETICS system in accordance with the manual			●	
Summary of the materials and components of an ETICS system	□	□	□	●
Rules on using components of an ETICS system	●		□	●
Rules on technical checks of an ETICS system	●		●	□
Visual inspections of ETICS system		□	●	□
Technological methods of maintenance interventions and repairs	●	●	□	●
Determining the corridors of access for maintenance interventions and repairs		●	□	
Determining the site for construction equipment during the intervention		●	□	
Plan of maintenance and repairs during the lifetime of an ETICS system	□		●	□
Updating maintenance and repairs plans			●	
Guidebook for users of an ETICS system	□		●	□

Note: legend / ● - responsible; □ – cooperates

In the mentioned papaer it is proposed that suggested tasks and responsibilities can be modified according to and based upon for the guideline construction of an ETICS system, and this is also would be part of the first chapter in the ETICS user manual.

By using analogy, in Table 2 are presented possible urbarchitectonic criteria for assessment of ETICS application, for the purpose of energy rehabilitation of buildings in general, including the adequate application for energy restoration of a façade thermal cladding of student hostels. The criteria proposed for validation of atypical influences would be obliging in determining of the minimum of visual-formal, and coloration-esthetic recommendations, with the primary purpose of the assessment of possible degradation of architecture and urbarchitectonic environment, and its prevention.

Table 2. Proposed urbarchitectonic criteria for predictive assessment of atypical impacts

Task of ETICS system	By		
	Urban planners	Designer	Manufacturer
Informing the public about the urbarchitectonic efects	●	●	□
Colouristic valuation and validity	□	●	●
Visual valuation and validity	●	●	□
Aesthetic valuation and validity	□	●	□

Note: legend / ● - responsible; □ – cooperates

Conclusion

The presented regulation documents have a minimum and very undefined application in the countries outside European Union. A discursive analysis presented by this paper has a goal of pointing to the relevance of such comprehensive analysis of all the aspect for the purpose of a more adequate application of ETICS. It can be concluded that such sort of documents, recommendations and technical instruction, by enacting the code on Energy efficiency of buildings (Republic of Serbia; October.2012.), is simply necessary and evidently needed not only for the purpose of harmonization of the European and domestic regulations, but also for the purpose of prevention of negative externality, which assumes the form of urbarchitectonic pollution.

Acknowledgement

This paper is a part of the scientific-research project: "Construction of Student hostels in Serbia at the beginning of 21st century", approved by the Ministry of Science and technological development of the Government of the Republic of Serbia, in Belgrade, January 2011. Project manager, prof. Ph D Nikola Cekić, Grad. Eng. of Arch. The Faculty of Civil Engineering and Architecture of the University of Nis. Project number: TR 36037.

REFERENCES

[1] Vasov M., Bogdanović I., Research of the structural, formal and aesthetic characteristics of the facade thermal insulation systems, Facta universitatis, Series: Architecture and Civil Engineering, Niš, University of Niš, Vol.3, No1, 2004, 69-77 p.
[2] http://www.sfsintec.biz/en/web/industry_solutions/construction/eis/ETICS.html
[3] ETAG 004., Guideline for european technical approval of ETICS with rendering, Bruseels, Edition 2000., Amended August 2011 and February 2013.
[4] Catalog ROCKWOOL - External Wall Insulation (ETICS), www.rockwool.hr
[5] Antosova N., Rules for the effective maintenance of buildings and maintenance of etics system with biocorrosion, Organization, technology and management in construction- Academic journal, June 2013, 654-662 p.

ESTHETIC INFLUENCE OF THE FAÇADE COLOR ON THE STUDENT HOSTELS ARCHITECURE

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***Abstract**: The color of the facade is a key, functional factor influencing the experience of an urbarchitectonic physical structure in space. In this paper, the focus is on the student hostels and their esthetic appearance. There are examples from the world of ecourbarchitecture crated after year 2000, for the purpose of a better identification of contemporary tendencies in conceptual-coloration design of the housing buildings of the academic population. This issue is not marginal. Coloration of the student hostels facades can improve the totality of the esthetics of the living environment dynamics, it can emphasize the value of the architectonic form and improve the visual communications in space. It is our view that micro-ambiance interior and exterior positions during reconstruction of the existing structures can be improved. This research indicates the importance of choice and application of color on the façade planes of student hostels, for a better esthetic recognition of the environment where the coloration diversity, and not a globalist approach, brings about a new image of student housing, a more convincing and attractive impression of its quality.*

***Key words**: Color, façade esthetics, student hostel, coloration diversity, visual communication*

1. Introduction

Color, on the façade planes of student hostels was in the past neglected as an esthetic, visual and designing factor having influence on architecture and users in the academic environment. The experience with the structures of student hostels from the past century, especially those from the second half of the century exhibits a poor coloration synopsis of the facades, which need an urgent regeneration, and the professional correction of their color shade quality. The influence on the condition of ecourbarchitectonic and ambient spirit is of an integrative character. It harmonizes and coordinates the language of geometrical forms in space. In metabolical terms, it affects the coherence of design of structures in space, develops a favorable concept of visual communications and renders the scenery more abundant. For an academic population, it is a challenge, interpolation of

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culturally responsible design and esthetic-visual variety of urban identity of a residential location. It is an issue connecting artifact structures with nature and conditions in the environment.

2. Research

This paper analyzes the following, latest ecourbarchitectonic coloration facades:

- Broadcasting Tower: Student Accommodation LeedsColor explosion of "Ambient color" in Darmstadt dorm "Lab"
- University Housing in Gandía, Spain by Guallart Architects
- The "Student Housing Tower Blok 1" in Presikhaaf, Arnhem, the Netherlands
- Student Housing Yersin, Paris, France
- Student halls of residence of the student union at the Dresden Wundtstraße 11
- Student Housing, Wildau Laubengang
- Dorm Veledastraße Essen - Duisburg with photovoltaic system on the entire south facade. Solar House in Essen
- The new student residence on the campus of the University of Utrecht
- Dorm Heilmannstraße in Stuttgart - Exterior

Fig. 1. Broadcasting Tower: Student Accommodation Leeds
(http://a-rchitecture.tumblr.com/post/1611295299/broadcasting-place-a-project-by-feilden-clegg;
http://designcouncil.tumblr.com/post/9121499144/a-rchitecture-broadcasting-place-a-project-by
http://en.wikipedia.org/wiki/Broadcasting_Tower,_Leeds)

The Student accommodation in Leeds is a central referential building in the city. It is a remarkable tower, with very specific yellow-ocher coloration of façade planes, and with playful, mildly rotated volumes in one part of the building. Apart from warm colors, the facades contain embedded flutes and glazed surfaces in the staggered vertical arrangement. They create an impression of an interesting collage. A monochromatic option in the appearance of the facades is dominant. In the immediate neighborhood, there are no vegetation structures, so the rigid-angled geometry of the volume, and the ground level façade planes in particular, is very accentuated.

Fig. 2. Color explosion of "Ambient color" in Darmstadt dorm "Lab"
(http://www.baulinks.de/webplugin/2013/1517.php;
http://farm4.staticflickr.com/3808/11876769046_94c75f8efb_o.jpg)

The new student dorm in Darmstadt, the external facades of the outer and atrium sections exhibit an abstract coloration composition with different, discretely selected warm colors, with and artistic and colorful message. The rigidity of the volume composition is intentionally softened. The idea was to soften and “cure” the too intense orthogonal geometry. Application of blue color is notable - a large stain is spread in many directions, even in the ground level surface of the atrium, which is a sixth façade planes, which accentuates its focal value and creates a coloration-visual, compositional proximity in connection with the vertical façade planes. The lawn in the atrium also has a positive coloration effects on the ecourbarchitectonic identity of the student dorm.

Fig. 3. University Housing in Gandía, Spain by Guallart Architects
(http://www.archello.com/en/project/sharing-blocks-universitary-housing-gand%C3%AD)

New student hostel structures in Gandía, Spain, contain a powerful red coloration of façade planes with vertically striped surfaces. Even though vertical façade planes are dominating, the coloration of the structure indicates the importance of potential of creation of a good design, and colorful, impressive architecture. An attractive space for the student population with conceptually different definition of color culture is formed. A more creative spirit of the environment is established, and the value of macroambient space is permanently increased. The implementation of red colors in the façade planes creates a unique, visually recognizable quality of a non-globalist profile is created, which is an important condition for integration and dialogue of forms in space. For this reason, this student hostel is very indicative for further analyses in the coloration design of future hostels’ facades.

Fig. 4. The "Student Housing Tower Blok 1" in Presikhaaf, Arnhem, the Netherlands
(http://plusmood.com/2009/09/student-housing-tower-blok-1-group-a/)

The attractive and unforgettable appearance of the "Student Housing Tower Blok 1" in Presikhaaf, Arnhem, the Netherlands is realized through square cladding, using dark brown panels of various shades. The joints of the panels in addition form a neutral, mosaic orthogonal image. The irregular glazed apertures on the façade of a prismatic volume, and the dominating monochromatic surfaces, are humble and harmonized with natural, vegetative coloration in the immediate environment. The create an impression of a modern city-building language, calmness and an unexpected esthetic simplicity.

Fig. 5. Student Housing Yersin, Paris, France
(http://www.trespa.com/uk/project/student-housing-yersin)

The structure of Student Housing Yersin in Paris, at a corner location, apart from the multicolor and quality visual composition of façade planes, has an exquisite archisculptural value. The façade is designed with dominant dark brown square and rectangular fields in with different shades. The panel joints constituted a discrete linear network, with modular grid, which in composition with the window apertures of various format create a mosaic picture. The recesses on the buildings, the open surfaces - loggias, are painted in bright red color. The provide contrast and they are well fitted into other colored surfaces of the student hostel.

Fig. 6. Student halls of residence of the student union at the Dresden Wundtstraße 11
(http://upload.wikimedia.org/wikipedia/commons/e/e0/Studentenwohnheime_Wundtstra%C3%9Fe.jpg;
http://upload.wikimedia.org/wikipedia/commons/f/f0/Fotothek_df_ps_0003781_x.jpg;
https://www.wh2.tu-dresden.de/node/80)

The 15-floor of the student hostel in Dresden, was rehabilitated in 2002. Then the formless, depressively monotonous façade obtained and new coloration envelope. The combination of red and dark brown vertical strips accentuated the verticality of ecourbarchitectonic structure, with a vegetation belt around it. The structure acquired in this way contemporary identity, through a consistently applied visual-coloration design. The coloration intervention significantly improved the situation in the urban space and brought about a better esthetic-visual comfort for the users in the exterior.

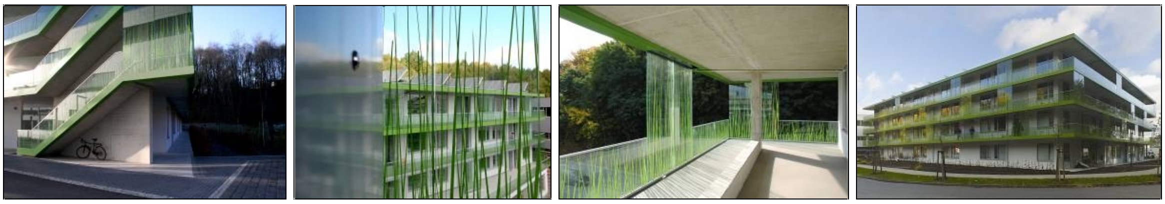

Fig. 7. Student Housing, Wildau Laubengang
(http://www.caparol.de/referenzen/wohnbauten/studenten-ziehen-ins-8222campino8220-ein.html; http://images.cdn.baunetz.de/img/1/4/2/3/4/8/5/2d92e954e9b9e942.jpeg; http://www.flickr.com/photos/sehw/8066863249/)

For the purpose of creating a better environmental connection of the student hostel and the environment, the glasses on the façade planes of the gallery were painted in green color mimicking the grassy structures. In the perceptive-psychological sense, the illusion of a hybrid connection of the artifact and the natural structure has been achieved, which improved the accommodation comfort of the users. This is a new form of unconventional esthetic understanding an and urban intervention on the location in 2006. The concept was generated from the analysis of environmental parameters of the location and the prevailing conditions. This was transmitted to formulation of a new coloration integrative image. Green diagonal crisscrossing pattern of lines (imitation of grass blades) on the glazed surfaces, suppressed the visual impression of the presence of building materials, and concealed the reinforced-concrete structure with right-angled geometry.

Fig. 8. Dorm Veledastraße Essen - Duisburg with photovoltaic system on the entire south facade. Solar House in Essen
(http://www.pflichtlektuere.com/06/05/2011/gruene-studentenheim/; http://www.krampe-schmidt.de/wp-content/gallery/swv/img_0835.jpg; http://www.panoramio.com/photo/53653108)

Two student hostels in Essen-Duisburg in 2011 also underwent a considerable rehabilitation, and an unusually imaginative coloration intervention. The verticality of the structures was accentuated, by painting the balconies on the façade in bright red and orange colors, as well as the sections along the window apertures. The southern façade, containing the living quarters is lined with contemporary photo-voltaic devices making use of the solar energy. This hostel provides significant energy saving. Application of such façade panels achieves a new, special dimension in formation of the student hostel envelope. The gable walls have coloration contrast in dark cladding. Longitudinal facades have a pronounced orthogonal, linear pattern.

Fig. 9. The new student residence on Holland architecture Campus University Utrecht pattern colours
(http://whotalking.com/flickr/Casa+Confetti; http://www.flickr.com/photos/27929982@N06/6803520813 http://www.plataformaarquitectura.cl/2013/04/17/lo-mejor-de-flickr-en-plataforma-arquitectura-abril-2013/)

The architect Marlies Rohmer[5], composed the artistic-esthetic composition of the facades of the student hostel in Utrecht of the network of multi-colored aluminum panels, where the windows are not visible. The façade planes have very strong colors, are mosaic in character, with window apertures among the “cracks”. In visual and designing focus is the impression of a colorful bee-hive with multi-colored confetti on its cladding. By this peculiar mixture of colors on the facades, the student hostel symbolizes a small microcosmos - presence of residents coming from all around the world. The case with the new, bold creation of the coloration culture of the structural façade enriched and emphasized the polysemic identity of this place in the city. Moreover, the structure became a contemporary iconic, symbolical, ecourbarchitectonic point of reference.

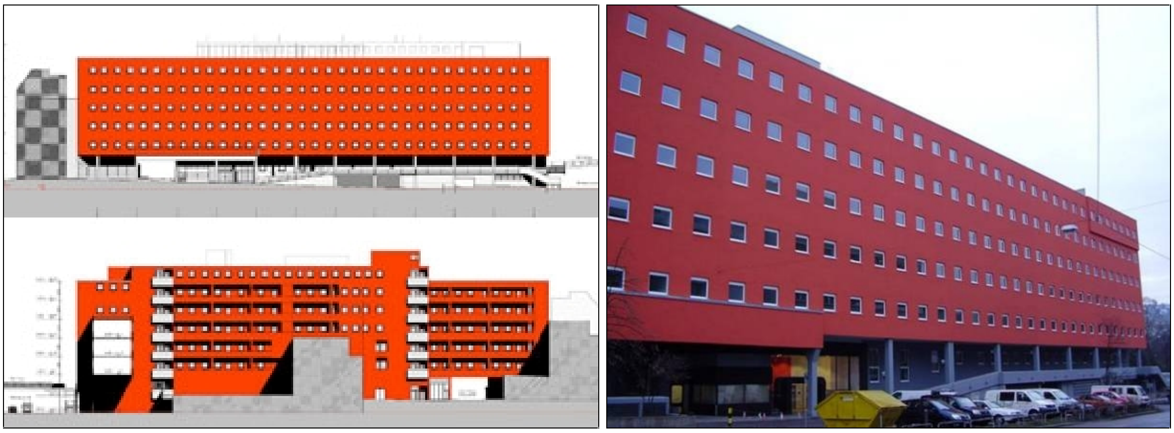

Fig. 10. Dorm Heilmannstraße in Stuttgart - Exterior
(http://www.studentenwerk-stuttgart.de/wohnheim/heilmannstrasse-4a-4b; http://www.kopp.de/html/aktuell/hauptak8.htm)

In 2007, the construction the Heilmannstrasse dorm in Stuttgart is finished. The architect Peter Kopp employed warm colors to simplify the appearance of facade planes. The prevalent color is dark red, calm monochromatic variant, for the purpose of synthetic-visual integration of all structural elements on the horizontal five-storey facade with the square pattern of windows. The alternative design with orange color is not applied, because it would disrupt the formal-esthetic balance and organic connection of structures in micro-ambient environment. The inspired coloration of the façade of the dorm changed the situation in the street setting. Different, contemporary conditions were established for understanding of spatial and visual city building values.

[5] Architectenbureau Marlies Rohmer, Postbus 2935. 1000 CX Amsterdam. http://www.rohmer.nl/

Conclusion

On the basis of the presented examples, it can be concluded that the color in ecourbarchitecture of the student hostels is an extremely important factor for good accommodation of student population in space. The latest realizations of the structures created after year 2000 demonstrated a tendency of color-painting of façade planes with the goal of esthetic-psychological improvement of exterior and interior spaces. The artistic and visual results are different. The anarchy of colors in academic environments of European communities is notably decreasing. It is demonstrated by the competitions for conceptual town-planning - architectonic design of structures intended for students. The architects, urban designers, visual artists, psychologist and others pay a special attention to the role of coloration in formation of ecourbarchitectonic appearance of the academic structures. Color can be used to efficiently correct and promote the innovated states of the existing physical structures. Color is a magical binder in the trialogue between visions, ecourbarchitectonic designs and users of space - students who should be able to interpret the genius loci on a daily basis, and which should be stimulating and inspiring. It is the tool which can radically change the banal language of the imitatively colored facades, which is static and unrecognizable, and the tool which can supply the anemic local cultural setting with a decorative-functional concept. It is a good option for the understanding of appearances of student hostels. The potentials of new technologies of painting of facades are splendid for essential quality transformation of visual-communication ideas of physical structures in space. It is dangerous if academic ecourbarchitectonic physical structures in space remain faceless, unremarkable and unremembered, with only bare engineering-technical functions and poor appearance of facades of haphazardly colored volumes. In the psychological sense, the phenomenon of coloration of student hostel facades in the total urban scenery must be noticeable and present on the face, in the gestures and behavior of each user. Those student hostels and streets with different light coloration appear to have more spiritual energy; they are felt as home places where it is better to study, live, work and create. It is a definite conclusion that the façade color of student hostels make those structures a better and more attractive space evoking respect.

REFERENCES

[1] Moor A., Colours of Architecture: Coloured Glass in Contemporary Buildings, ASIN: B00EBGC9YY, MITCH, 2006.
[2] Cherri House, City Quilts: 12 Dramatic Projects Inspired by Urban Views, C & T Pub, 2010.
[3] Dirk U. Hindrichs, Fassaden / Façades, Birkhäuser Architecture; 3rd ed., 2010.
[4] Mahnke F. H., Color, Environment & Human Response, Wiley; 1996.
[5] Meerwein G., Color - Communication in Architectural Space, Birkhäuser Architecture; 2007.
[6] Linton H., M. Toy, J.-P. Lenclos, Color in Architecture: Design Methods for Buildings, Interiors, and Urban Spaces, McGraw-Hill Professional Publishing, 2003.
[7] Reusch H., G. Donauer, Fassadengestaltung mit Farbe, Deutsche Verlags-Anstalt, 2007.
[8] Gage J., Color and Meaning: Art, Science, and Symbolism, University of California Press, 2000.
[9] Bissattini M., Form and Colour: Architecture, Archideos Libri, 2013.
[10] Hershman S., House Colors: Exterior Color by Style of Architecture, Gibbs Smith, 2007.
[11] The Plan, Plans and Details for Contemporary Architects: Building with Color, Thames & Hudson, 2011.
[12] Milich Z., City Colors, Kids Can Press, 2006.

ESSENTIAL CONTEMPORARY MATERIALS IN STUDENT HOUSING ARCHITECTURE

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Abstract: *There are materials that stood the test of time for architectural applications and there are new materials which are used only in most recent projects but appear to offer new and improved aesthetics and performance. In order to assess their strengths and weaknesses a case study scientific method is used which analyses some of the architectural projects. They are chosen carefully to allow us to draw conclusions on a wide range of material use on student housing and university campus architecture. It is not economically viable or easy to create large test models such are university student housing buildings which makes this approach the most practical and authentic considering it uses real objects instead of simplified models. This research gives insight and starting point for designing contemporary dormitories and university buildings which strive to surpass their predecessors with potential of greater structural plasticity, usability and engaging spaces currently in demand in university settings.*

Key words: *Material, contemporary, architecture, design, student, university, housing*

1. Introduction

This research is continuation of my larger PhD study for dissertation which focuses on student housing in Europe and applicable design concepts to dormitories in Serbia. Architects spend much time drawing the perfect shape of the building for the given context but equally important is their materialization. Not every material pertains to every shape or surrounding. Even the varying planned functions of rooms require different material styles. With the advent of ever more technological solutions for treating and finishing raw sources we now have a myriad of combinations for cladding our newly constructed or renovated objects. Student housing in Serbia is built traditionally in concrete and brick but maybe it is now time to try something different. Since on a tight budget and a sensitive topic where there is no room for error, it is not possible to experiment with building constructions just to assess their performance. The goal of this paper will be to provide insight on performance of the buildings using different materialization styles and on material

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properties. This would hopefully allow us to make informed decision on choosing the right material for future building design concepts.

1.1. Methodology

Methodology consists of analysing available data on materials from scientific research and on case studies where these materials are applied to buildings. It is not always easy to find exactly student dormitories or university buildings built in a new style of material use but we are helped by the fact that these types of architectural creations are very much similar to multi-storey housing and other public buildings because they contain both smaller sleeping and larger socializing areas. This allows us to draw conclusions even from these similar edifice styles.

1.2. Context

There is a noticeable trend in current student housing developments to use modern and improved but not necessarily proven materials and colours. This gives an enticing aesthetic to the property drawing more users and ensuring the success of a housing project. Usually student spaces are scarce and all rooms will be leased but better looking buildings will be able to maintain a higher price or be a reward for better performing students. Also living in a modern clad building and looking at its advanced solutions induces thinking about technology among young academics which will hopefully spur even more development. All buildings will have their more or less successful details which why we must try new materials and each time use that experience to draw conclusions on how to avoid failed concepts and reuse the promising ones. This will save a lot of resources and increase speed of development. Countries which are not on top of developed countries list such are Bulgaria and Serbia can and should learn from the “experiments” conducted in real scale in countries with more abundant resources. This will narrow the gap in advancement. I have used quotes for experiments since those are usually very well thought through concepts which required large investment in research and testing. Still, not all of them were a stellar success.

Finally new materials and careful use of traditional ones show promise to reduce the burden on ecosystem and this characteristic will be highly valued and balanced with long term economic viability when design decisions are being made.

2. Essential Materials

Depending on many factors (available resources, location, size and function) deciding which materials are most important varies in results. For that reason this paper focuses on some of the materials most abundantly used in recent projects and pertaining to applicability on student housing.

2.1. Composite fibres

Most important example are some of the buildings designed by Zaha Hadid. Her architectural practice uses complex shapes defined with curves which thrive in different cladding than predominantly rectangular objects. We will look at Heydar Aliyev Center in Baku, Azerbaijan. It is relevant to this research since the buildings context resembles the one of Serbian cities which were influenced by the urbanism and planning of soviet modernism with rigid rectangular shapes. Architects of this project had the idea to express the sensibilities of Azeri culture and the optimism towards the future [1]. Structurally this centre consists of: space frame system and a concrete structure. Space frame system was essential in creating a free form structure and exterior cladding made of Glass Fibre Reinforced Concrete (GFRC) and Glass Fibre Reinforced Polyester (GFRP). GFRC consists generally of cementitious matrix composed of water, cement, sand and admixtures, in which short length glass fibres are dispersed [2]. This materials were chosen for their powerful plasticity and ability to respond to different functional demands. Advantages of fibre reinforced materials in comparison to metal reinforced ones include non-corroding behaviour, and low coefficients of thermal expansion. Such characteristics are highly valued for applications on facades because of the exposure to varying and high levels of humidity and temperature. In addition they can weigh substantially less than pre-cast concrete panels since it is easier to make them thinner. This goes to only a few millimetres or centimetres because there is no need for concrete cover like when steel reinforcements are used. Shape is achieved by utilising CNC cut 2D ribs and 3D milled Styrofoam blocks [3]. This leads to reduction in loads on supporting structural components. GFRP is an easy to clean cladding material which fares well in high air pollution areas even when in light colour because it is dirt-repellent itself. As all other parts of building it should also have high durability and low maintenance efforts.

GFRC and GFRP are very applicable to student housing and university buildings. It gives edifices a modern look and supports curved shapes very well. This way of cladding revitalizes the whole block which is usually dominated by rectangularity.


a)

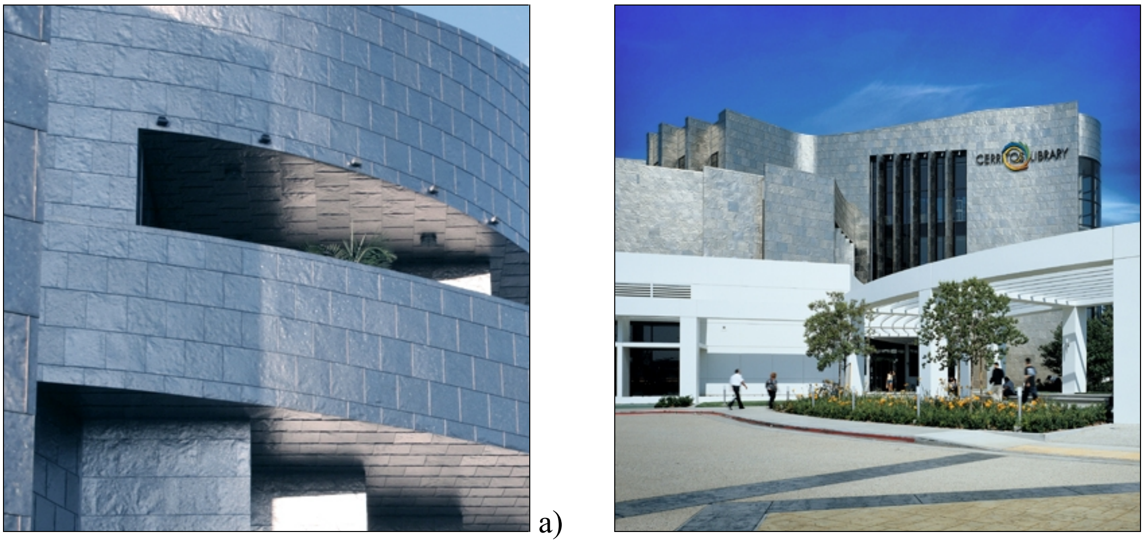
b)

Fig. 1. Example of a composite fibre clad building - Heydar Aliyev Center in Baku: a) finished look (photo by Hufton+Crow) [1]; b) supporting space frame and concrete structure during construction (photo credit Zaha Hadid Architects) [3].

2.2. Metals - titanium

Well known titanium clad buildings are Frank Gehry’s Guggenheim Museum in Bilbao and Cerritos Millennium Library in Cerritos, California. Titanium tiles used on museum are only 0.38mm thick. As with composite fibres use of titanium allows thinner elements, lighter structural loads and higher corrosion resistance [4] compared to concrete and stainless steel solutions. Cerritos Millennium Library wanted to distinguish its experience from traditional libraries and present itself as inspirational and futuristic by use of modern technologies and for the first time in USA titanium as cladding material. Guggenheim Museum was also first to use this type of sheeting but in Europe [5].

For architectural uses and cladding student housing this material can be recommended because of its superior characteristics and modernistic aesthetics. It is very visually compatible with concrete and glass structures. A possible downside could be higher cost of production and montage.



a) b)

Fig. 2. Example of a titanium clad building - Cerritos Millennium Library: a) skyline terrace with tile details; b) building shown in broader context. [6]

2.3. Glass

Glass was used even on lavish villas of Herculaneum and Pompeii but with sophistication of manufacturing processes now it can again be a stroke of luxury for new buildings with unprecedented ways of use. Now it can be utilized as a complete structural material, through the use of special films, glues and coatings [7]. A comparison line can be drawn between university and museum exposition buildings. Recent project Louvre Lens by SANAA architects uses glass as main cladding material combining different finishes (anodized aluminium) to achieve different levels of transparency, translucency and reflectance. Objects with dominant glass parts appear open and welcoming due to increase in luminosity. As such socialising becomes easier and more common. It also allows for enjoyment of surroundings from a usually acclimatized area so even hot summers or windy winters become tamed when observed from the inside of such edifice. Following this exemplary use of glass in this style is recommended for university building areas such are student information centres, communal spaces, canteens or other common rooms where additional daylight and transparency can bring forward conversations and bonding in the social structure. The façade's role has changed from being a simple shield from outside natural forces to being their manipulator [8]. By filtering unwanted UV rays and providing thermal insulation, today's complicated glass panels can serve as a semipermeable membrane which gives users only pure light.

2.4. Wood

It is now widely recognized that wood offers a small environmental footprint with respect to energy and resource use, as well as air and water pollution [9][10]. In accordance with this, many authorities (government bodies) have devised and implemented wood-use strategies. For example British Columbia, Canada implemented wood use through its 2009. Wood First Act, requiring that provincially funded projects use wood as the primary source of construction material [11]. In case of student housing use of wood is certainly recommended but only for smaller scale projects as main construction material. If we analyse current dormitories in Nis, Serbia, they are too large to have been built in wood (more than 4 stories). Still future projects in smaller scales could be made of wood, provided that there is an available location big enough for such development. Student eco-village would be an appropriate location for these wood edifices. Implementation of wood use for student housing purposes is far from simple and would require thorough architectural and urban planning in accord with local authorities. If correctly executed it could present a state of the art success in eco housing and an inspirational environment for young academics to live in during their university years.

Notable recent project which sensibly uses woods is "Besançon Art Center and Cité de la Musique" by Kengo Kuma & Associates in Besancon, France. Wood connects this project with the environment. Fusion of this material with glass and metal creates a well round up edifice which is both modern and eco-friendly.

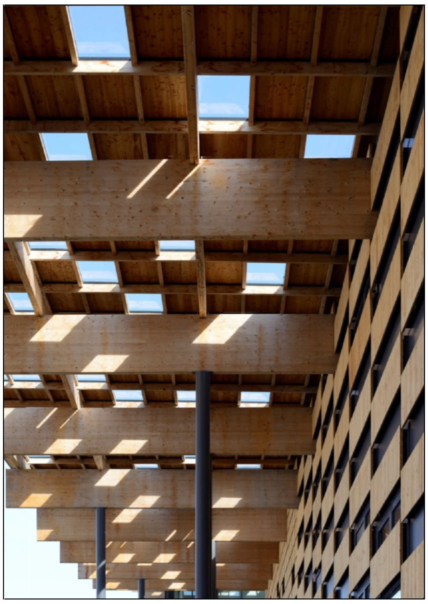

a)

b)

Fig. 3. Example of wooden cladding: a) façade partially covered with wood elements in irregular checker pattern; b) similar solution is applied to brise-soleil design. [12]

Connection of different functions is mirrored in combination of different materials. Pattern used on façade during daylight hours creates a shadow in the interior similar to the one of a large tree resulting in a peaceful and relaxing atmosphere.

Conclusion

Modern approach to materialization of edifices is more than needed in the case of student dormitories as their users are the ones who will need to continue developing new solutions for better living in balance with the environment. As we saw in these case studies it is quite possible using contemporary materials to create buildings of attractive aesthetics, long lasting structures and pleasant interiors. Glass, wood, titanium, composite fibre reinforced materials have plenty of positive characteristics which should be harnessed in architecture of student housing. Use of these materials is already experimented on other types of buildings and proven effective. Hopefully more authorities will join the initiatives to responsibly use more wood as a construction material and create local networks of processing plants in combination with transportation infrastructure which should result in economical processed wood. Hindrance to use of mentioned contemporary materials can only be of their low availability on the local market or their high price otherwise they are highly recommended for application on student housing projects.

Acknowledgement

This research is conducted in the framework of the project approved by the Serbian Ministry of Education and Science, number TR 36037: "The construction of dormitories in Serbia in the early 21st century".

REFERENCES

[1] Zaha Hadid Architects, Heydar Aliyev Centre, [Online] [Cited: 27 Feb 2014.] http://www.zaha-hadid.com/architecture/heydar-aliyev-centre.

[2] Ferreira, J P J G; Branco, F A B. The use of glass fiber-reinforced concrete as a structural material, Experimental Techniques. Blackwell Publishers Ltd.

[3] Buildipedia, Zaha Hadid's Heydar Aliyev Cultural Centre: Turning a Vision into Reality, [Online] [Cited: 27 Feb 2014.] http://buildipedia.com/aec-pros/from-the-job-site/zaha-hadids-heydar-aliyev-cultural-centre-turning-a-vision-into-reality.

[4] Lide, D. R., ed. CRC Handbook of Chemistry and Physics (86th ed.), Boca Raton (FL): CRC Press, 2005. ISBN 0-8493-0486-5.

[5] Emsley J. Titanium. Nature's Building Blocks: An A-Z Guide to the Elements. Oxford, England, UK: Oxford University Press. 2001. ISBN 0-19-850340-7

[6] Cerritos Library, Photo Gallery, [Online] [Cited: 02 Mar 2014.] menu.ci.cerritos.ca.us/galleryExteriors/cl_exteriorGallery.html.

[7] Richards B. New Glass Architecture, Laurence King Publishing, 2006, 9 p.

[8] Elkadi H. Cultures of Glass Architecture (Design and the Built Environment), Ashgate, 2012.

[9] CWC. Green by Design: Renewable, durable, sustainable wood, Ottawa, Canadian Wood Council, 1996.

[10] Ried H., Hug S., Inkinen A., MacGregor J., MacQueen D., Mayers J., Tipper R. Using Wood Products to Mitigate Climate Change: A review of evidence and key issues for sustainable development. International Institute for Environment and Development and The Edinburg Centre for Carbon Managemenet, UK, 2004.

[11] Izard I. Wood First Act (Bill 9 - 2009). 2009 Legislative Session: 1st Session, 39th Parliament, Third Reading. Victoria (BC), Canada. Legislative Assembly of British Columbia, 2009.

[12] Kengo Kuma and Associates, Besancon Art Center And Cite de la Musique, [Online] [Cited: 03 Mar 2014.] http://kkaa.co.jp/works/besancon-art-center-and-cite-de-la-musique-2.

ARCHITECTURE AND URBAN PLANNING OF ECO FRIENDLY STUDENT HOUSING

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Abstract*: With the rise of awareness for mounting ecological problems students should be exposed to artefacts which alleviate them and propose a different approach to architectural and urban creation. Newly constructed dorms should be devoted to preserving the ecosystem using a variety of urban planning and architectural solutions safe for the environment and users. This paper discusses the state of the art of eco buildings for student dormitories by analysing their architectural design, materials, shapes, colours, and urban aspects which include positioning, surroundings, vegetation, and insolation. Special attention is given to sustainability and applicability of these concepts to particularly student housing in Europe. Even though university dormitories and campuses are not the most abundant architectural form that should be converted to eco buildings and spaces, its modernisation in this way can have an important psychological and educational effect on young adults who live many years in such surroundings.*

Key words*: Architecture, urban, planning, ecology, student, housing, university, preservation*

1. Introduction

There are multiple widely accepted solutions for creating eco projects. Significant reductions in carbon footprint comes from using materials that require less energy for processing and transport. Secondly materials and shapes can be such that they preserve building's use of energy for heating or cooling. With new legislations in many countries renewable construction materials are being required [1] and their use is assisted. Every country should asses their local availability of raw materials and regulate this are in order to promote abundant sources and preserve the environment.

Urban planning plays a more important role than it is obvious. Careful selection of student housing complex location is key in enabling architects to orient buildings for optimal insolation, space usage, function distribution and aesthetics. All artefacts should ideally be in synergy with their context. Most often universities are located in an urban environment. Some are on the other hand detached from the city but well connected with

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it. These second ones require even bigger connection with nature but also very often offer more spatial freedom, so low rise structures can be constructed on these locations. Wood as one of the widely available materials is more suitable for lower and smaller buildings.

1.1. Methodology

Architecture as a science distinguishes itself by its holistic approach to research topics. Simplification of complex models and their scaling is most often used for evaluating design concepts. Still even the most experienced architects and urban planners can overlook how some detailing, material characteristics, texture, might appear in real scale. All buildings with their respective site plan elements need to be observed in all times of the day and in all weather conditions. Colour temperature of daylight changes during the day and in accordance with weather and time of the year. Some materials and colours are more susceptible to these changes than others. For these reasons it is important to also study edifices in real scale in architectural terms. This paper is part of a larger study and will here present only a subset of case studies used to analyse already built successful projects of ecology preserving housing. Data is used to draw attention to exemplary solutions and create guidelines for future urban planning and architectural developments. Cases are selected by relevance to student housing, their age and level of advanced technology used in achieving their designs.

2. Eco Student Housing Projects

2.1. Smart Student Units

A direct solution for designing a student unit which is affordable, environmental-friendly and smart was to reduce it to 10 square meters. According to Tengbom Architects area in each unit is reduced from current requirement of 25 square meters to only 10 through legal consent [2]. Each of these compact-living flats offers a comfortable sleeping loft, bathroom, kitchen and even an appropriately sized garden with a patio. Materialization is dominated by the use of cross laminated wood as a construction material in order to reduce significantly carbon footprints of these smart units. Rent is reduced by 50% which might prove important for students with low incomes who are ready to sacrifice some of the luxury of additional space for monthly savings. Wood is chosen for this project because it is renewable and locally available resulting in decrease of transportation costs.


a)

b)

Fig. 1. Smart student unit: a) exterior; b) interior design also predominantly made of wood. (Photo by Bertil Hertzberg) [2]

A similar solution to student housing could be offered in Serbia too but only if urban planning devises an area big enough and well connected to university buildings. It is easy to imagine eco villages with many units constructed of local wood resources. It appears that these units can be stacked together to form groups of up to four units since two sides are windowed in order to reduce thermal transfer to outside. For year 2014 22 of described units are planned for students to move into. This is a good experiment in real scale of such solution for housing students.

2.2. Charles David Keeling Apartments

Named after the American environmental scientist and oceanographer whose research rouse awareness in the world to the build-up of carbon dioxide and the greenhouse effect. This student housing project is designed by Kieran Timberlake with a goal of becoming a model for energy and water efficiency using distinctive design features such are green roof, passive shading devices, carefully setup daylighting, and a water recycling system. As mentioned in my previous papers certain rooms in Nis dormitories suffered from overheating due to excessive insolation [3] which forced their tenants to use reflective foils on windows for protection from the afternoon sun. There was a clear lack of any passive or active shading devices, so there is a recommendation for next projects or renovations of existing student dorms in Nis to include a shading device.

Charles David Keeling Apartments are also different from student housing in Nis by their use of green roofs and storm water management system. Landscaping on the ground integrates retention ponds and bioswales for collection and filtration of rain and gray water. Cleansing process is visible as temporary streams on site. This water is later used for irrigation of that same landscape greenery.


a)

b)

Fig. 2. Keeling Apartments: a) Shows vegetated roof in function of bio retention and bio remediation. Pollutants and sediment are filtered from the water by use of rocks, soil, and plants; b) Apartments are cooled in natural manner with ocean wind, deep overhangs, and sun controlling screens. (Photo by Tim Griffith) [4].

Apartments and communal spaces like exterior walkways and roof terrace are situated to provide inspiring views of ocean and the surrounding mountains. Corridors are single loaded with units on one side only in order to allow optimal natural ventilation and abundant daylighting. Outdoor living is promoted by this building openness and surrounding landscaping leading to places of convergence and outdoor circulation for better student interactions. Building arrangement takes advantage of location's wind directions for cooling the objects in combination with deep overhangs on south and west facades. Additionally west facades are protected by industrial fiberglass shading. [4] It is noticeable that this project took great care of west façade which is prone to overheating in the afternoon sun, when the air and building has already accumulated a fair amount of heat and likely will not suffer from the problem of mentioned dormitory in Nis.

This well thought design was also awarded with Platinum certification from the United States Green Building Council making the building the first LEED Platinum student housing in the University of California. Refined solutions used here to save energy and offer students a pleasurable living space can be applied to student dormitories in Serbia too.

2.3. Modular dormitory in Barcelona

Interesting housing offer for students was designed by H Arquitectes and dataAE taking place near the Valles Architecture School (University Politecnica de Catalunya) in St. Cugat del Valles, Spain. Special feature of this project is that interiors of rooms are blank and students are left to decorate and finish as they want. For the exterior, metal screen surrounds the object and is planned to become covered in vegetation in order to provide energy savings by reducing thermal exchange and providing shade. Long overhangs create shade for the walkway from which the apartments are accessed. Design team has calculated savings of 50% in energy associated with construction materials and 70% in energy demand compared to a standard building using cycle of life analysis according to CTE regulations. Dormitory is composed of 57 pre-formed concrete modules which were trucked in and craned into place. Each module encompasses one studio apartment with its required plumbing and electrical wiring. After craning the module's connections are planned for easy plugging in. Apartments also include a small kitchenette and a washroom unit in the corner. Rest of the studio is left for residents to decorate and furnish. Modules are recyclable and movable [5].

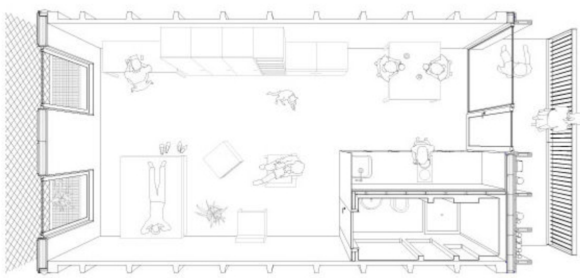

a)

b)

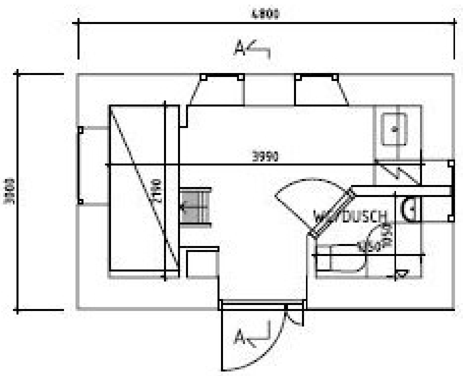
Fig. 3. Modularity: a) Modules are easily transported by trucks and craned into place; b) Example of interior use of one such module. (Photo by Adrià Goula) [5].

For better use of space whilst still not requiring elevators these modules are laid out in two stories and in two lines on opposite sides of a central atrium which seems like an optimal solution. Modular construction for housing has been used for many residential buildings in Serbia and such use could apply to student housing. This shows that a simple solution can be very effective and cost friendly. Still it requires a larger area than a high-rise building so it is more suited for campuses outside the city core.

2.4. Micro Home

Another solution from Sweden similar to the one described in 2.1 part of this paper is Micro Home offered by AF Bostader (one of the largest student housing companies in Sweden). It is located in Lund and provides only 12 square meters of living space. It offers the bare essentials of student life: sleeping loft, bathroom with toilet and shower and a kitchenette completed with a dining area. Due to the small size socializing and encounters with tenant's friends and colleagues are better performed outside of micro home. Although autonomous living was not in high demand in dormitories in the city of Nis in Serbia as verified by a questionnaire [6], it is apparently higher in Nordic countries. This micro home is set to be cheap to build and maintain resulting in lower rent for the student wishing to live alone (2500 kronor compared to 4167 kronor which is the average rent for newly built student apartment, but three times the size) [7]. It is questionable how much energy will be spent on heating this home compared to usual student dormitories where rooms are stacked and sharing the same thermal envelope, wiring and plumbing.


a)



b)

Fig. 4. Micro Home: a) Exterior design and urban planning positioning of a sample micro home; b) Typical floor plan. (Photo by Jan Nordén) [7].

We can consider this a well thought test in real scale on how much such dwellings are practical. In contrast Serbia has a higher average temperature so in case a similar solution is applied in this geographical area, heating would be a lesser expense. Creating an eco-village consisting of cottages using traditional Serbian design for students could also be used as a tourist attraction and form of income in summer months when students are on holidays. With wood as the main construction material it would also be eco-friendly without requiring expensive technology for production and montage.

Alternative to testing real scale models is use of parametric processes in computer simulations, as used on a case of a student housing complex on campus of the University of Patras, Greece [8]. This type of process is usually cheaper but requires careful setup of the model and test parameters for accurate results. Still it can analyse many different variations of project designs without requiring expensive construction costs. It is best to use a combination of both design decision making processes for architectural and urban planning of student housing projects.

Conclusion

Analysed projects provide us with a large set of real scale empirical evidence data. Each case study shows reusable successful solutions for building future student housing. On one side we have simple solutions, using traditional shapes and simple renewable materials like wood which can be easily replicated in countries with a mild climate and accessible wood resources. The other side are high tech materials in combination with complicated solutions and shapes with green roofs, large glassed areas and metal construction elements. Each type has its distinct advantages and architects and urban planners need to work together with governing bodies to find the most fitting area and building type for the available budget. With the aging population in Serbia a careful approach to "studentification" [9] should be considered in order to transform local communities to a sustainable level with enough young people. This is challenging to control and direct with policies or regulations but can provide a better balance of generations.

Acknowledgement

This research is conducted in the framework of the project approved by the Serbian Ministry of Education and Science, number TR 36037: "The construction of dormitories in Serbia in the early 21st century".

REFERENCES

[1] Izard I. Wood First Act (Bill 9 - 2009). 2009 Legislative Session: 1st Session, 39th Parliament, Third Reading. Victoria (BC), Canada. Legislative Assembly of British Columbia, 2009.

[2] Tengbom Architects, Smart Student Units, [Online] [Cited: 03 Mar 2014.] http://www.tengbom.se/en-US/projects/207/smart-student-units

[3] Dačić M, N. Cekić, M. Vasov, A. Kostić, I. Bjelić: "Analysis of typical floor plans of student dormitories in Nis – Serbia" 13th International Scientific Conference VSU'2013, June 2013, Sofia, Bulgaria, ISSN 1314-071X, p. III–16-21.

[4] Charles David Keeling Apartments, KieranTimberlake, [Online] [Cited: 31 Mar 2014.] http://www.kierantimberlake.com/pages/view/21/

[5] H Arquitectes' Modular Dorm, Inhabitat, [Online] [Cited: 31 Mar 2014.] http://inhabitat.com/h-arquitectes-modular-housing-lets-barcelonas-architecture-students-design-their-own-dorm/catalunya-student-housing-h-arquitectes-1

[6] Dačić M, A. Kostić, M. Lukarevska: „Questionnaire on architectural properties of student dorms in Niš" iNDiS 2012 international scientific conference 28-30. November 2012, Novi Sad, Serbia, p. 780-787

[7] The Local, Students compete to rent Sweden's 'smallest' flat, [Online] [Cited: 06 Mar 2014.] http://www.thelocal.se/20120124/38692

[8] Chronis A, K. A. Liapi, I. Sibetheros, A parametric approach to the bioclimatic design of large scale projects: The case of a student housing complex, Automation in Construction, Volume 22, March 2012, p. 24-36

[9] Smith D, The Politics of Studentification and `(Un)balanced' Urban Populations: Lessons for Gentrification and Sustainable Communities?, Urban Studies, November 2008, 45: 2541-2564

ACOUSTIC ASPECT OF INNER PARTITION WALLS MATERIALIZATION IN STUDENT HOSTELS ARCHITECTURE

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Abstract*: Today modern architecture approach to energy efficient buildings should include all four aspects of comfort. Therefore, in addition to thermal, ventilation and lighting comfort, of particular importance is also the realization of an appropriate acoustical comfort. The first step in solving the appropriate requirements from the standpoint of acoustic comfort and sound protection should be the architectural design and planning. In addition to these requirements, equally important part in the design process is materialization of internal partition walls. Contemporary architecture of student hostels building requires reviewing of new concepts in construction and materialization of interior walls structure. This paper discusses the state of the acoustic comfort in student hostels by analysing constructional design, materialization, shapes and functional aspects of their inner partition walls.*

Key words*: Contemporary architecture, materialization, acoustic design, student hostels*

1. Introduction

In the architecture of contemporary student hostels, realization of acoustic comfort is one of more demanding designing aspects. Actualization of importance of soundproofing is primarily the consequence of application of contemporary designing concepts as well as new technologies in prefabrication and materialization of space, even though increasing of criteria and standards of all forms of housing is nowadays ranked among the relevant factors.

Regulations and legislations in the field of acoustics in civil engineering includes a relatively limited number of documents, which in one part refer to the architectonic designing, while most of them refer to acoustic testing of building materials, elements and structures, i.e. on their acoustic control via the field test over the executed works. By this, as much as it is possible, the acoustic comfort and soundproofing is ranked among the

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more important aspects of architectonic-engineering designing and construction, even though it does not belong to the top, when the sequence of importance is considered.

Having in mind all the previously mentioned facts, as well as the difficulties in application of the existing and new regulations, most frequently because of the insufficient knowledge of it, this paper is an attempt to view the acoustic comfort primarily through the application of preventive designing principles of soundproofing. The presented general analysis, on the example of interior partitions of student hostels, indicate the increasing necessity of a serious designing approach aimed at preventive provision of a quality acoustic comfort, according to the standard ISO 6242-3, i.e. soundproofing,, with the goal of improving the student standard by improving the housing conditions in the student hostels. [1]

2. Preview of legislation and standards of the Republic Serbia

Considering the global state of affairs of the humanity, the most important task at the national level is enactment of legal regulations of soundproofing, measuring methods, allowed relevant levels as well as the methods of control and sanctioning of all careless noise polluters. The consistency of the EU regarding the protection from noise bore fruit by enacting the recommendation in 1996 entitled *The European Union's Green Paper on Future Noise Policy*. The recommendations comprise possibility of every country to individually, at the adequate levels, enact standards and codes for soundproofing.

At the level of the Republic of Serbia, as long ago as in 1967 a document entitled "Code on minimum technical conditions for housing construction" (Official Gazette of the SFRY no. 45 of 1967), which can be considered the beginning of at least a formal obligation of the designers and constructors to consider soundproofing in designing and constructing of buildings. Nowadays, this obligation is established by the series of SRPS standards under the common title "Acoustics in civil engineering" (i.e.: "Acoustics in housing building construction"; "Acoustics"; "Engineering acoustics"), of which only a part of them is formed by translation of the appropriate ISO standards designated as SRPS ISO. Very important standards for the designers are two standards: SRPS U. J6. 201 / 1990. – Technical conditions for designing and construction of buildings, and the other SRPS U. J6. 215 / 1982. – Technical conditions for designing and construction. Acoustic quality of small and medium sized rooms.

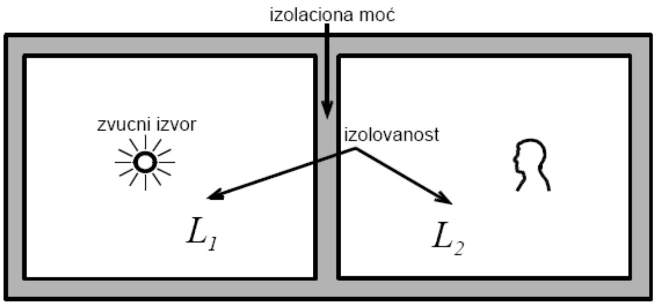
In the framework of the regulation "Environment protection Law", (Official Gazette of the RS no 66, 1991) the harmful effects of noise on the job is for the first time defined by the document „Code of general measures and norms for occupational protection from noise in working premises " (Official Gazette of the SFRY no. 45/71). The maximum permissible noise levels in the living environment are given in the document "Code on the permissible level of noise in the environment", (Official Gazette of the SFRY no, 1992). At the present time, in the Ministry of environment and spatial planning of the RS, the Law on the protection from noise in the environment is being prepared. [2]

The contemporary standards and norms introduced a completely new approach in consideration of noise in buildings. Those are the standards SRPS EN 12354 "Acoustics in civil engineering – estimation of soundproofing of buildings based on the acoustic performance of structural elements, those being: SRPS EN 12354-1; Part 1-Soundproofing insulation between the rooms SRPS EN 12354-2 Part 2- Soundproofing Insulation of impact sound between the rooms SRPS EN 12354-3; Part 3 – Soundproofing insulation of external noise. In the entire Europe, the soundproofing in designing must be treated according to the requirements of these norms and standards. In some neighboring countries they are already in force (for instance, Slovenia has been applying them since 01/01 2013). Apart from the ISO standards, other international and national norms and recommendations are observed in practice (IEC, EN, DIN, and the others). In the rare cases, where there are no international standards or recommendations, the recommendations and opinions of the acknowledged experts in this field are used, as well as considerations of this problem of the most relevant authors in the literature [2]

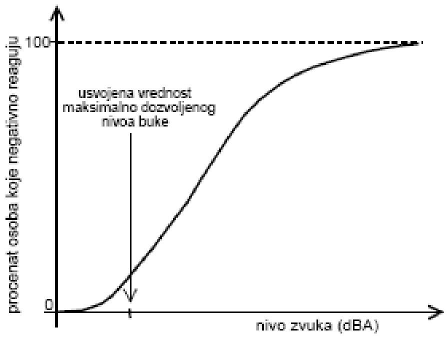
3. About the sound protection and acoustic comfort

The soundproofing problem in housing building construction in general, and by this in the student hostels, boils down to the relationship of any two given spaces at the level of functional-architectonic organization of it. In simple terms, it is the relationship of the room with a source of sound, and the room where the hearer is located. Fig.1a. In terms of the student hostels architecture, it is a relationship of the noise generator and the tenant student – hearer. The concepts characterizing this relationship, that is, the problem of soundproofing are:

- soundproofing D – level difference (L1 - L2) in the emission and reception rooms,
- sound reduction index R – capacity of a partition to prevent sound transfer.



a)



b)

Fig. 1. Elements of sound protection in buildings: a) the basic terms which define sound insulation; b) the principled look of the curve that defines acoustic dilemma [3]

Conducting and realization of soundproofing through the set of measures taken to reduce the noise to an acceptable level, is complicated by two key causes. The first is the fact that human hearing sense is a very specific organ with extreme requirements calling for a very great damping of sound energy in the partitions. The second cause, for which the soundproofing is so complex to perform, is in the mechanical nature of sound, and its "elusive" propagation.

The relativistic approach in standardization of the permissible noise levels is the complex question which is known in the literature as the "acoustic dilemma", described by prof. PhD M. Mijic in one of his papers in this way [3]: *Acoustic dilemma can be described by a curve whose principal form is presented in Sl. 2b. The increase of the level of ambient noise in the human environment causes the increase of number of people who will feel affected. Adoption of the criteria for the maximum permissible level of noise, at which no person would be affected is not rational, and often, not possible. Because of this, all the existing standards for noise have the values at which it is expected that percentage of the affected will be lower than some preset limit, which is determined by the percentage of realistically attainable results (5%, 10% or similar). The existence of the acoustic dilemma, illustrated by the diagram in Fig. 1b, is significant in the construction acoustics as it explains that soundproofing does not attempt to silence the ambient noises, but to reduce them down to the acceptable levels for the most of the population.*

Yet, if the problem is reduced architectonic-engineering dimension, it is possible to generally limit it to definition of the criteria for the acoustic quality of internal partition structures. Usually the sound propagation concept is based on the mechanism of the sound passage through one partition. However, the volume of a building, as a stereometric space, represents a complex system of several different partitions in the widest sense of complexity of this system. Understanding of space is the key, both in terms of architectonic understanding, and in the understanding of ways where the sound energy pass. Exactly this knowledge calls for a complex consideration of the soundproofing, taking into account all the possible ways of passage of sound energy. Therefore, the soundproofing does not depend only on the partition between two rooms, but on all the lateral vertical and horizontal partition structures (lateral walls, floor slabs) and their structural ties. Neglecting of complexity and interaction of any of the listed influences is the key problem in practical understanding of sound insulation and soundproofing.

4. Partition walls as a elemnent of sound insulation in student hostels

Student hostels, as a special form of housing, equally belong to the category of public structures and the category of structure of specific collective housing. Such architectonic-spatial categorization and organization communicates through the mutual relationship of characteristic rooms of typical horizontal and vertical plan. Solution of the problem of their mutual arrangement and grouping must obey two parallel principles which synergetically lead to the solution and reflect in: administrative control of usage of sound sources inside the building and in the adequate materialization of building.

Therefore, the key task of on an engineer-architect is to, within the limits an administrative control, provide a minimum needed materialization of the elements of civil engineering structure which will in a sufficient, minimum prescribed manner, solve the noise problem.

In the general case, the acoustic comfort (soundproofing by internal partitions) of the buildings – student hostels is achieved through optimization of three influences:

- mass of the partition (insulation according to the mass law),
- discontinuity in partition (in materialization of the partition) and
- adequate details (in the construction of the partition and structural ties of the partition with the adjacent structures).

At the first sight, it is not difficult to conclude that materialization of partitions, included indirectly into every of the influences (mass; discontinuity; details), has key role in realization of this type of comfort. A special importance in achieving of soundproofing is the discontinuity of the medium through which the sound propagates. Realization of the discontinuity by partitions, through variation of dimensions, type of material and methods of tying of elements of its structure is the essence of their materialization and the basis of the acoustic division into:

- single partitions (partitions with two discontinuities),
- double partitions (partitions with four discontinuities) and
- multiple partitions (partitions with multiple discontinuities).

Materialization of contemporary architectonic structures of student hostels are nowadays based on application of contemporary materials treated by the advanced technologies of prefabricated and assembly construction. Architectonic-engineering principles of partition materialization are primarily determined by their construction procedure and are divided into:

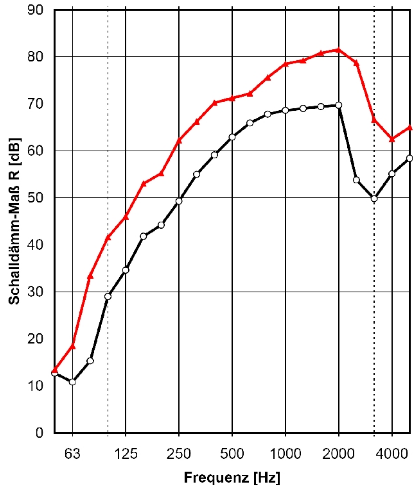
- load bearing-traditional building system using wet construction and
- prefabricated buildings system using dry construction.

The partitions built by the traditional building system are analyzed from the aspect of civil engineering acoustics in a number of papers an various studies. Contrary to them, the partitions constructed by the dry construction, which is an increasingly used method of materialization of internal vertical partitions, and even of some parts of structures of horizontal partitions require special designing-construction commitment in order to provide a good acoustic comfort.

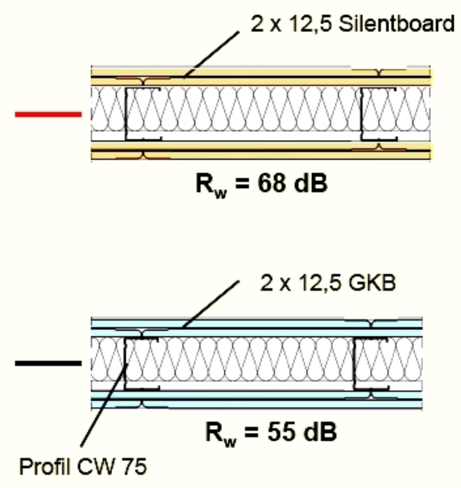
4.1. Drywall partition – gypsum walls board system

The walls of gypsum-cardboard slabs are acoustically classified as a special case of partitions with multiple discontinuities. Through such partitions, the sound is transferred in two ways:

- through the cavity between the panels (cavity =air + wool) and
- through a grid systems (metal or wood stud).



a)



b)

Fig. 2. An exsample of drywall partition: a) Chart of sound insulation of the shown examples; b) two exsamples gypsum walls board system

The acoustic efficiency of these walls in comparison to the traditional walls constructed in the load bearing system is presented in Table 1. By comparing of the estimated values of the sound reduction index, it is clear that the values vary in a very small range, regardless of the differences in the basic structural composition. The values of sound reduction index of drywall partition of relatively low surface mass (small dimensions), under certain circumstances have the same or approximately same value of Rw as the walls having the multiply larger weight, and whose acoustic quality is based primarily on the mass law. The importance of measured values is evident, since according to some acoustic experts, *a purely theoretical approach to this problem is very difficult, and almost impossible* [4].

Table 1. Estimated sound insulation according to DIN 4109 [5]

Kind of the constructions	Weight (kg/m^2)	Estimated sound reduction index (dB)
plastered brick wall of thickness 24 cm	360	51
plastered brick wall of thickness 34 cm	496	54
concrete brick wall of thickness 15 cm	360	51
drywall partition 100 mm, single covering 12,5 mm, mineral glasswool 80 mm	25	51
drywall partition 100 mm, double covering 12,5 mm, mineral glasswool 80 mm	49	56

This, paradox of a kind in soundproofing of gypsum walls board system is achieved by multiple discontinuities and mineral wool – wall infill, contributing to dissipation of energy inside the partition. Except this, one of the more important principles is elimination of rigid ties between the cladding panels which is achieved by doubling the substructures and by eliminating the so called lateral sound conduction.

Based on these considerations and analyses of sound proofing of gypsum walls board systems, which is partially displayed in this paper, the entire problem can be reduced to the group of elements which must be possessed by the structure for the purpose of achieving better performances and good acoustic comfort. Therefore, by uniting the conclusions in this paper, and those presented in numerous other analyses, one general conclusion must be drawn, that the insulation capacity of drywall partition – gypsum walls board system depends on the:

- mass of gypsum panels,
- distance between the panels,
- elasticity of ties in substructure,
- mineral wool quantity,
- number of discontinuities inside the partition and
- details in construction.

Conclusion

The presented discussion of the state of the acoustic comfort in student hostels, has a goal to demystify application of lightweight partitions of the, drywall partition – gypsum walls board system type, whose insulation capacity is in some cases overstated, but sometimes minimized. It must be emphasized that by the consistent application of details in construction (the most important principle) and by adding some of the principles mentioned in the text, will result in a certain measurable influence on the total effect of improvement of their acoustic performance. In essence, the first step – principle is that each of the above mentioned activities should be conducted, unless it has been already conducted. Repetition of the steps-principles which have been drawn, must be selected according to the efficiency and economic justifiability which can be achieved by their multiplication. For instance, by doubling the panels in the cladding, it is possible to improve the insulation capacity for around 6dB, and by changing the weight, the improvement effect becomes even more pronounced. The need for optimization of the listed principles is more than evident. In addition, one must be very careful, since certain interventions, by shifting the resonant frequency, the things may become aggravated. The problem is additionally complicated by the very complex theoretical analysis. Therefore, the first step is the consistent application of the listed principles and details, and the second is always the same in acoustics: to hope for the best.

Acknowledgement

This paper is a part of the scientific-research project: "Construction of Student hostels in Serbia at the beginning of 21st century", approved by the Ministry of Science and technological development of the Government of the Republic of Serbia, in Belgrade, January 2011. Project manager, prof. Ph D Nikola Cekić, Grad. Eng. of Arch. The Faculty of Civil Engineering and Architecture of the University of Nis. Project number: TR 36037.

REFERENCES

[1] Vasov M., Grdic Z., Toplicic-Curcic G. Zvucna izolacija unutrasnjih pregrada kod zidanih konstrukcija, Konferencija "Zidane konstrukcije - nosivost, trajnost i energetska efikasnost", Beograd, 2010.g., str. 117-132 (in Serbian)
[2] Drincic D., Krstic S., Zekovic A., Martinovic D. Merenja i zastita od buke, Ecologica vol. 16, No. 54, 2009, 141-150 p. (in Serbian)
[3] Mijić M. Akustika u arhitekturi, Nauka, 2001 (in Serbian)
[4] http://www.ravago.rs/Trendovi/Akustika.html
[5] Kurtovic, H. The evalution of the transmission loss of light weight double walls with elastic steel studs, TELFOR, 2008, 649-652 p. (in Serbian)

COLOR PARAMETER IN PRE-SCHOOL FACILITIES

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Abstract*: Color in the architecture of pre-school facilities is one of the important parameters of space. In addition to thermal, acoustic, visual and air comfort it is also necessary, among everything else, to establish aesthetic comfort by properly including the right color parameters. The element of color is very closely related to the physical and emotional development of pre-school children. Given the importance of color of preschool facilities in the development of a child's personality, in this paper the accent is put on the examination of the color correlation of external and internal environment and a pre-school child. In this paper, a review of the current state of color has been made, through analysis of the aesthetic comfort parameters of the existing pre-school facilities in Serbia and beyond, with the emphasis on the positive and negative solutions of exterior and interior design. The main objective of the research paper is seen in the tendency to define the correct choice of colors and tone complex which match the children's abilities to understand the physical structure of space and its color.*

Key words*: color, space, architecture, child, preschool facilities.*

1. Introduction

It is generally known that the choice of colors and their nuances, in their internal and external physical environment, is very important process. Preschool facilities require careful and precise choice of colors, given that the basic beneficiaries of these institutions are children in a sensitive phase of growth. Element of color as an effective and powerful tool, which is correlated with children's progress, behavior and other psychological and mental states and abilities, can significantly contribute to a children's development.

Color is a second language by which children can understand space and orient in it [1]. The child needs to understand color because it gives him the psychological impression [2]. To date, numerous and significant research in the area of influence of color to work,

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learn, play and other skills and psycho emotional states of children was conducted. There are numerous literatures dealing with the issue about relation between colors and emotions of persons in different age. Different opinions exist about the influence of color to children of preschool age starting from the middle of 20th century till today. While certain groups claimed that children understand and recognize only the basic colors, and therefore they should dominate the area and stimulate children, later appeared notions that a vibrant and intense colors are not desirable in the architecture of these institutions and that the space should encourage by its form and heat (access which included natural colors and textures, with occasional accents to architectural elements by color). Architectural - visual effects of external facade planes of parent units and the entire object of children's preschool institution are important for a sense of comfort and children's need to get together with the identity of the house that replaces them home. Hence, there are present continuous efforts of architects towards predominantly natural and warm materials (wood, brick) to be used and to use form, plastic and colors to come closer to the children's imagination. [3]

Because of the importance and role of color as an integral and indispensable element of any architectural edifices have, the issue of color correlation with activity and psychoemotional conditions of children has been associated with the architecture of facilities for their education. In this paper, the aspect of the influence of the color spectrum to preschool children and its relation with the space in function to meet the children's needs for an inspiring and stimulating environment is analysed. In order to foster children's progress, the issue of reviving colorings of objects that are partially or completely lost their identity ambient is involved. The main objective of this paper is the inclusion of color element in creating architecture that would be appropriate children's abilities to understand and perceive an area, in order to ensure a comfortable and pleasant stay.

2. Role and importance of color in preschool facilities

One of the numerous principles of preschools space design, which is cited by *Jeffrey A. Lackney*, is a rich stimulating environment created through the use of different colors, textures and application of "teaching" architecture. [4] Color in an environment intended for education should, among other things, with their visual characteristics should provide a relaxing feeling, and at the same time stimulating and supportive environment that encourages visual processes, reduces stress, causes the development of mental abilities and all these through visual stimulation (color relationships, research and identification of models and patterns). Visual stimulation actually rewires the brain, making stronger connections whilefostering visual thinking, problem solving, and creativity. [5] Color enhances the degree of attention, helps the intellectual development of children through mental stimulations, thereby enhancing their creativity, imagination and memory. The negative impact of color, inadequately implemented in the children's pre-school environment is reflected in the eyestrain, glare, distraction and reduced concentration. Proper use of color can certainly contribute to a positive perception of space, which also effectively influences the activities of children and reduces negative behavior and aggression.

The presence of the colors reduces monotony and passivity of space (Fig. 1. a). Thus, in the areas of children's preschool institutions different colors should be included and applied in order to reduce the monotony of space and fostered and refreshed visual perception. However, it needs to find moderation. Excessive use of colors (more than six colors) in the environment makes an effort for children's mind cognitive abilities. On the other hand, there is an opinion that the children's objects for play and props to perform different types of activities, themselves are enough colorful, so it is advisable for space coloring to be reduced or monochrome (Fig.1. b).


a)


b)

Fig. 1. a) Kindergarten 8 Units Velez-Rubio,
b) Kindergarten Barbapapà, Comune de Vignola, MO, Italy
http://www.archdaily.com/129662/kindergarten-8units-velez-rubio-losdeldesierto/
http://www.archdaily.com/45766/kindergarten-barbapapa%CC%80-ccd-studio/

3. Impact and choice of colors

The coloring of colors present in the exterior and enterior of pre-school facilities should necessarily be in proportion with children's comprehension of space and its components. The influence that applied color in space architectural composition produces to the general conditions and abilities of children and teachers is multifaceted and very important. The color is associated with physiological and psychological states both children and adults and has both positive and negative effects. The physiological impact of colors, due to eye exposure to a particular range and composition of colors, is reflected in the change in blood pressure, temperature, heart rate, breathing, and brain activity. Also, color has a strong impact on our emotions and feelings. In this sense, some colors are associated with several different emotions, a true and vice versa, some emotions may be associated with more than one color [5]. The general wisdom seems to be that colours are either 'warm' and'advancing', or 'coo1' and 'receding. [6] Studies have found that bright colors such as yellow and green promote a positive mood, while darker colors give raise to a negative mood. According to Taylor and Gousie warm colors evoke muscle activity and increase blood pressure, while cool colors calm and relax [7]. On the basis of the children's parent unit stays are preferred warm tones creating a relaxing atmosphere in which children can focus on their predicted performance of daily activities. Existing law regulations (norms for planning, construction and equipping of pre-school institutions) suggests the use of bright and still colors, for children's group stays rooms. [8] This proposal is certainly justified because it creates an atmosphere that does not disturb the flow of their daily activities. The existence of a single opinion on coloring area of pre-school facilities is uncertain, and may be said that it is based on personal-peculiar ideas and perceptions of the children's space designers.

4. Physical properties of space correlated with child development

"It is now known that the quality of the *physical, designed environment* of early childhood centers – size, density, privacy, well-defined activity settings, modified open-plan space, a variety of technical design features and the quality of outdoor play spaces – is related to children's cognitive, social and emotional development." [9]. Mentioned factors as a sum affect the performance of planned daily activities for children and to their psychological, physical and medical condition. From the qualitative properties of the designed internal and external environment of the physical structure and installed equipment and furniture, successful children's proper growth and development, will greatly depend. The color parameter is besides the distinct elements separated, also one of the most important factors of pre-school facilities space that can significantly contribute to the establishment of a richer and more inspirational environment and fertile climate for the upbringing and education of children of preschool age.

Preschool children learn about the surrounding environment through the system of senses (touch, smell, sight, and hearing) and therefore the physical structures in which they reside during part of the day should meet their needs, to encourage them and trigger exploration of the environment. "Projected spaces elements may support the child and help it to function within the limits of their abilities, and at the same time provoke processes that lead to progress." [10] Therefore, the color may be a response to a number of functional and aesthetic requirements in the function of satisfying their needs for an attractive environment. Getting children into preschool facility space can be improved by clear differentiating the parts of space through coloring with proper color selection, allowing the dynamics of space rises to a higher level. So warm nuances of the color spectrum can be used in order to establish a more intimate environment, and can visually reduce the size and volume of the space, while cool colors are used to visually increase the space making it the unrestrictive, or more liberal. Aesthetic requirements are certainly associated with attractiveness, creativity, imagination and diversity of the area, expressed through a combination of color, texture, shape, volume, etc. The aesthetics of the design space and aesthetic of equipment, expressed through form, color, texture, contribute to children stay at the preschool facility indoor environment to be more pleasant and stimulating (Fig. 2.).

Fig. 2. Interior of kindergarten in Tromso, Norway; Exterior of kindergarten Ecole Maternelle Pajol, Paris, France
http://www.belowtheclouds.com/2008/08/05/moderna-dagis-av-70%C2%B0n/
http://www.jeanniejeannie.com/2012/06/a-kindergarten-building-covered-in-rainbows/

5. Coloring preschool facilities revitalization

New age included the processes by which the spirit and identity of the object is transformed and reshaped into new refined state. Revitalizing steps and actions can certainly affect the improvement of not only the physical, the energy performances of buildings, but also ambiental and aesthetic properties. In this way through more purposeful use of the external and internal environment, is achieved. The revival of pre-school facilities, should include the implementation of elements of color (colorize facade and the inner planes, as well as replacement of old equipment with new equipment coloring), in part or completely impoverished and antiquated architecture intended for children.

A significant proportion of preschool facilities throughout Serbia consist of structures built in the second half of the twentieth century. Analyzing the objects of the Southeastern Region of Serbia (sample of 25 pre-school objects) [11], in terms of coloring outside facade planes of the indoor environment and equipment, it is generally found lack of inspiring elements of the external and internal environment (general devastation of interior and exterior, Fig. 3, 4). In these objects mainly dominate light tones of wall and ceiling surfaces, natural-looking facade planes while the intense color tones are present in children's accessories and children's activity products.

Therefore, based on the conducted research, it can be concluded that in revitalization processes of these properties, it is necessary to include and involve area refining by coloring surfaces and equipment. It is certainly necessary to analyze in details the process and assess the extent necessary to revive the space by space coloring (proper selection of positions that need to be painted, the correct choice of colors and nuances).

Fig. 3. Kindergarten "Snežana"-Knjaževac [11]

Fig. 4. Kindergarten "Lane", Leskovac [11]

Conclusion

Color in preschool facilities plays a crucial role. Based on all the above analyzed and considered it can be concluded that the color, among other architectural elements, is the language of the visual identity of physical structures. Preschool facilities with its form, function, materialization, the applied textures and colors composition should provide a pleasant and comfortable environment that will certainly be the basis for further successful and effective children promotion and development. Inspiring and challenging preschools environment, which is versatile enough to meet the numerous needs of children, is created, among other things, the introduction of color element. Its importance is reflected in the impact it has on the physiological and psychological states of children (mental health, moral, emotional condition, behavior and performance of pre-school children). Therefore, making the right decisions about the choice of colors is essential for creating an environment where children are visually stimulated and encouraged to explore the area and learn. Basic tendency in the coloration of this type of public objects is seen in the establishment of parameters of aesthetic and visual comfort, proper selection and composition of colors. The result of this research work is perceived as contributing to the decision-making process in the coloration process of facilities for education of children of preschool age.

Acknowledgement

The paper was done within the scientific project "Revitalisation of the Kindergartens in Serbia– Program and Methods for Improvements of Ambient, Functional and Energetic Quality", No TR36045funded by Ministry of Education and Science, Republic of Serbia. Project manager, prof. Ph D Danica Stankovic, Grad. Eng. of Arch., The Faculty of Civil Engineering and Architecture of the University of Nis.

REFERENCES

[1] Dudek, M., Kindergarten architecture, E & FN Spon, London, 1996.
[2] Ivanovic-Sekularac, J., Predskolske ustanove i komfor, Biblioteka ACADEMIA, Zaduzbina Andrejevic, Belgrade, 2000.
[3] Stankovic, D., Aspekti vrednovanja nacina materijalizacije i stepena ekonomicnosti u projektovanju maticnih jedinica decjih ustanova, Zbornik radova Gradjevinsko-arhitektonskog fakulteta, Nis, 19, 2003, 53-62.
[4] Krklješ, M., Programski, funkcionalni i prostorni ĉinioci arhitekture predškolskih ustanova u Vojvodini, Univerzitet u Novom Sadu, Fakultet tehničkih nauka, Novi Sad, 2011.
[5] Daggett, W., Cobble, J., Gertel, S., Color in an Optimum Learning Environment, Rigor, Relevance, and Relationships for All Students, 2008.
[6] Lawson, B., The Language of Space, 2001., Architectural Press, Oxford, 63.
[7] Spencer, C., Blades, M., Children and their Environments: Learning, Using and Designing Spaces, Cambridge University Press, New York, 2006, 98
[8] Normativi za planiranje, izgradnju i opremanje predskolskih ustanova, Beogradska zajednica obrazovanja i Gradski fond za neposrednu deciju zastitu, Belgrade, 1972.
[9] Moor G., Takemi S., O Donnell L., Children's physical environments rating scale, Australian Early Childhood Education 2003 Conference, Hobart, Australia, 2003.
[10] Stankovic, D., Svojstva prostora za boravak u funkciji psiholoskog razvoja dece, Zbornik radova Gradjevinsko-arhitektonskog fakulteta, Nis, 22, 2007, 175-180.
[11] Stankovic, D., et al. (2011.) Scientific Project "Revitalisation of the Kindergartens in Serbia – Program and Methods for Improvements of Ambient, Functional and Energetic Quality" Annual Report, Faculty of Civil Engineering and Architecture, Nis

IMPACT OF THE MODERN AGE ON THE ARCHITECTURAL COMPOSITION OF DORMITORIES

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***Abstract**: With the progress of society, science and technology, the needs of modern students have also become much more complex. Besides its basic purpose of providing a place to live, learn and work the composition of the dormitory introduces other contents of social character. The newly created rich and diverse program of activities, as well as the transformed style and a way of life, have directly influenced spatial urban-architectonic redesign and the reorganization of the dormitory composition. The aim of this research paper is to find the potential types of architectural organization of dormitories that will meet a set of newly formed students` needs, and other numerous functional requirements, which will at the same time, be in the function of sustainable student housing. The paper discusses a number of examples of existing dormitories from the architectural aspect of the organization of space, which could serve as exemplary types for the future architectural organization of the dormitories. The paper puts emphasis on defining practical solutions that will meet the physical and mental, spiritual and educational development of the student's personality, with the reference to the current standards of design and examination of possibilities for their correction.*

***Keywords:** modern age, architectural organization, redesign, student needs, sustainable capacity.*

1. Introduction

Education is the key resource of today regarding overall socio-economic development of every state. Dealing with the issue of students' accommodation for a period of few years, in which they are away from family home, is one of significant factors which influence quality of education. Seen on a global level, number of students in state and private universities and other educational institutions is rising. "Housing is an integral part of a students's academic and social life" [1]. Research has shown that majority of young people, when enrolling the university, encounters the problem of suitable accommodation, or residential space which will satisfy their needs during the period of

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their students' lives and directly contribute accomplishment of their basic goal, which is "gaining" quality education. A certain number of students earn the right to live in the dorm, while another number of students, who also have the right to live there, are being denied due to the lack of sufficient capacity or the reason of inadequate and non-stimulating residential and public space in the dorm (residential, living and work space of low quality). Dorms in Serbia were built in the second half of XX century and are dorms of rational programs, "the term rational usually referred to financial side of the problem and the quality was defined by a place to sleep and a desk" [2]. Listed existing problems indicate the necessity of finding more quality concepts of students' dwellings which would meet multiplied needs of modern students. Thus, modern age dorms should represent not only necessary living space (places), but also places of multilayered psycho-physical enrichment, intellectual rise, education and student perfection.

Basic intention of this study is directed to the research of modern student needs, defining the place for their accomplishment and analysis of social content within student inhabitation. This study especially analyses the aspects of living in private area of the dorm-rooms but also considers spaces for mutual needs, socialization and other, which have crucial role in program content of the dorm. Basic goal is creation of residential "pattern" which will meet requests and needs of XXI century students. Emphasis is on provision of more quality conditions through defining of program content and introduction of new spaces in order to satisfy numerous students' needs.

2. Shaping program content according to the function of modern students' needs

There are numerous researches on human existential needs nowadays (studying, sleeping, rest, nutrition, etc.) and the needs which regard perfection and enrichment of human values and characteristics. "Out of many needs in general – following groups of needs, whether physiological, psychosocial (belonging, friendship, unity, safety, separation-seclusion, etc) or educational and cultural (upbringing, studying, self-educating, establishing contacts, etc.) are especially distinctive and influence space structure and organization" [2]. Satisfying of aforementioned needs is influenced, among other, by the space in which human exists or is staying. "Modern students have multiple and more complex needs. In addition to demanding adequate living conditions of their personal space, students also express the following demands: spending quality time with the people from their surroundings, taking part in various cultural, educational, sports and recreational events together with those more entertaining ones... Furthermore, modern campuses include many other common facilities such as classrooms, libraries, TV rooms, social activity rooms, entertainment rooms, Internet clubs, cafes, recreational facilities not only within the construction itself but also on the premises." [3].

In order to create favourable conditions for normal development of a student, one has to create conditions and living atmosphere which the student had in their own family home. [3] According to some research it is determined "that students spend one-third of their waking hours in their rooms". [4] Total amount of time spent in students' rooms is greater than amount of time spent in any other part of the dorm. The design of the individual student room and its immediate surroundings is the key planning element in college housing. [4] Student's room is an "individual area"-space for personal needs of an individual (sleeping, relaxing, reading, work, listening to music and other activities). [2] Students want to establish a unique home territory that is fixed in space and that is the focus of those activities most important to them. The room is focal point of private and semi-private activities. For students it is "home" territory. By leaving family home and entering the dorm, student starts a different kind of life and is exposed to different social environment- he/she starts a life in a collective. While the division of living areas is flexible or even preferred during the first year of studying and living on campuses, for those senior students it is necessary to provide specific housing conditions [5]. The time of adjusting to new situation will depend on the degree of successful spatial organization and accomplished functional connections within the facility, as well as on psychological profile and characteristics of a young person. In order to "overcome" this transition phase, it is essential to establish functional and creative, inspiring environment, or the environment which will, with its tangible, visible characteristics, include and activate young person-student. "Life in a group or life in a collective implies that spatial organization and content-solutions creates conditions which would satisfy both individual and collective mutual needs so they do not jeopardise each other." [2] Process of socialization and introducing modern student into collective of the dorm, occupied with numerous technical-technological achievements which direct student to individual residence and private space of the dorm, is accomplished by including space for interaction and space for mutual activities.

Inventory of social contents that appear in dorms built in XXI century is more complex and rich. In order to satisfy mutual needs in the dorm, it is necessary to provide flexible spaces which will be suitable for current students' demands. Unique functional and adaptable spaces such as facilities for students' gatherings- parties, performances, displays and other activities, would greatly contribute more quality staying in the dorm. Spaces for recreation and various types of sporting activities are somewhat novelty in comparison to the dorms built in XX century. Modern student, who lives „a fast life", is in need of suitable spaces for relaxation and rest. Special groups of students demand for introduction of contents into basic composition program of the dorm which will meet their specialized study programs and activities. This especially refers to students at art universities (music, art, applied and performing arts), architecture and other, for which it is necessary to create spaces for their primary student work and activities. This group of facilities includes facilities for listening and „creation" of music, drawing rooms, rooms for painting and sculpting, workshops, as well as facilities adapted for drama activities.

Rich and economically developed countries and societies can meet all mentioned requests and needs of student population. On the other hand, developing countries can meet these demands only to some extent. Valorisation of basic specialized facilities that are significant for introducing into dorm composition should be conducted within forming of project task and defining of program content.

3. Transformation of dorms' architectural composition

"Student's residence belongs to the category of special collective residence. This specificity is consisted of: definition of user category (age structure of students in dorms is 18-26 years of age), relatively short staying in the dorm (4-6 years) and the concept of residence oriented and subordinated, primarily to demands of intellectual work." [2] Architectural fund of dorm facilities designed and built within second half of XX century is the result of "prevailing" financial conditions and socio-economic situation. Analysis of certain number of those facilities has shown imperfections in space which should satisfy "higher level" needs. Social contents within these facilities are not sufficiently present, while in some are completely excluded, by which the dorms are reduced to residential care of students. In contrast to older construction fund, modern dorm, apart from basic needs (sleeping, studying, work), should, by its spatial frame and program, also provide accomplishment of other needs (physical and emotional, social and cultural). Model of modern student residence includes, apart from basic factors or private space-individual territory, other factors such as semi-public and public sections of the dorm. Changes in everyday functioning and way of life, arising as a product of perfected and developed community, have conditioned the transformation of dorm's space. Social contents are usually found on ground and last floors of the dorm, while residential area is in-between. Combination of residential and public contents of the dorm is also possible. Basement includes drive units, economic-service blocks, garaging (for cars and bicycles) and similar contents. In some cases, basements contain designed small and big halls for various types of activities (shows, music performances, parties, cultural events and other manifestations).

Relation towards people with special needs is raised to a much higher level, thus adapting and adjusting modern dorm space (physical elements for elimination of horizontal and vertical barriers).

According to aforementioned, existing dorms that were mainly used for residence need to transform, adapt and reuse certain spaces, in order to meet numerous needs of modern student. Future architectural practice demands obligatory introduction of various contents which will meet the needs of modern students.

Continuation of this work shows positive examples of construction practice with the aim of emphasising the significance of a dorm with rich and complex content for the life of students.

3.1. Dorm- My Space, Trondheim / MEK Architects

Designer solution of architectural studio MEK architects, of the dorm called My Space, is the realisation of a brainchild and an idea of architects on creating a facility for student residence as social network where dorm users (116 residents) depend on each other (Fig.1). The facility with storeys (Po+P+5) was built in Trondheim, Germany for the needs of Norwegian University of Science and Technology in Trondtheim. Basement of the facility consists of technical facilities and a garage. Functional organization of basement area has dominant contents of public character, while first floor is the combination of mutual facilities and residence units. Other floors are exclusively residential.

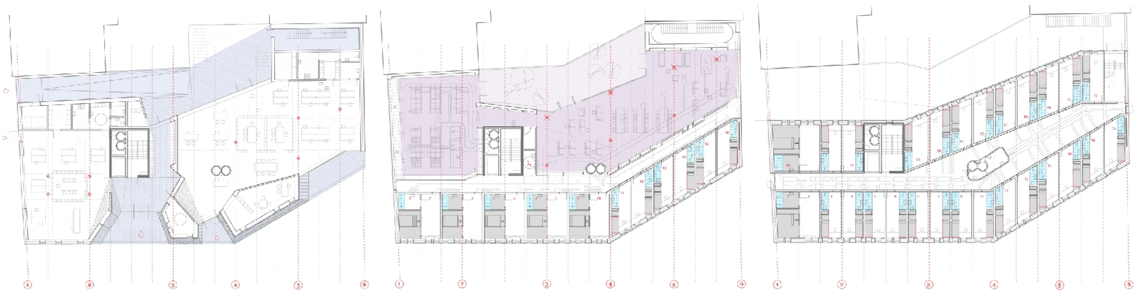

Fig. 1. Base of the ground, first and second floor of residential facility for students- My Space [6] (http://www.pichaus.com/all-architecture-residential-slideshows-enrique-krahe-housing-murado-&-elvira-@2eab5c11ead555759a0ac69b839be23a/)

Instead of grouping program content of public character into functionally separated spaces, designer team decided to create large flexible social areas available to all students, or the areas that unite those students. With the aim of providing community led atmosphere, they have created flexible salon and "ultra-kitchen" for self-service, designed as an experimental space for use and relaxation of 116 students which can also be used for social activities such as competitions and cooking seminars. This type of structuring mutual facilities, through collective actions as the means of strengthening the bonds within newly founded community, encourages residents to create rules for functioning, stimulates their responsibility and ways of balancing their own interests. The facility can be seen as unfinished structure which demands from residents to finish it. This is primarily done because of their exploration of space and adapting to their current needs, which they accomplish together within the community and with other students. Hall communication of the first floor is the divider between residential units and the salon used for mutual gatherings, work and group studying. The second and the third floors consist only of residential units, based on irregular hall communication in shape, which has an additional function- informal gatherings and socializing of residents, accidental meetings and communication.

3.2. Tietgen Student Hall (Tietgenkollegiet)

Famous and awarded dorm Tietgenkollegiet, known as imposing round building with inner yard of massive dimensions, is located in Orestad, newer county in Copenhagen, Denmark (Fig. 2). Construction of the facility was completed in 2006, based on designer solution of architectural studio Lundgaard & Tranberg Arkitekter. The dorm facility, with all necessary contents for undisturbed lives of students, is designed as a facility consisted of seven floors with capacity of 3600 rooms for students. The architects have created space for student community as a whole and for every individual student with identical emphasis on individual residential units and mutual public contents such as kitchens and salons for gathering and socializing of residents.

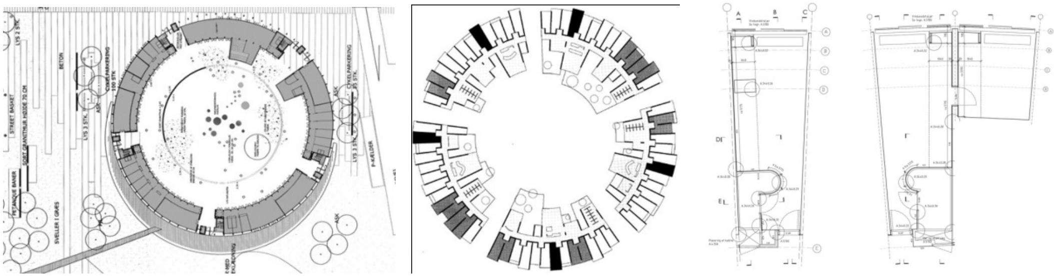

Fig. 2. Parterre solution; base of standard residential floor of the dorm and student’s room (http://www.dac.dk/en/dac-life/copenhagen-x-gallery/realized-projects/tietgenkollegiet/)[7]

Main, cylindrical shape or the mass of the facility is divided into 5 vertical segments which divide the facility, both visually and functionally, onto parts (figure). These segments enable approach to central yard and residential floors of the facility. Unlike most dorm funds across Serbia, in case of this dorm, program content referring to public contents is significantly more complex. Contents that are mutual for personnel and dorm residents are grouped in the ground floor of the facility. The ground floor primarily includes public contents: coffee bar, auditorium, study and computer halls, workshops, reading rooms for studying and research work of students, laundry, music rooms and meeting rooms, as well as parking space for bicycles. This floor has a designed hall consisted of a salon and a large hall that can be divided in two separate rooms. These facilities, when integrated, enable holding large entertaining activities for students, or, when divided, holding three smaller events at the same time. Within standard floors, 360 residential units are organized around the rim with the views on surrounding environment, while mutual functional spaces, such as kitchens, utility rooms, mutual staying and balconies are oriented towards inner yard. Each facility floor, within functional frame, includes five segments, each with twelve residential rooms and accompanying contents.

This dorm has provided satisfaction of needs for students of various faculties. For example, for the students of music academy they have designed a space consisted of two music rooms (one with a piano and the other with drums). For recreation and maintenance of physical health they have foreseen a gym and open spaces for activities such as basketball, etc. In order to encourage students’ interaction and their socialization, they have designed open spaces- mutual balconies.

This dorm is exemplary not only in sense of shape but also in sense of rich and successfully achieved program content and functional connections within.

Conclusion

Dorms, regarding the significance they have for the development of education and specialization of students, demand special designer attention and approach. "Designing of dorms essentially involves dubious analysis of students' needs and aspects of collective residence." [3] Needs of modern student, which student dorm has to meet with its program content and correct architectural organisation of contents, are various and largely multiplied. According to increased needs, program content of dorms is transformed and adjusted to the needs of modern student. Thus, within a composition of the dorm, apart from most significant factor- student's room (private space), there are numerous public contents or spaces for various types of social activities and specialized spaces for individual activities regarding study programs. Therefore, in the future design practice it is imperative to predict beside comfortable residence units equipped with all the elements that will meet the personal needs of students (including students with special needs), also the facilities of social content.

REFERENCES

[1] Neuman D. J., Building Type Basic for College and University Facilities, John Wiley &Sons, 2003.
[2] Cekić N., Studentski domovi u Srbiji, Građevinsko-arhitektonski fakultet, Univerzitet u Nišu, 1996.
[3] Kostić A., Dačić M., Cekić N., Arhitectonic Spatial Organization of Student Dormitories ICAR 2012, International conference on architectural research, Bucharest, 2012.
[4] Gutman R., People and Buildings, Transaction Publishers, New Jersey, 2009.
[5] William J. Zeller, Eric D. Luskin. Student Housing Design in the Digital age, SCION
[6] www.pichaus.com
[7] www.dac.dk

MEMBRANE STRUCTURES ON CULTURAL AND EDUCATIONAL FACILITIES

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Abstract: *As one of the most attractive structural systems, membrane structures are often used as roof structures for public facilities. Their greatest structural advantage is their low self-weight. The combination of double curved form and internal tension forces allows them to span large distances. This paper analyzes four structures built for cultural and educational purposes. Certain advantages and disadvantages of the membrane structural system are also pointed out through this analysis. The analyzed buildings are selected from across the world, and they show the possibilities of using membrane structures in combination with traditional structural materials. The function of the membrane varies: from application on the façade to secondary and primary roles on the roof of the structure. The spans covered by these membranes range from several meters to a few tens of meters. Due to the high cost of the membrane structures their application always adds a certain amount of exclusivity to the building.*

Key words: *Membrane structures, cultural facilities, educational facilities, double curvature*

1. Introduction

Membrane structures are often used for covering of public facilities. This relatively new structural system is characterized by double curvature, large spans, relatively short life span, high prestress forces and high deflections [1]. It is very economical, since it uses the least possible amount of material to cover a certain area. This is achieved by minimal surface forms and material thickness of only about 1 mm. The result is a structure with the self weight of only about 1 kg/m^2 [2]. The production process of the material is still expensive, making the overall cost high, which slows down the wider use of membranes. This is the reason why they add a certain amount of exclusivity to the building. The process of design and analysis of the membranes is complicated and not yet regulated by standards, so various methods and software are used, which leads to different results for

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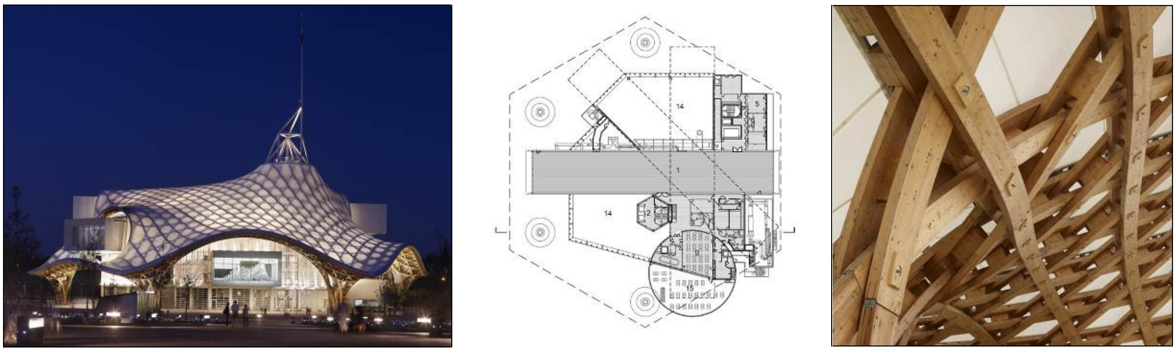
the same structure [3]. Formfinding was the major issue that is now successfully solved by the use of computer software [4, 5].

2. Analyzed facilities

This paper shows the analysis of four buildings with membranes structures. The application of membranes varies from a double façade, to the cladding on the roof or the complete function of the roof. All of them were constructed in recent years, thus representing the state of the art in this field.

2.1. Pompidou Cultural Centre in Metz

Pompidou Cultural Centre in Metz is the first Pompidou Centre outside of Paris. The design of this project was made by the famous Japanese architect, Shigeru Ban, who was chosen among the world's best architects applying for this job. The Centre Pompidou-Metz is covered with a unique roof structure consisting of timber space grid and membrane cover. Under the roof there are three floors, which serve as exhibition spaces.



a) b) c)

Fig. 1. Pompidou Centre: a) view at night; b) floor plan; c) detail of the roof
http://www.archdaily.com/490141/centre-pompidou-metz-shigeru-ban-architects/

The main shape used for this design was a hexagon. The hexagon shape is important to the French since France has a shape similar to it. The floor plan is shaped as a hexagon with a side length of 50 meters. The roof structure is divided into hexagons with side lengths of 3 meters. During the design process it was realized that the use of only hexagons, similar to the honeycomb, results in several problems. When a space-surface structure has this shape, it is unstable in its plane. Other than this, it is very difficult to connect members in joints, since they are three-directional. For such connections steel cast parts have to be used, which add a lot of weight to the structure. Thus the design team worked out an innovative solution that solved these problems. By extending the sides of the hexagon, a small triangle between the hexagons is formed. Together with the six triangles, each hexagon looks like a six-pointed star, although this shape is less noticeable than the hexagon. The triangles give the whole structure in-plane stability. At the same time the problem with connections is easier to solve, since the joints are now two-directional. Also, the timber members can now be continuous.

The roof structure has four point supports at the edges, one point support at the high-point, and one edge support. The point supports are impressively designed as space structures, and are a continuous part of the roof structure. The form of the roof is curved, but does not fulfill the requirement for stability of the membrane structures. Membrane structures need to have double curved form with negative Gaussian curvature, which is not the case. Thus the membrane on the roof of the Centre Pompidou-Metz does not have support role primarily, but is used only as a cover supported by the space grid structure.

Instead of the membrane, many other cladding systems could have been used. The span is about 6x6 meters which does not exceed the standard for traditional claddings. However, even when used only as a skin, membranes have advantages over the traditional systems. They adapt much better to the shape of the supporting structure, thus creating a smooth surface. They are also translucent and provide diffuse lighting of the interior space. The self-weight of the membrane is extremely low, so they add little weight to the support structure. The only alternative considering the self-weight are pneumatic structures made out of ETFE. They are lighter than membranes, and they are transparent, but are dependent on electricity to keep the inner pressure high.

It can be concluded that the application of the membrane over the space grid supporting structure for the Centre Pompidou-Metz was a complete success. During the day this structure looks attractive due to its curved form, and the proper selection of building materials. However, at night, when the building is lightened from the inside, seeing it from the outside is a breath-taking experience.

2.2. King Fahad library

King Fahad library is one of the most important cultural institutions in Saudi Arabia. This building is located in the most developed part of Riyadh, on the intersection of two major boulevards. The library was originally built in 1980 and later did not fit its urban surroundings. It was therefore decided to reconstruct this building. The project was done by Gerber Architecten, and in 2013 it was open to public. The same company is doing a project for a nearby metro station that will complete the picture of Riyadh as a modern and progressive city.

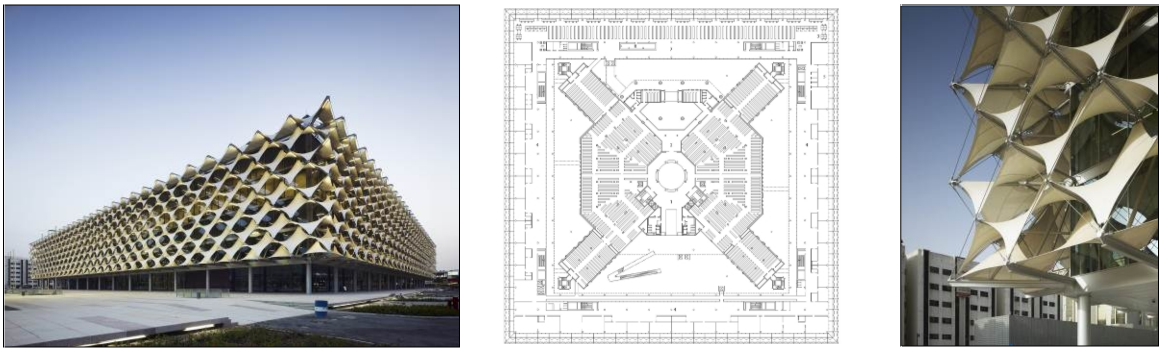


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Fig. 2. King Fahad library: a) view from the street; b) floor plan; c) detail of the facade
http://www.archdaily.com/469088/king-fahad-national-library-gerber-architekten/

The floor plan of the old library building had the octagonal shape, four stories, and a reinforced concrete dome in the middle. The reconstruction project was fairly radical, and proposed the construction of a new building around the existing one, thus creating a building in a building. The new building has the shape of a square with the side of 120 meters. The old dome was demolished, and a glass dome of the same size was built. The roof of the new building covered the roof of the old one, thus creating one more floor. The old building is now used as a storage space for books, and its roof is now a reading space. The space for women only is provided on the first floor. The main entrance is on the ground floor between the new and the existing building. The new building acts as a double façade, which improves the energy efficiency of the whole structure.

However, the façade of the new building is designed as a double façade. This means that this building has a triple façade. The outer layer of the façade is designed as a membrane structure. This serves as a good example of membrane application on the facades. In this particular case, membranes are used in a very interesting and innovative way, and are divided into smaller elements than usual. Contrary to this, there are examples where the membranes on the facades are used with their maximal spans. In these cases, the interior is protected from the sunlight, but there is no visual connection between the interior and the exterior. On the façade on King Fahad library something that was thought impossible was successfully carried out. The façade lets in as little as 7% of the sunrays in the worst case, when the sun is at its low point, while at the same time the visual contact between the inside and the outside is not obstructed. Sun protection is especially important in this part of the world, since the outside temperatures are often over 50 degrees Celsius. In order to create a static façade with such good properties, it was necessary to use specialized software for insolation and for optimization of the form of the membrane structure on the façade. Membranes on the façade are approximately 3x3 meters in size, and look like quadrilaterals, although they are actually double curved hexagons. They have two fixed edges, and two point supports. The depth of the façade is about 150 cm. Membranes are arranged in 8 horizontal rows overlapping by half of the height. The cable net is used as a supporting structure.

2.3. Skysong

Skysong is one of the most attractive membrane structures in the world. It is located at the University of Arizona campus in the USA. It covers one of the crossroads in the campus. Nearby there is the Innovation center of the University. Skysong does not have a particular function other than being a magnificent space sculpture. Even though it covers a large area, it doesn't really provide protection from the sun or the rain. Its significance is in welcoming the visitors to the campus with a strong impression of weightlessness.

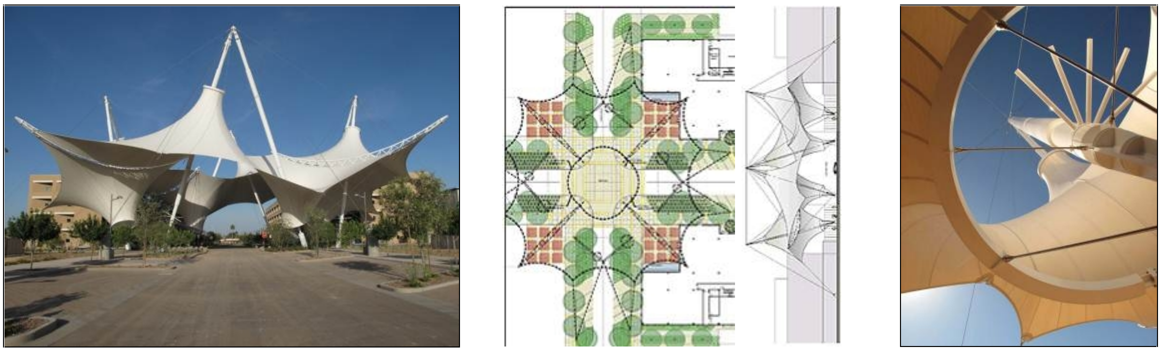

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Fig. 3. Skysong: a) view from the street; b) plan; c) detail of the roof
http://www.archdaily.com/31562/skysong-at-asu-campus-ftl-design-engineering-studio/

The sculpture is actually the structure itself. It is free from any redundant details, and owes its attractiveness primarily to its form. The color is white, like in many other membrane structures, so the attention is not drawn away from the form. The only visual supplement are the shadows from the sunlight, which always make these forms more dramatic. However, a thorough analysis of this structure reveals some unexpected information. The structure is actually not that complex. It consists of four A columns, arranged so they form a square. A very similar concept was applied to the structure of Rosa Parks transit center in Detroit, where the same type of columns was used, but arranged in a linear fashion. It is striking how the two different arrangements of the same elements can have such different visual results. While the structure of Rosa Parks transit centre appears perfectly in order, Skysong looks almost chaotic. The height of the columns is 35 meters, and they weigh 1200 kilograms each. A membrane cone is hanged on each of these columns, alternately one with the high point and one with a low point.

The structure covers the area of 80x80 meters, but has a circular opening in the middle with the diameter of 15 meters. This opening is not the designer's wish, but a structural necessity. During the early years of membranes, Otto Frei realized that this central part of high-low membrane structures is unstable. This happens due to the low curvature which results in high deflections, and consequently causes ponding of water and snow in this area. The best solution for this problem is eliminating the central part of the structure and making a structural opening. The structure of Skysong has one extraordinary solution. Prismatic trusses are used for edge supports, but they are not supported by the columns. They are hanged by cables from the tops of the adjacent columns, which produces a special impression of lightness, and it seems they are hovering above the ground. Still they provide the necessary support for the membranes. Stabilization cables had to be added since the columns are not interconnected by beams. Also the edge cables had to be used on every edge. Stay cables are grouped so the obstruction of the ground communication is minimized.

2.4. Sun Valley music pavilion

Sun Valley music pavilion is located in Sun Valley, Idaho, USA. This building has been erected in less than 12 months, and was put in use in 2008. It consists of two parts, one of which is a retractable membrane structure that is in use during summer. There are about 1500 covered seats, and 2000 more are out in the open. The fixed part of the structure covers the stage and the facilities behind it. This part of the structure is also very interesting, although it is less attractive than the membrane structure in front of it. The supporting structure consists of two truss arches. The arches have two upper and two lower chords, and they are rhombus in cross-section. The arches have the same supports, but are tilted in different directions. The lower arch is almost horizontal, and has additional supports. The higher arch is tilted by 60 degrees, and serves as support for both the retractable and the fixed part of the structure. Its longitudinal section is a parabola, which is defined by the thrust line of the arch [6]. The space between the arches is covered by the cable net roof. Cable nets are very similar to membrane structures, but have to be covered with additional cladding. In this case the cable net is covered with timber panels. The fixed part of the roof has a saddle shaped form.

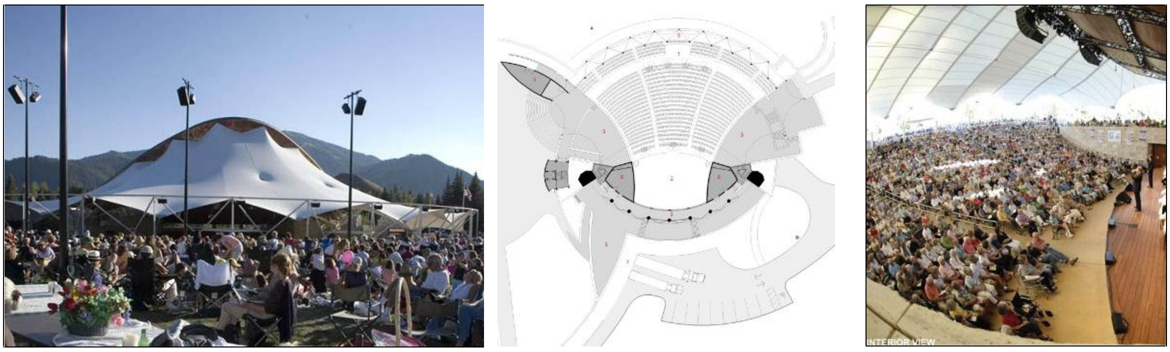

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Fig. 4. Sun Valley Music Pavilion: a) front view; b) floor plan; c) interior
http://www.archdaily.com/33982/sun-valley-music-pavilion-ftl-design-engineering-studio/

The retractable membrane structure serves as a cover for one part of the seats. It has a general saddle shape with minor deviations. On one side it is supported by the arch truss, and on the other by the steel structure which had to be added on the outer side. The span of the membrane is large and without any internal supports so the spectators have an unobstructed view from the covered seats. However, the seats outside the membrane have a much lower visibility.

Since Sun Valley is a famous ski center, the idea was for the truss arch to represent the mountain, and for the membrane structure to represent the slopes. The fact that this is a high altitude area has certain downsides. Most importantly, the snow load is much higher than usual. In this specific case, up to seven times higher than average. This is the main reason why the membrane structure is designed as retractable. It is opened and closed only once a year, unlike the membrane retractable roof over the Wimbledon central court, for example. One of the major problems of membrane structures in general are high deflections under external loads. These deflections last only as long as the external loading is applied, but are much higher compared to the traditional structural materials. In certain cases, the allowed deflection can reach even 1/10 of the span. There are several possibilities for reducing these deflections, but the most effective one is increasing of the membrane curvature. Since it was not possible to achieve a high curvature in Sun Valley, the designer decided to retract the structure during the season of high loads. Other options for reducing deflections are the use of rigid edge supports and the increase of prestress values. Since this membrane structure is used for covering of a music pavilion, it is expected that the membrane has good acoustical properties. Researches showed that the acoustics of this space is excellent. The design team proudly promoted Goethe's idea that "architecture is frozen music".

Conclusion

The four analyzed buildings show the variety of both the use and spans of membrane structures. The spans range from just a few meters up to one hundred meters. The combination of their beautiful forms and supreme structural properties always attracts the attention of the passers-by, regardless of their interest in architecture. Membrane structures are a yet unsurpassed bond between architecture and engineering. It is likely that their properties will be perfected and the cost will go down, since the production process is improving rapidly. However, the question is: if they become widely available and widely used, will they become monotonous?

REFERENCES

[1] Milosevic V., D. Kostic. The problem of large deflections in membrane structures. Proceedings of IV International Symposium PhIDAC 2012, Nis, 2012, 388-394
[2] Forster B., M. Mollaert. European Design Guide for Tensile Surface Structures, Tensinet, Brussels, 2004, 354 p.
[3] Gosling P. D., et al. Analysis and design of membrane structures: Results of a round robin exercise, Engineering Structures, 2013, Vol. 48, 313-328
[4] Bridgens B., M. Birchall. Form and function: The significance of material properties in the design of tensile fabric structures, Engineering structures, 2012, Vol. 44, 1-12
[5] Bletzinger K.U., E. Ramm. Structural optimization and form finding of light weight structures, Computers and Structures, 2001, Vol. 79, 2053-2062
[6] Milosevic V., B. Milosevic, N. Milosevic. Thrust line dependence on the load and sag, Proceedings of Savremena dostignuca u gradjevinarstvu, Subotica, 2014, in press

MEMBRANE STRUCTURES ON SPORT AND TRANSPORT FACILITIES

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Abstract: *This paper presents a research done on covering sport and transportation facilities with membrane structures. In their relatively short history, membrane structures have found the best application on sport facilities. Stadiums are especially suitable for covering with membranes since the advantages of the membranes are fully utilized, while there is no need for thermal insulation. Transport facilities are included in this research as the type of buildings most frequently covered with membranes. Building membrane structures requires the least possible amount of material, which works as both cladding and structural support of the roof. Four characteristic examples of membrane roofs are analyzed in this paper. Selected buildings have been constructed in the last five years and represent state of the art in designing membrane structures.*

Key words: *Membrane structures, public facilities, saddle shape, textile roof, tensile structure*

1. Introduction

Membrane structures are one of the most attractive and most commonly used structural systems for covering of sport facilities. They have found best application on football stadiums due to the fact that they provide low thermal resistance as stadiums are usually open. They are also often used on other sport facilities that do not require thermal insulation. Transport facilities are usually not in need of thermal protection, but they do provide protection from wind, snow, rain and sunlight. Thus, membranes can often be seen on bus stops, transit centers, parking lots, airports... When covering transport facilities, membranes usually have smaller spans, although there are exceptions, like the Central train station in Dresden. If, however, thermal protection is needed, there are a few possibilities for providing it. The most successful solution is the use of double façade, with one or both facades made out of membranes.

The main reason for the attractiveness of membranes is their double curved form with negative Gaussian curvature, obtained through the formfinding process [1]. This form is relatively unusual in architecture and thus attracts a lot of attention. This type of form is

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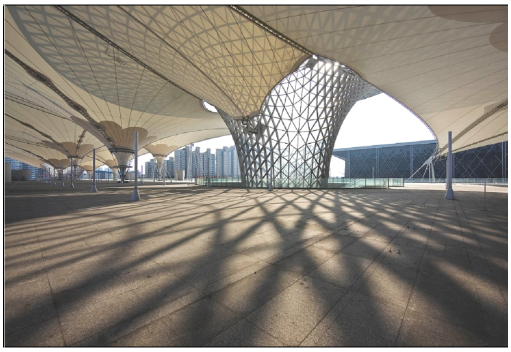
necessary for the membrane stability in the structural sense, and is dependant on supports, internal and external forces [2] and the type of membrane material used. Two most common types are PVC and PTFE membranes, with various subtypes [3]. The advantage of membrane material is that is serves as both support and cladding of the roof.

2. Analyzed facilities

Four characteristic structures are analyzed and presented in this paper. One opened pedestrian walkway, one stadium, one closed sport facility and one transport center, all built in the last few years.

2.1. Expo Axis

The World Exhibition, also known as the Expo, is one of the most important architectural events in the world. It is held every two or three years and gives the opportunity to many participant countries, especially to the host county, to show their latest achievements in various fields, where architecture plays one of the most important roles. The People’s Republic of China was honored to host the Expo in 2010. After the spectacular Olympic Games in 2008 held in Beijing, this event allowed China to once again demonstrate its growing influence in the world. It is important to mention that there is a longstanding rivalry between Shanghai which hosted the Expo, and Beijing which hosted the Olympics. For this reason, enormous financial recourses were invested in organizing the Expo in Shanghai. Now that it is over we can conclude that this was justified since it significantly improved the reputation of Shanghai and China in the world.



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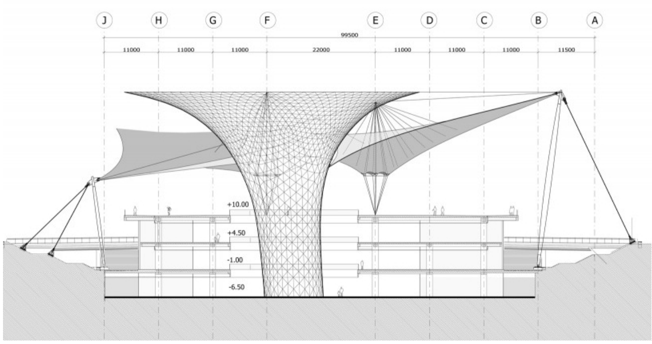

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Fig. 1. Expo Axis: a) view from the walkway; b) cross section
http://www.archdaily.com/57749/shanghai-2010-boulevard-knippers-helbig/

Membrane structures and the World Exhibitions have a long common history. At the Expo in Montreal in 1967 the German Pavilion was covered with a membrane which became the first famous membrane structure in the world. Since than almost every Expo gave the primary or one of the most important place to membrane structures.

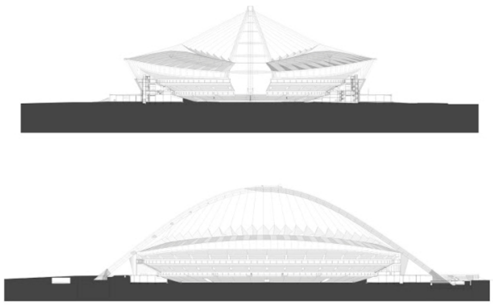
One of only four buildings that has not been demolished after the Expo, is the Expo Axis. This structure is really the axis of the area where the Expo was organized. It is located between the three major parts of the exhibition and serves to interconnect them. Expo Axis is a three story building whose main function is to be a pedestrian walkway. The third story allows the pedestrians the view to the whole exhibition from high ground. The stories are made of concrete, and the cover is a unique combination of membrane and space grid structure. The roof structure is 100 meter wide and 1000 meters long. The space grid structure has an inverted cone form, and is divided into a triangular network. The membrane structure has a similar shape, and is structurally independent from the space grid structure, although they make one entity in the visual sense. What is extraordinary about this membrane structure in the structural sense is its huge span. To cover this span the thickest and strongest membrane material was used. In certain parts the material had to be doubled, which results in less light translucency in these areas. Columns with stay cables are used for the supporting structure. One of the requirements that had to be fulfilled is that the failure of one column does not impair the global stability of the structure. This was achieved by adding more safety cables to the structure, which was experimentally proved.

The whole structure is completely open, and the shape of the cover emphasizes this impression. A special feature of this structure are the LED lights placed on the space grid. They make it possible to broadcast shows, making the structure a video screen. This looks fascinating to the spectators, due to the size and the curvature of the "screen".

2.2. Durban stadium

Durban stadium, also known as Moses Mabhida stadium, was built for the World Championship in football in 2010. This is one of the most spectacular stadiums in the world. Its cover is a hybrid structure consisting of arch and membrane structures. It was built in only two and a half years. The building is 320 meters long and 280 meters wide, has an elliptical shape, and is 45 meters high, disregarding the arch. The stadium capacity during the World Championship was 63000, and was later reduced to 54000 seats. Stands are made out of concrete and are independent from the structure of the cover. Seats are colored in different colors in the lower part so even when all the seats are not occupied the stands do not look empty. In the higher part of the stands, the seats are colored white so they match the design of the cover.

a)



b)

Fig. 2. Durban stadium: a) bird view; b) sections
http://www.archdaily.com/44595/south-africa-world-cup-2010-moses-mabhida-stadium-gmp-architekten/

The main feature of this stadium is a gigantic steel arch that spans over the longitudinal axis of the stadium. Its span is 340 meters and the height of 106 meters. The arch serves as a support for the membrane structure. The membranes are hanged on the arch by steel cables. The membrane cover consists of 208 individual membranes. Each one of them has a rectangular shape, with one corner above the level of the other, giving it enough double curvature. From the distance it appears that the cover is actually a folded structure made out of concrete. The PTFE membrane material was used. The membrane structure covers about 88% of the seats, or 46000 m^2. On the outer side the membranes are supported by the outer compressed ring. The ring is 880 meters long and supported by 100 columns forming the façade.

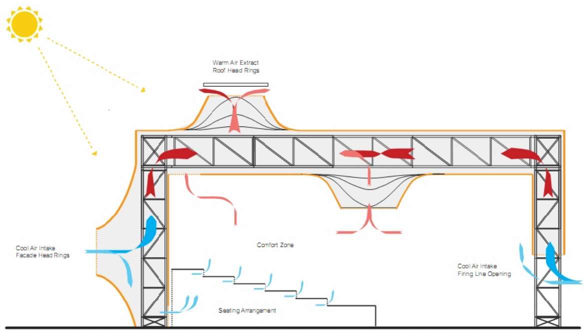
Durban stadium is similar to Wembley stadium in the use of a huge arch, but the arch in Durban is bigger, making it a state of the art in arch construction. The possibility of making such a big arch is explained by the lightness of the cover structure, owing to the low self weight of the membrane. The only issue with the arch in Durban is that it is positioned in such a way that it creates a shadow on the football field during certain hours of the day. Although the arch is very high, and the shadow is diffuse, it may still interfere with the matches.

The stadium in Durban with its huge arch is so attractive that the owner is organizing a wide range of activities for visitors. One of the most popular is the ride to the top of the arch in an escalator. Such activities are crucial in providing the financial sustainability for stadiums. The cover of this stadium plays an important role in the visual identity of the structure. With its repetitive form and neutral color, it emphasizes the dominance of the arch. The whole structure of the stadium is a great example of excellent cooperation between experts in the field of architecture and structural engineering.

2.3. Olympic Shooting Venue in London

The Olympic Shooting Venue in London is dislocated from the Olympic village and other facilities used during the Olympics. It is located in south-east London, close to the O2 Arena, which is one of the most significant buildings in the world covered with membrane structure. The shooting venue consists of three buildings with the total capacity of 3500 seats. These buildings are functionally separated, so one is used for the 10 meter competition shooting, the second for the 25 meter competition shooting, and the third one for 50 meters.

a)



b)

Fig. 3. Olympic Shooting Venue: a) view from the entrance; b) cross section
http://www.archdaily.com/244370/olympic-shooting-venue-magma-architecture/

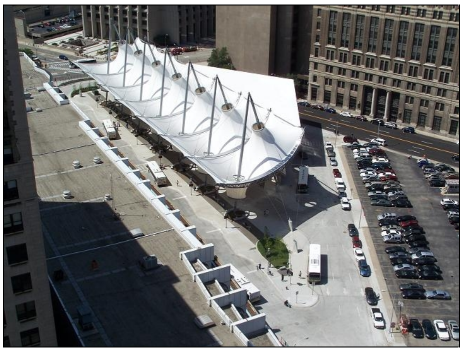
The architecture of these three buildings is unique, and unseen in the world. Membrane structures are used for both the roof and the facade. The basic forms of these structures are simple cuboids with different side lengths. The originality of this design lies in the fact that one of the main structural requirements for membranes, the need for double curvature, is here skillfully used as an esthetical element on the facade and the roof. This element is designed so it fits the function of the buildings perfectly. The cones on the facade and the roof that give double curvature to the structure are directed outwards, which undoubtedly looks like the membranes have been shot at from the inside. The "holes" are emphasized by different colors, and the membrane is realistically deformed. One must pay the tribute to the designer for representing the function of the building on the facade so successfully, both in the phase of creating the idea, and realizing the idea. This is done in a way that is not too intrusive to the observer, with minimal use of details, but with a strong impact.

The buildings differ in spans, and in colors used for the „holes“. The largest building has them colored in purple, the medium in orange and the smallest in blue. One of the main characteristic of these buildings is that they are designed so they can be completely assembled, and disassembled. The buildings are assembled for the Olympics in London, and will be also used for the Paralympics, after which they will be disassembled. They will be transported to Glasgow and reused for the Commonwealth Games in 2014. A similar concept was seen at the Olympic stadium in London, also covered with a membrane structure. A part of the stands of the stadium are designed so they can be reused in Brazil for the Football World Championship in 2014. Such a flexible structural design of public facilities is innovative and completely justified in financial and energy efficiency sense. During events the number of users is enormously higher compared to the inactive period, so the flexible capacity leads to savings, and also has less environmental impact. Further progress in creating flexible buildings can certainly be expected [4], and membrane structures will certainly find their place in this trend due because they can be quickly assembled and disassembled.

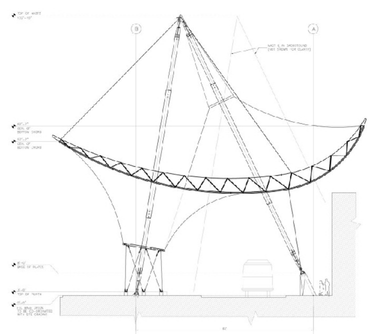
The support structure is the same in all three buildings. Steel trusses are positioned in two orthogonal directions. Stands are also made out of steel so they can be disassembled. The supporting structure is covered with membranes from both upper and lower sides. In this way, one type of double façade is created. This produces much better thermal and acoustical properties of the buildings. The double façade is designed to have a controlled air temperature between the two membranes. PVC membranes were used for the facades and the roof of all three buildings. The reason for selecting the PVC membrane rather than the PTFE membrane is the fact that it has better properties related to repeated disassembly and transport, which are planned for these structures.

2.4. Rosa Parks Transit Center

Rosa Parks Transit Center is located in Detroit. Named after the African American activist for human rights, this station plays an important role in the transportation network of the city. Detroit is well known as the center of American car industry, so everything related to transport has a special significance in this city. This is one of the reasons why such an attractive structure was selected for the design of this transit center. The design team is FTL Design Studio, the same one that made the design for the Sun Valley Music Pavilion. The covered area is about 4500 m^2, and consists of terminals and a building with amenities.



a)



b)

Fig. 4. Rosa Parks Transit Center: a) bird view; b) cross section
http://www.archdaily.com/30880/rosa-parks-transit-center-ftl-design-engineering-studio/

The open membrane structure is divided in seven identical parts. These parts consist of a double curved membrane, one A column, and edge beams. Edge beams in transverse directions are made as trusses and curve-shaped. They are positioned between every two parts of the structure, and also at the two opposite ends of the structure. Since they are not covered by membranes, there is a gap in between membranes which lets the rain and snow through the structure. Longitudinal edge beams positioned at one side of the structure impair the good impression about the structure. Their role is in providing longitudinal stability, but it seems not much thought has been given to their esthetics. They appear to be heavy and disturb the overall architectural idea. The A columns serve as supports for the membrane structure. Their height is about 30 meters, and their supports are about 20 meters apart.

The membrane structure has a very attractive and unusual shape. To get this shape two simple cones on rectangular bases were used, one pointed up and one pointed down. In such way, rainwater from both cones is collected in one place, and it can be used for different purposes right at the transit center. The span of the structure is not very large, about 15 meters in transverse and 35 meters in longitudinal direction. The two-cone shape is repeated in every seven parts of the structure. PTFE material was used for the structure. The advantages of PTFE over PVC membrane are a longer lifespan of about 30-40 years, and a higher tensile strength [5]. However, it is more expensive and harder to produce. The main reason for selecting PTFE membrane is its ability to resist dirt. Because of the top coating layer that is made out of teflon which does not hold on the dirt from the polluted air in big cities like Detroit. The downside is that PTFE membrane has the brownish color after installation, and needs to be exposed to sunlight for a certain period of time to get the final white color.

It has to be pointed out that the biggest issue about the structure of the Rosa Parks Transit Center structure is its openness. This is solely a functional deficiency, since it does not provide sufficient protection from either the rain or the sunlight. This could have been prevented by altering the form of the structure, with minor structural changes. However, the visual appearance of the structure as it is, is very beautiful. An especially nice visual effect is achieved at night when the structure is lit by artificial lighting. The light sources are positioned so they emphasize the curved form of the structure. At night this transit center becomes a visual landmark, like lighthouses used in maritime transport.

Conclusion

The presented analysis of these four structures shows various possibilities of membrane use for covering of sport and transport facilities. These facilities benefit from the advantages and minimize the disadvantages of membranes thus making beautiful, attractive and economical structures.

REFERENCES

[1] Tong L.P., Z.Y. Chen. Form-finding and structural analysis of tensioned cable-membrane roof supported by steel trusses and arches, Journal of Civil Engineering and Architecture, 2008, No. 1, 28-35

[2] Milošević V., V. Nikolić. The form-force relation in membrane structures, 3rd International Scientific Conference moNGeometrija 2012, Novi Sad, Faculty of Technical Sciences Novi Sad, 2012, 271-278

[3] Forster B., M. Mollaert. European Design Guide for Tensile Surface Structures, Tensinet, Brussels, 2004, 354 p.

[4] Milošević V., V. Nikolić. Space flexibility of multi-family housing, III International symposium for students of doctoral studies in the fields of Civil Engineering, Architecture and Environmental Protection, Novi Sad, University of Novi Sad Faculty of Technical Sciences, 2011, 195-201

[5] Seidel M. Tensile Surface Structures: A Practical Guide to Cable and Membrane Construction, Berlin: Ernst & Sohn, 2009, 229 p.

SCENARIOS FOR BUILDING OF ECOLOGICAL INDUSTRIAL TERRITORIES IN THE TOWN OF BALCHIK

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Abstracts*: In the scope of the theme is included the possibility of ecological development of the existing industrial zones in the town of Balchik. There are included an analysis for their hygiene characteristics and the degree of contamination during the years, development and planning decisions according to their geographical location and analysis for sufficiency of the hygiene requirements for health defense of the settlement environment, in which they are located. There is included a situation of all roads to them and outside them. There is included an analysis of the existing buildings and prerequisites for building or liquidation of ecological and non ecological zones and the possible criteria for them.*

Balchik is a coastal town in Dobrich region in North Eastern Bulgaria, located close to the resort complex of Albena. It is located at 45 km from the town of Varna and at 60 km from our boundary to Romania. On the territory of the town are located an yacht harbor, located close to the harbor for public transport. The Balchik harbor is ranked at third place in Bulgaria in terms of cargo traffic, after the towns of Varna and Burgas. There is located a military airport with reduced functions. The intentions in this base to be organized civil flights and its use as a military and civil airport will establish the town of Balchik as a transport knot, providing working places and a better use of the natural resources of the region. These are serious prerequisites for development of an industrial zone in the suburbs of the town, which has a historical heritage, needing rehabilitation. The process of reconstruction and the building of ecological industrial zones proceeds in several consecutive stages. (See Table 1).

The existing zone is close to main road Varna – Durankulak, which provides also a free access. There are available the three types of transport (water transport, car transport and airway transport. Disadvantage is the lack of railway transport and prevailing movent of the wind. Often there are gusts of wind from the North West (to the direction of the town), which imposes an obligatory building of well developed "*contact green border*". With it, there is separated a natural boundary of the industrial zone, separating it from the living zone, which defenses the town from the harmful emissions and diminishes the noise and the winds.

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Table 1.

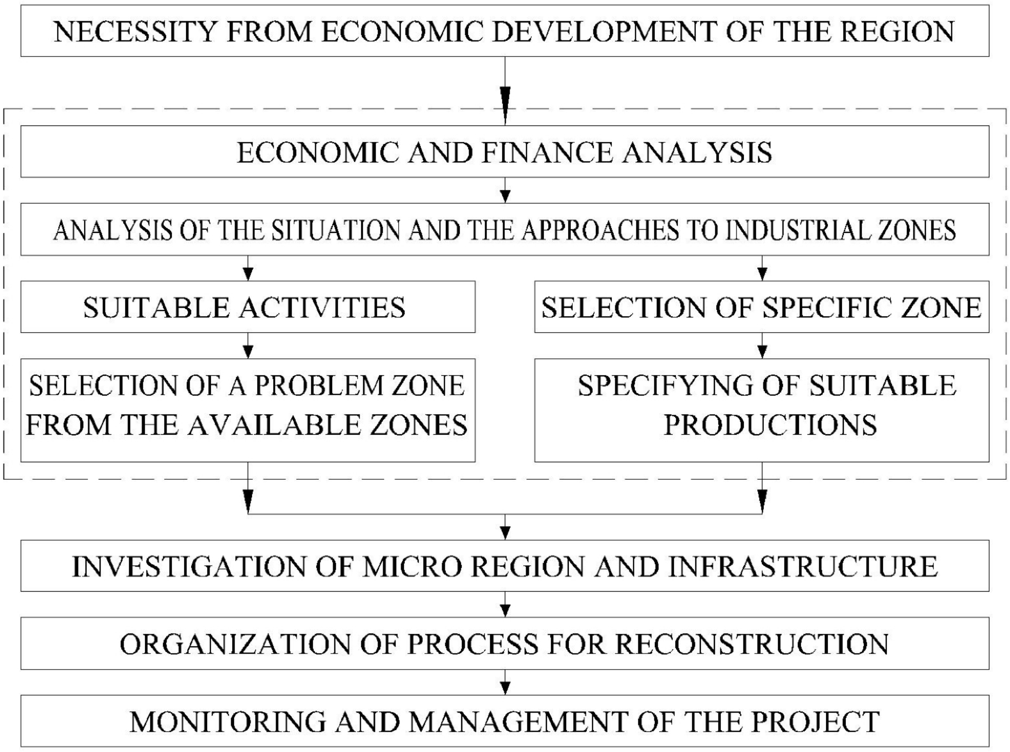

Fig. 1.

Fig. 2. Cargo harbor

For analysis of an industrial territory is necessary the setting up of subdivision for industrial micro regions, which facilitates the viewing of the buildings and their location on the territory.

Industrial micro region is an aggregation of industrial land properties. The private stewardship of the buildings makes difficult the defining of the exact boundaries of an industrial property and its scope. Because of this reason, we have conditionally divided them in micro regions.

Because of the big scope of the industrial zones in the town of Balchik, we will view only the industrial zone “Balchik – West”. There are located the micro regions, which stewardship is difficult for defining. The buildings are primarily used for storing of wheat cultures.

A detailed analyzing of the zone shows problems in functional and technological decisions, communications and location, which imposes a part of the buildings to be removed, and other buildings to be reconstructed, in order to be efficient and ecological. A certain number of buildings could be rehabilitated. This justifying is based on detailed viewing of each of the micro regions.

Fig. 3. Military harbor and Eastern living quarter in the town of Balchik

Fig. 3. Zoning of the zone

The territory of *Region 1* is foreseen for a yard of an agricultural and industrial cooperation. This is a free, unbuilt territory, serving for stewardship of the equipment of the cooperation. *Region 2*: There is placed "Fuel and Construction Materials". The buildings here are in extremely bad condition. According to the cadastre, there are many small buildings, but in fact, up to now there exists only a low, lengthened building, serving for a store house.

Fig. 4. (2.2)

Region 3: Agricultural Sector "Selected Seeds". On the territory of this micro region are located the following buildings: 3.1 (industrial building, in a bad technical condition), 2.5 (store house – in a bad condition, not well located), 2.6 (canopy – a frame building), 2.11(unmanaged building, in a bad technical condition) и 2.12(weighting machine of transport means, not well located, which supposes possible relocation). The above mentioned compromised buildings are proposed for demolition, because of their bad condition, which does not respond to the necessary requirements.

Subject of reconstruction are: 3.2 (industrial building – with well preserved construction, which gives a possibility for reconstruction; in the project decision is made a proposal for its separating as an industrial building, because of its big storey height. 3.4, 3.6 и 3.3 – to be reconstructed as store houses, as they have a suitable height, suitable construction and are located suitably for loading and unloading works) 3.3 (store house), 3.4 (store house), 3.6 (store house)

Fig. 5. (3.1, 3.4, 3.4, 3.11)

The newly built silos /2.17/ will be preserved *(5.1) (5.17, 5.16)*

Region 9: On this territory are located semi – demolished buildings (9.2, 9.3), which are unmanaged and are potentially dangerous for the people. The cauldron for brandy – 9.1 is unsuitably located, it is in a bad technical condition and is architecturally improperly built. This aggregation makes necessary the demolishing of these buildings.

Fig. 6. *(13.10)*

Region 10: On this territory are separated various ware houses and canopies, managed by a private tenant. Their bad condition and their amortized construction would lead to their demolishing. These are namely Това са именно 10.1 (ware house), 10.2 (ware house), 10.3 (canopy – garage), 10.4 (service building).

The buildings, which we view, are unmanaged buildings, because of a lack of production, which leads to outdating of the problem. There exists economic inefficiency and a lack of infrastructure or highly amortized infrastructure. The not used industrial buildings quickly acquire a kind of a decline. Getting known the potential of the industrial buildings with their adjacent areas is a challenge for their renovation and the building of ecological industry according to the living quarters, which are located close to them. The first projects for "recycling" of industrial buildings date from the middle of the 20. century. The process enters in a new stage in the 70s, after the fuel crisis. The industrial buildings begin to be considered as a means for improving of the urban environment and as a new idea decision in town developing aspect. In such a way, the labour, the means and the materials, imputed for their building are preserved and they acquire a new meaning.

The observations in this region arise the following questions:

Is it possible the building of ecological industrial zones and territories by renovation of the existing ones?

- *Industrial heritage* is a part of the national historical heritage;
- *The renovation* with achieving of environmental friendliness contributes to the town development of all neighbouring zones;
- *Ecology* – the suburban industrial zones are in harmony with the living zones, without violating of the nature;
- *Functionality* – the percent of the buildings for revitalization is bigger than the percent of newly constructing buildings. The industrial buildings, which will be renovated, can be converted in other clean, harmless industrial buildings with a new function.

Is there a clear regulation in the legislation, for building of such zones and will the state support this activity?

- From MAY, 2011 is cancelled Regulation No 7 of 1992, for the hygiene requirements for health defense of the settlement environment. With this is stopped the preparing of expertises of this type.

Is there a perspective for development of industrial ecological zones and territories in Bulgaria?

- The perspective to be built industrial ecological zones in not a novelty. The main task for the development has to be preparation of a program for phased renewal and development.

All of this is connected with the innovations to the renewable sources of energy and in such a way will be stimulated the entrepreneurs or the state to renew these zones. Example for this are the building of BIOGAS installations, photovoltaic and geothermal installations, which can be applied for each production.

REFERENCES

[1] Sivrev L., The Bulgarian Industrial Architecture, Observed in 1980 – 81, Varna Free University "Chernorizetz Hrabur", University Printing House, 2012.

[2] Sivrev L., Industrial and Transport Buildings and Complexes, Module 2 , Varna Free University "Chernorizetz Hrabur", University Printing House, 2013.

ESSENCE, BENEFITS AND FACTORS OF POLYCETRISM. THE CASE OF SOFIA (EXAMPLES OF VITOSHA, KREMIKOVTSI AND NOVI ISKAR)

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Abstract*: Polycentric urban development has quickly become a widespread paradigm in regional policies perfection of different spatial urban structures. Problems of polycentric systems that formed in the cities are the subject of many scientific developments of the last few decades. Instead of traditional redistributive policies of the features of the 1960s and 1970s, the concept of polycentrism emphasizes the internal potential, development of regional capacity to organize activities, equal treatment of all parts, equality and approach of nuclear-centered system rather than strict zonal approach [1].*

Key words*: Polycentrism, Sofia, Vitosha Region, Kremikovtsi Region, Novi Iskar Region*

1. Essence of polycetrism

According to some studies, polycentrism is considered primarily a generator of urban synergies through cooperation between cities and urban areas [2]. In the same papers, polycentrism is reduced to a concept aimed at balanced regional development (cohesion), economic growth (competitiveness) and managing the expanding urban development policies (governance). Hence the role of polycentrism as modern solution to the spill and urban sprawl. The ideas of polycentrism are considered as a new form of development of the monocentric city with opportunities to solve its main problems posed by high density and the difficult access to the historic city center and the ever increasing distances to the periphery. However, the term 'polycentrism' does not have a single and unique sense as it can be interpreted in different ways, depending on the context and scale, in which it is used. Thus, it can acquire different meanings depending on the different consequences that it supposes [3]. Polycentricism may be considered at low planning level as an opportunity by building subcenters to achieve spatial organization of the chaotic city dispersion [4]. Hall and Pain [5] believe that politsentralization which is discussed on a higher macro level of large urbanized parts of the world, arises through a long process of very extended decentralization of major central cities to the adjacent small, old and new. According to some authors polycentrism is a grouping of different phenomena in the urban environment subordinate to morphological and functional dependencies [6]. Causes of sprawl are looked for in the development of many key sectors which lead to the formation of specialized

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subcenters for consumption of culture, entertainment, etc. [7]. The development of a system of nuclei or polycentric subcenters enables a combination of various functions that may be concentrated at the periphery and to form a high density around itself [8]. Understanding of polycentricism is sometimes presented in different contexts depending on the scale of the city as Giffinger [9] places at the base of a polycentric system nuclei-nodes that are interconnected through functional relationships. The same author seeks other dependencies of micro (in the city) and macro (amongst different cities) levels to improve mutual interests between the center and the periphery in order to achieve a synergistic effect. Hence an essential element of polycentric development becomes the interconnection and complementarity between the different levels of polycentric development [10]. Veneri and Burgalassi [11], in turn, see the concept of polycentricism in two aspects: as morphology of urban development, covering the size of the city and the population as a functional feature defining the distribution of activities on polycentric systems. The analysis of these urban systems is inevitably associated with commuting to the main city center.

The possibilities for direct urban mobility exactly determine the significance of these subcenters in the urban structure and form them as attractive for their inhabitants [12]. Some authors believe that sprawl can have four main dimensions: low density of occupation of large areas, strict separation of home from work, the network of roads and difficult access to the main center, and the lack of well developed and defined subcenters [13]. Others think that they can identify six main causes of urban growth: the density of an urban area; aesthetic justification for common development pattern of an urban area; dependence on road transport, leading to the spatial mismatch between the home and workplace and reducing the quality of environmental protection; the influence of local government and the lack of planning; existing models of urban development in areas of the city as well as the natural process of growth of the city [14]. According to some scholars, a polycentric city includes six main elements: the existing, traditional business core, secondary core business; tertiary business core, peripheral town and specialized centers [15]. Spatial relationships within the cities can take many different forms, such as commuting or traveling for business purposes. Spatial organization of each of these functional links is not necessarily identical with the other and therefore polycentricism may occur based on the analysis of one type of functional coupling and monocentrism based on the analysis of a different type functional relationship [16]. Some researchers argue that decentralization of polycentric systems will help bring the commercial activities to large residential complexes and reduce travel distances, but the figure of the car as the main cause of urban sprawl should not be underestimated [17]. Reporting on the importance of daily commuting is an important point in the study of Knaap et. al. [18] where it is considered that economic development should be linked to housing policies that encourage the development of residential functions within the transit roads. Urban sprawl is examined by many authors who propose measures for the measurement of various indicators, which take into account the increase of urban areas. For example, Song and Knaap [19] note that urban subcenters continually increase, and they propose measures for the measurement of this process, such as the configuration of the streets and the traffic system, mixed-use land and the pedestrian access. From all of the above, it could be argued that cities are 'engines of growth'. Cities are places where, for a variety of reasons, people do the best things they are capable of. There is still much to learn about the variability of urban forms, such as polycentricism, how and why it evolves and why it is so important for cities [20].

In the case of Sofia, the Mater Plan of the city as a tool for implementation of modern urban policies also considers the importance of the concept of polycentric development. It is integrated into the plan as a desire to find a balance in the development of the compact city (historic core) and periphery (suburban areas). Three urban regions will be examined: Vitosha, Kremikovtsi and Novi Iskar, for which there is available urban data (Fig. 1). They report the largest new urban areas and their functional composition, the pivotal center position and possibilities for decentralization. In the context of the specificity of the development of Sofia and the Master Plan previsions precisely those features are outlined that appear as a new urban environment (Figs. 2-5). Thus, determination of the nature of polycentric development in the case of Sofia, will be led by several key factors, which take into account the available research on the issue and the data that the study is ensured with, namely:

- Proximity of the regions to the compact core.
- Existing specific natural features.
- Existing specific functional characteristics of the regions.
- Various functional composition in the regions.

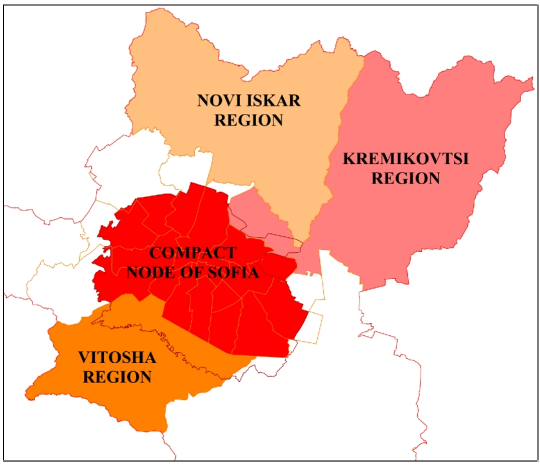


Fig. 1 Scope of the study, Vitosha, Kremikovtsi and Novi Iskar Regions and their relationship with the compact core of Sofia

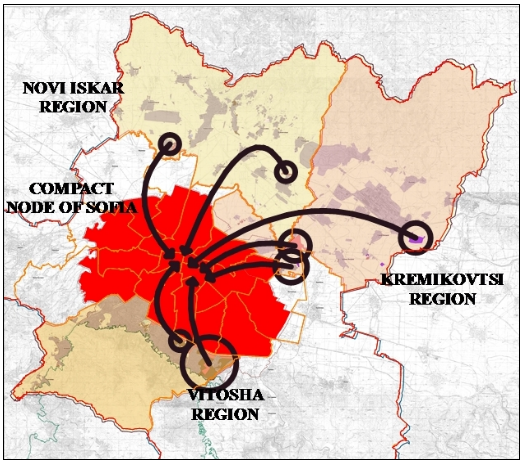


Fig. 2 Scheme of formation of polycentric systems in the new urban areas in the regions and their relationship to the compact core

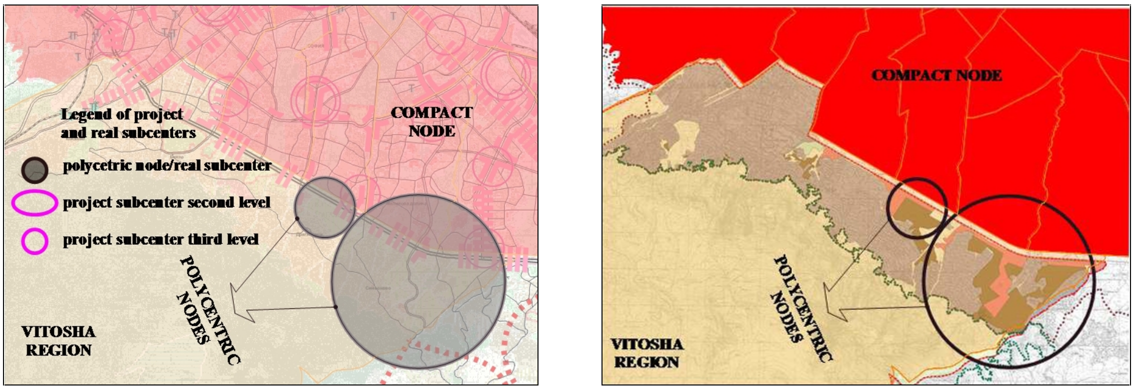


Fig. 3 Schemes of new urban areas in the period 2006-2013 in Vitosha Region and their relation to the previsions of the the Master Plan

2. Benefits of the polycentrism for sustainable urban development in Regions Vitosha, Kremikovtsi and Novi Iskar

As a modern concept of sustainable urban development, polycentrism has its advantages noted in the extensive literature on the subject. For example, Aguilera and Mignot [12] consider that a polycentric development model in which jobs in and around functional mixed subcenters, succumbs more readily to the organization of mobility, especially by repeatedly reduction of commuting. Moreover, they believe that the emergence of a polycentric structure will be an important point regarding mobility and sustainable development of the monocentric city as a whole. In the case of Sofia and the areas of research it can be noted that the emergence of new urban areas with mixed functional characteristics happens mostly around the entrance and exit roads of the city, which facilitates the development of polycentric structures (Fig. 6).

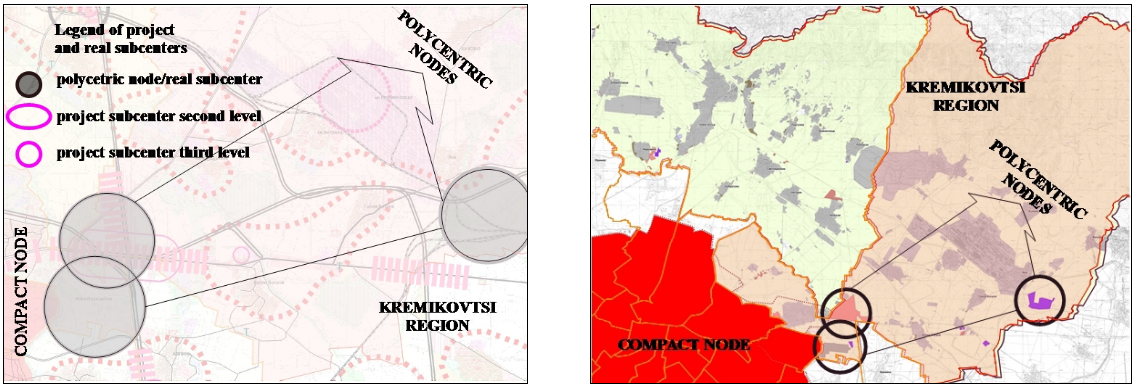


Fig. 4 Schemes of new urban areas in the period 2006-2013 in an area Kremikovci Regeion and their relation to the previsions of the the Master Plan

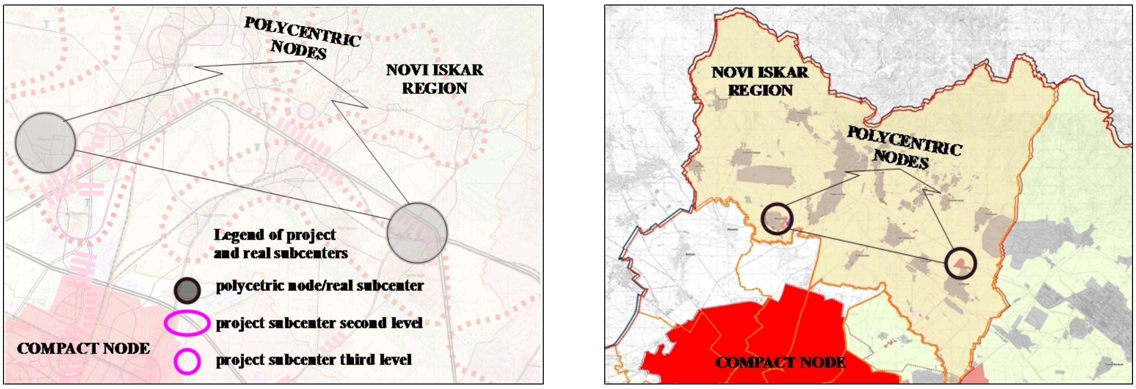


Fig. 5 Schemes of new urban areas in the period 2006-2013 in Novi Iskar Region and their relationship to the previsions of the the Master Plan

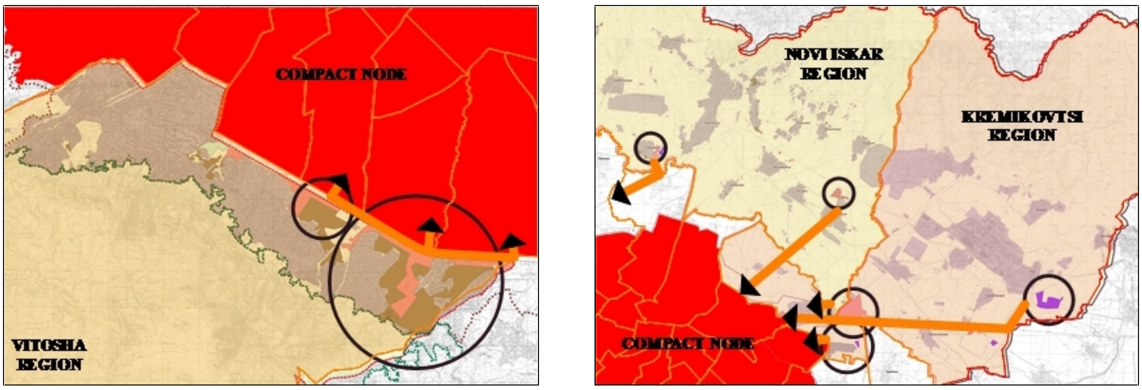
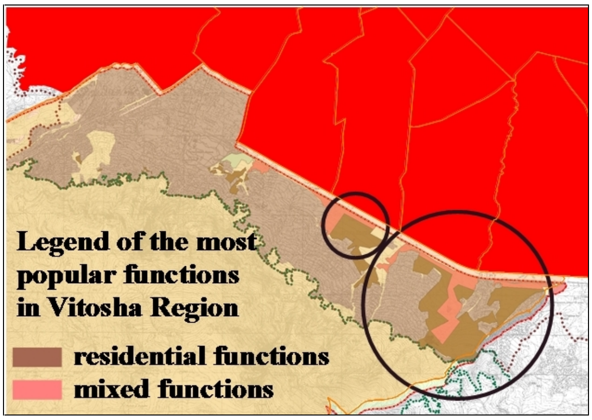
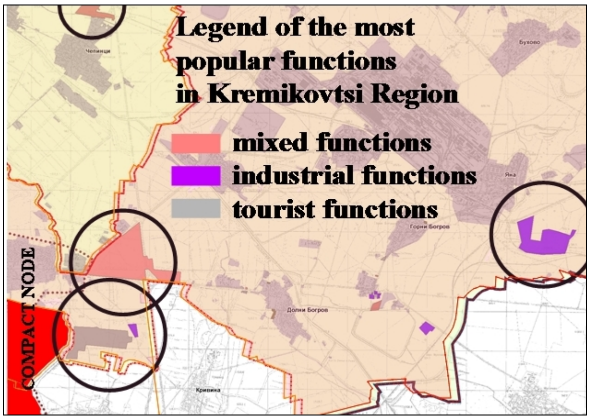


Fig. 6 Scheme of potential transport links between polycentric cores and compact core

Knaap et. al. [18] believe that regional plans and policies will increase the growth of jobs in selected economic centers, especially those with transit service. Such a concentration should lead to economic growth, increase visits, reduce travel and have positive impact on the environment. It is pointed out that such economic policy, however, should be linked with housing structures whose development can be promoted in the transit areas. Thus through the polycentric development activities which are currently inherent to the main center are reallocated. A similar trend is observed in the example of Sofia, where it can be clearly recognized that the urbanization of new and diverse range of functions territories are placed in the period 2006-2013 (Table № 1) The appearance of zones with mixed features is observed especially residential structures in places with transit, which leads to a positive trend for the development of polycentric forms with a serious preponderance of housing outside the compact core (Table № 2, Fig. 7).





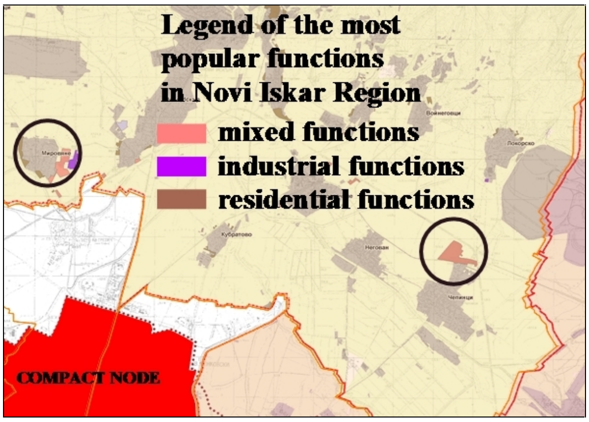


Fig. 7 Schemes of the prevailing functional composition of polycentric cores in Vitosha, Kremikovtsi and Novi Iskar Regions in Sofia

Table 1. Balance on the territories for the period from 2006 to 2013

№	Region	Tipe of territories	Area 2006 (ha)	Area 2013 (ha)	Difference between the two periods (ha)	In-crease (%)
1	Vitosha	urbanised	2514.43	3116.04	601.61	24.9
		Vitosha Natural Park	7685.50	7685.50		
2	Kremikovtsi	urbanised	3405.68	3758.55	352.87	10.4
3	Novi Iskar	urbanised	2751.44	2622.24	129.20	4.7

Source: Sofia Municipality, Directorate 'Architecture and Urban Planning', Municipal Enterprise 'Sofproekt - Master Plan'

Undeniably one of the main positive aspects of polycentric development is the reduction of commuting and congestion of the transport network [15]. This should be done through the deployment of labor functional structures away from the main center which will be partially unloaded to the possible extent, by the load of commuting. A similar trend should also keep part of the travel flows as a whole and to reduce congestion at the input and output transport channels. In the case of the issue areas of the city, except the mixed functional areas in which function work is also advocated, industrial areas with a direct opportunity to develop employment outside the main center have a great participation (Table № 2, Fig. 7).

Table 2. Balance of the biggest areas for its intended purpose

№	Region	Tipe of territories	Areas of territories (ha)	Ratio (%)
1	Vitosha	New urbanized areas with residential use	398.37	66.2
		New urbanized areas with mixed use	178.05	29.6
		Other territories	25.19	4.2
		Total for the region:	*601.61*	*100.0*
2	Kremi-kovtsi	New urbanized areas with mixed use	166.42	47.2
		New urbanized areas with industrial functions	90.49	25.6
		Other territories	95.96	27.2
		Total for the region:	*352.87*	*100.0*
3	Novi Iskar	New urbanized areas with residential functions	56.94	44.0
		New urbanized areas with mixed use	30.81	23.8
		Other territories	41.45	32.2
		Total for the region:	*129.20*	*100.0*

Source: Sofia Municipality. Directorate ‘Architecture and Urban Planning’, Municipal Enterprise ‘Sofproekt - Master Plan’

In a study of the positive aspects of polycentric development in the regions of Sofia the following three can be summarized:

- Reduction of traffic from the compact core to the periphery.
- Formation of new residential areas in the regions outside the compact core.
- Development of new work territories outside the compact core.

3. Factors which stimulate polycentric development

Factors promoting polycentric development in monocentric cities will be studied on the basis of contemporary processes of urbanization in the period from 2006 to 2013.

It should be noted that urbanization in the region is concentrated mainly in the places provided by the Master Plan (Fig. 3 - Fig. 5), and in all three examples mainly mixed development of multifunctional and completely residential areas in the regions of main communication arteries who appear stimulating factor polycentric structure in the region are observed (Fig. 6).

In areas located to specific natural attractors such as the Region of Vitoha and the nearby Vitosha mountain can also be considered as a factor stimulating polycentric development with typical residential structures due to the rise of new urban areas with more than 66% (Table № 2, Fig. 7).

In other areas similar strong and attractive landscapes may not be available, but in the Region of Kremikovci the formation of a large industrial territory (the most significant area for the three examples) is observed, which is extended to the largest existing industrial complex in the country and this trend can also be a factor stimulating polycentric with industrial functions (Fig. 7).

The existing small places in the Region of Novi Iskar, for example, also generate major new urban areas around them and thus they become a factor in the polycentric development (Fig. 7).

In the study of factors stimulating polycentric development in the regions of Sofia, four pivot points can be summarized:

- Input-output transport communications.
- Existing specific natural attractors.
- Existing unique functional units.
- Existing small settlements.

Conclusions

In the context of the analyzed sources on the topic for polycentrism and the model of development of the three regions of Sofia the following conclusions can be draw:

Firstly, you need to keep in mind the proximity of the areas to the compact core and the possibilities for polycentrism it suggests. Furthermore, all polycentric nuclei are close to the borders with the compact core, which shows that the polycentrism in regions requires fast and easy links.

Secondly, the existing functional structure of the area and the importance that it has for the formation of polycentric cores must be taken into account. The functional profile of existing settlements and large specialized functional complexes (residential, industrial) with its capabilities are a place that attracts all polycentric structures.

Thirdly, the importance of natural resources and their strong influence on the organization of polycentric cores with mainly residential functions should be noted.

Proposals

In the context of the conclusions the following proposals for the formation of new and development of existing polycentric structures can be given, namely:

- Improvement of transport links with the area and especially the new urbanized areas located adjacent to the border with the compact core.
- A detailed study of functional capacity of existing settlements in the regions and specialized large complexes for their transformation into polycentric cores.
- A study of natural resources in the regions, except the Region of Vitosha, and opportunities that can be used to propose the formation of specific polycentric systems for living and recreation.

REFERENCES

[1] Sandberg K., E.J. Meijers, *Polycentric development: panacea for regional disparities in European countries?*, in: C. von Schweinichen (Ed.) Sharing responsibility for our region: Redefining the public interest for territorial development (paper presented at 10th UNECE Conference on Urban and Regional Research, Slovak Republic: Bratislava), 2006, 160-161.

[2] ESPON-INTERACT, *Polycentric Urban Development and Rural-Urban Partnership – Thematic Study of INTERREG and ESPON activities.* Available at: http://www.espon.eu/export/sites/default/Documents/Projects/ESPON2006Projects/ESPONINTERactStudies/PolycentricUrbanDevelopment/fr-INTERACT-Poly-Jan2007.pdf, 2006, 10-47.

[3] RePUS - Regional Polycentric Urban System, Final report: Interreg III B strategy for a regional polycentric urban system in Central Eastern Europe Economic Integrating Zone. Available at: http://www.repus.it/repus-docs/repus_finalreport.pdf, 2007, 10-12.

[4] Davoudi S., *Can polycentric development enhance competitiveness and cohesion?* ESPON/SPAN Seminar 22-23 February 2005. Queen's Univ. Belfast. Available at http://www.qub.ac.uk/research-centres/span/FileStore/ESPON/Filetoupload,152913,en.pdf, 5, 2005, 37.

[5] Hall P., K. Pain, The polycentric metropolis: learning from the mega-city regions in Europe. Earthscan. London, 3, 2006.
[6] Vasanen A. Evolving polycentricities. The development of urban spatial structure in Finnish urban regions. University of Turku, 2013, 13–17.
[7] Verkoren O., A. Romein, A.M. Fernández-Maldonado, *Polycentric Metropolitan Form: Application of a 'Northern' Concept in Latin America.* Footprint: Delft School of Design Journal. 5, 2009, 128-130.
[8] McMillen D.P., *Polycentric urban structure: The case of Milwaukee.* Economic Perspectives. n. Q II. 2001, 15-27.
[9] Giffinger R. *Polyce - Metropolisation and Polycentric Development in Central Europe.* Urban Policy - Challenges, Experiences, Ideas 25-26.06.2013. Report on commission to ESPON. Warsaw.
[10] Johansson M., Polycentric Urban Structures in Sweden – Conditions and Prospects. 2002
[11] Veneri P., D. Burgalassi, *Questioning the effects of polycentric development.* Issues of definition and measurement for the Italian NUTS-2 regions. Aosta: Paper presented at XXXI Conferenza Italiana di Scienze Regionali, 2010.
[12] Aguilera A., D. Mignot. Urban Sprawl, polycentrism and commuting. A comparison of Seven French Urban Areas. Urban Public Economics Review, 2004, 93-95.
[13] Ewing R., R. Pendall, D. Chen, *Measuring Sprawl and Its Impact*. Washington, DC: Smart Growth America. Available at http://www.smartgrowthamerica.org/research/measuring-sprawl-and-its-impact/, 2002, 3.
[14] Galster G., R. Hanson, M. R. Ratcliffe, H. Wolman, S. Coleman, J. Freihage, *Wrestling Sprawl to the Ground: Defining and Measuring an Elusive Concept.* Housing Policy Debate 12 (4), 2001, 682-704.
[15] Lin D., An.Allan, J. Cui, R. McLaughlin, *The Effects of Polycentric Development on Commuting Patterns in Metropolitan Areas.* Available at http://www.regionalstudies.org/uploads/Dong_Lins_Final_Paper_for_RSA_Beijing_Global_Conference_of.pdf, 1-3, 2012, 8.
[16] Burger M.J., B. van der Knaap, R.S. Wall, *Polycentricity and the multiplexity of urban networks.* European Planning Studies DOI: 10.1080/09654313.2013.771619, 2013.
[17] Smith D.A., *Polycentric Cities and Sustainable Development.* Regional Science 04.09.2009. Available at http://www.slideshare.net/DuncanSmith/polycentric-cities-and-sustainable-development, 2009.
[18] Knaap E., C. Ding, Y. Nu, S. Mishra, Polycentrism as a Sustainable Development Strategy: Empirical Analysis from the State of Maryland. Journal of Urbansim, 23-25.
[19] Song Y. and G.J. Knaap. *Measuring Urban Form: Is Portland Winning the War on Sprawl?* Journal of the American Planning Association 70 (2), 2013, 212-216.
[20] Lee B., P. Gordon. Urban structure: its role in urban growth, net new business formation and industrial churn. Région et Developpement. 33. 137, 2011, 154-155.
[21] A project of The Master Plan of Sofia Municipality. Available at http://www.sofproect.com/documents.aspx?AspxAutoDetectCookieSupport=1.

ARCHISCULPTURAL STRUCTURES OF THE ARCHITECT ZAHA HADID

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Abstract: *Brilliant ecourbarchitectonic sculptural creations by the architect Zaha Hadid, especially those at the turn of this century are a motive for avant-garde consideration of formation of physical structures in space. Abandoning of rigid-angled, polygonal volumes and entering of a conceptually new world of biomorphic, amoeboid and free forms in designing, starts a new chapter in the history of city-building. The focus is on the fitting of newly designed structures into the existing structures and integration with surrounding artifact and natural environment, with a notable tendency of engineering-organic linking with the structures having the characteristics of the flora and fauna realms. The top design structures, presented in the paper, were created at the beginning of this century. They are a fruit of maximum creativity. They are a harbinger of a new, more complex identity and modernity in the future urbarchitectonic spatial entities. They foreshadow a more flexible way of modeling of cultural - artistic and living space - creation of a new city-building philosophy, new history of plural development of cities. The structures by the architect Zaha Hadid are an important factor for differentiation of the identity of structures as well as the dialog of forms in the complex artistic-multicultural environment.*

Key words*: archisculptural quality, biomorphic structures, design, philosophy of building, multi-cultural environment*

1. Introduction

"We often observe nature in order to create an architectural work. The elegance, cohesion and beauty of the natural world are a genuine source of inspiration to us." - Zaha Hadid

Ecourbarchitectonic forms of the architect Zaha Hadid changed the way of understanding of creation of physical structures in space. The conicoid geometry in her works, which brings new archiscuptural values of the structures, ushered in a new, powerful designing-artistic freshness which deserves admiration and respect. In creation of

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very diverse, elegant, inspirational and functional forms of physical structures, she brought the world of artifact forms closer to nature, and created a synthesis with smoother contrasts. She ushered in a new era of environmental-urbanologic philosophy, of expanded boundaries without rigid-angled engineering, governing and prescriptive volumes. It is an iconic ecourbarchitecture, setting the scene for the city-building concept of the beginning of 21st century and the future. The paper presents the structures characteristic for the exquisite mastership in creative fusion of the structures and the environment; curved, natural lines and warped and distorted surfaces were used in a manner of Deconstructivism. We cannot not notice the surprising technology, new materials, fascinating and playful volumes, conceptually fresh city building spirit of graceful, essentially simple architectonic designing and avant-garde beautiful forms in a perfect flow, which are dynamic and which are leaving no observer indifferent.

2. Research

The paper analyzes the following, latest ecourbarchitectonic creations of Zahe Hadid:

- Zaha Hadid's Futuristic Burnham Pavilion for Chicago
- Helix Hotel, Abu Dhabi, Zaha Hadid
- Abu Dhabi Performing Arts Centre by Patrick Schumacher and Zaha Hadid
- • Zaha Hadid / Patrik Schumacher, Madrid Civil Courts Of Justice, Madrid, Spain
- Zaha Hadid's Beko Building In Belgrade
- Zaha Hadid Architects have unveiled designs for a theatre in Rabat, Morocco
- The Mobile Art Pavilion in Paris for "Chanel" by Zaha Hadid Architects
- Zaha Hadid, Jesolo Magica - Retail and Business Centre for the resort of Jesolo near Venice in Italy, 2010 - 2014
- Stone Towers in Cairo, Egypt by Zaha Hadid Architects
- Zaha Hadid & Patrik Schumacher, Cairo Expo City, project in Egypt

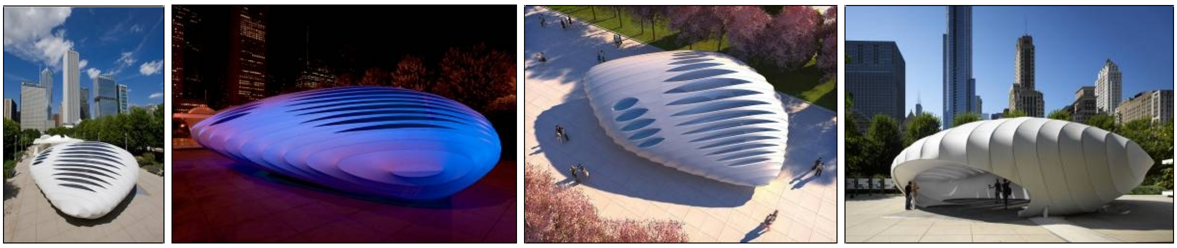

Fig. 1. Zaha Hadid's Futuristic Burnham Pavilion for Chicago
(http://www.bustler.net/index.php/article/zaha_hadids_futuristic_burnham_pavilion_for_chicago/;
http://www.noveformy.cz/blob/blob-reference/burnham-pavillion/
http://www.zaha-hadid.com/architecture/burnham-pavillion/)

Futuristic Burnham Pavilion for Chicago in the Millennium Park is a part of the creator's opus, where a complex physical ecourbarchitectonic form from the flora nad fauna realms can be recognized. It softens the geometry of artifact structures in the immediate environment, and ushers in a new genius loci, and creates new artistic, visual-esthetic harmony of relations in space, exhibiting new culture and a pattern of futuristic building vision in ecourbarchitecture and archisculptural planning. The architecture theorists say that it is an impressive public sculpture, contemporary lightweight „tent" with taut, twisted fabric creates an extraordinary impression of lightness and significant visual-artistic, communication-functional change in space.

Fig. 2. Helix Hotel, Abu Dhabi, Zaha Hadid
(http://www.funis2cool.com/travel/hotel-helix-abu-dhabi.html; http://www10.aeccafe.com/blogs/arch-showcase/2012/05/09/the-helix-hotel-in-abu-dhabi-uae-by-leeser-architecture/hh_d_6-floor-plan/; http://vietnamarchitecture-nguyentienquang.blogspot.com/2013/12/architecture.html)

The design[5] of the Helix hotel in Abu Dhabi, on the water surface is a splendid, dynamic fusion of ecourbarchitectonic, sculptural form with the nature. The hotel is conceived with spiral and staggered, rotated floors covering in most part the Zayed bay - inlet in Abu Dhabi. On the roof are situated the running trek and the swimming pool with a transparent bottom, which makes visible eight floors below. The idea was to create a luxury, non-stereotypical hotel, having a good quality and iconic design with five stars, on the coast line, in the neighborhood of the Sheik Zayed bridge. The conceptual design exhibits creation of the dynamic space with a visual impression of an esthetically powerful, impressive structure, whose upper floors expand, which in part appears to floats on the water, and defines the local identity of the location, and of the space. The vistas of the occupants of luxury apartments are oriented towards the water surface of the bay, while the center of the structure is designed with a large void and diverse innovative volumes which in the central part have the pronounced curvilinear, non-rigid-angled hotel corridors, but spectacular, geometrically conicoid communications. This sculptural structure of the complex content, emphasizes the different, non-traditional designing and methodological-philosophical approach in design of contemporary and lavish hotels.

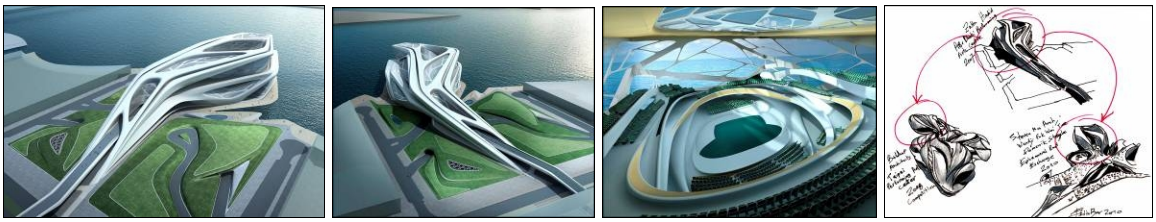

Fig. 3. Abu Dhabi Performing Arts Centre by Patrick Schumacher and Zaha Hadid
(http://www.architectural-review.com/architectural-style-wars-at-the-royal-college-of-art/8626973.article; http://www.newarchitecture.biz/2010/12/abu-dhabi-performing-arts-centre-by.html)

Abu Dhabi Performing Arts Centre with the surface area of 62.770 m^2 is also one of archisculptural structures located on the water surface. With ten floors above ground and four floors under ground, it is envisioned as a new cultural center with rich functions: five theatrical halls, a concert hall, a flexible opera house, dramatic rehearsal hall, etc., with combined seats for za 6.300 visitors, as well as the Academy of drama arts. The structure adheres to the terrain contours in and organic way. Evolution biology, in short, examines origin, evolution behavior and procreation of species in time. Eleftheria Fasoulaki[6] points out that the structures remind of an "enormous set of possibilities of prospective genetic

[5] „Lesser Architecture“ of New York is an internationally recognized design company. It won the first prize at the competition for conceptual town planning and architectonic design.
[6] http://www.generativeart.com/on/cic/papersGA2007/09.pdf, Eleftheria Fasoulaki: Genetic Algorithms in Architecture: a Necessity or a Trend? Master of Science in Architecture, Computation Group. Department of Architecture, Massachusetts Institute of Technology. Email: efasarch@mit.edu

sequences, and that this is source of inspiration" and that it will remain important in the architectonic terms and in terms of the study of complex computational problems in architecture and engineering.

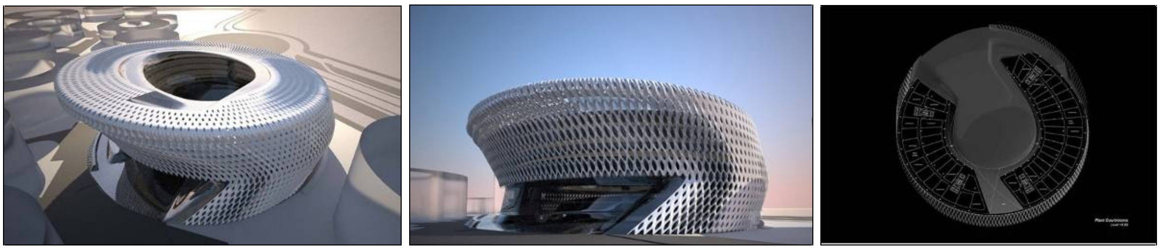

Fig. 4. Zaha Hadid / Patrik Schumacher, Madrid Civil Courts Of Justice, Madrid, Spain (http://inhabitat.com/civil-court-for-madrid-from-zaha-hadid/; http://europacon corsi.com/ projects/26424-Zaha-Hadid-Architects-Patrik-Schumacher-Madrid-Civil-Courts-Of-Justice-madrid-Spain-/images/792560)

Madrid Civil Courts of Justice structure - 74,448 m^2, belongs to archisculptural forms having impressionable, flowing tectonics. Its façade plane is characteristic; it is based on the circular volume, which ascending towards the upper floors, soft lines and surfaces changes its profile and size of the spiral volume. Apart from that, the metal façade is of a grid-elastic type with perforations having various sizes and forms, which produces a special visual esthetic-artistic experience. The roof area also contains perforated openings, while the central part has a large public atrium. The ecourobarchitectonic forms evoke the biomorphic natural structures.

Fig. 5. Zaha Hadid's Beko Building In Belgrade
(http://www.businessinsider.com/zaha-hadids-beko-building-in-belgrade-2012-11)

Beko Building In Belgrade - 94.000 m^2, is a complex multifunctional physical architsculptural structure which should be a cultural center of the city at the turn of 21^{st} century. It is located at the foot of the Kalemegdan fort, and it is intended to regenerate the old urban fabric. The design of the structure is the results of the local conditions, where tow essential, dominant axes of the city intersect. The geometrical composition of this structure with soft curving lines is radically different from the polygonal volumes in the neighborhood.

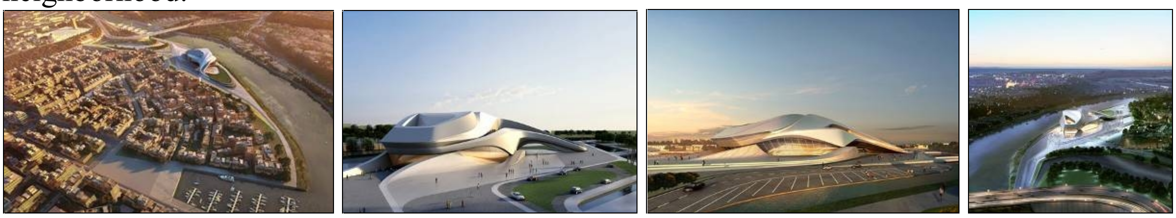

Fig. 6. Zaha Hadid Architects have unveiled designs for a theatre in Rabat, Morocco
http://www.dezeen.com/2010/11/22/rabat-grand-theatre-by-zaha-hadid-architects/

The fluid form of the Rabat Grand Theatre, Morocco - 47.000 m^2, is placed in the Bouregreg Valley, across the surface area of 6.000 ha, at a splendid island between the old part of the city and the river Bouregreg. It was designed as a multifunctional complex with the most contemporary infrastructure and dynamic design, with 2.050 seats in the theatrical hall, with 520 seats in the smaller hall, with, 7.000 seats in the amphitheater and experimental area for performances. It has a high artistic sculptural-innovative expression. When it will have been finished in 2014, this archisculptural structure will be a major landmark, place of cultural development and most attractive destination in the Mediterranean.

Fig. 7. The Mobile Art Pavilion in Paris for "Chanel" by Zaha Hadid Architects
http://wordlesstech.com/2011/05/19/mobile-art-pavilion-zaha-hadid/

Mobile Art Chanel Contemporary Art Container is structure which can be assembled and disassembled is intended for exhibitions-promotions activities in Hong Kong, Tokyo, New York, etc. It is currently located in Paris. It was built in 2008 - 2010 for the company "Chanel" with an area of $700m^2$. The volume of the structure has an amoeboid-conicoid form having dimensions 29m x 45m. For the construction 74t of steel were used. The exhibition pavilion has exquisite sculptural properties, which are equally valuable in the exterior and interior, with a lot of elegant, harmonized arch forms in space. The walls and roof area are transparent, so that there is sufficient daylight in the interior. The designing - functional concept of organization of space is directed towards the access of the building and focal courtyard area.

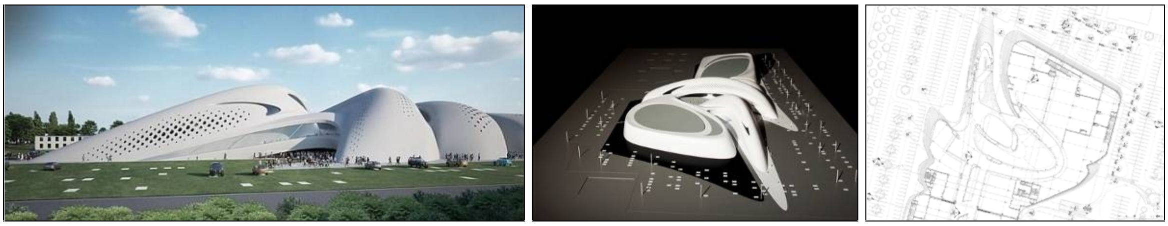

Fig. 8. Zaha Hadid, Jesolo Magica - Retail & Business Centre, 2010-2014
Designs the Jesolo Magica Retail and Business Center have designed a retail and business centre for the resort of Jesolo near Venice in Italy; http://freshome.com/2009/11/10/zaha-hadid-designs-the-jesolo-magica-retail-and-business-center/; http://www.algeria.com/forums/open-board-forum-libre/17711-architecture-51.html;http://static.dezeen.com/uploads/2010/03/dzn_Jesolo-Magica-14.gif

Jesolo Magica Retail and Business Center, near Venice, belongs to organic archisculptural forms similar to floral petals in nature. There are opinions advocating a return to nature and natural life to "modern caves", and leaving the contemporary rectangular, inhuman, concrete boxes. In this design, the volume is done with the distribution of structural elements on the orthogonal matrix in the composition. Apart from attractive sculptural, organic powerfully flowing forms, the façade plane which is curvilinear, perforated, joining the roof area, with unequal openings of a visually attractive grid work is attracting additional attention. This brings about a new city building idea -

where the stereotypes and uniformity is reduced, and the artifact structures are fitted into and merged with the natural ambient.

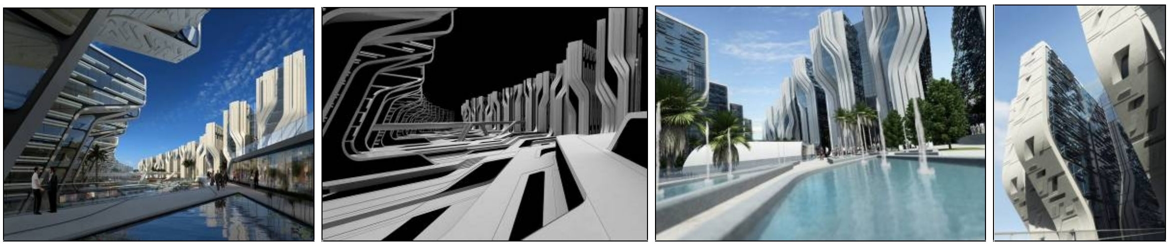

Fig. 9. Stone Towers in Cairo, Egypt by Zaha Hadid Architects
http://www.architectsjournal.co.uk/news/north-african-unrest-forces-hadid-to-shed-staff/8610881.article;
http://www10.aeccafe.com/blogs/arch-showcase/2012/06/01/stone-towers-in-cairo-egypt-by-zaha-hadid-architects/

The design of architecture of stone towers - residential and office buildings in New Cairo, Egypt, of 2008, on an area of 179.970 m^2, brought a new archisculptural, flexible desing and a different visual-artistic and esthetic articulation in the space of physical structures. There are no unison, uniform repetitions, nor static volumes. On the contrary.Tthe masses of the structures are flowing and the polygonal concept of volume formation is abandoned, without right angles. There are softly and mildly undulating façade surfaces near the water communications with vegetation. The particularity is the parking space, for approximately 7.000 vehicles, covering an area of around 500.000m^2 in the basement section. The visitors of the complex can access the river delta from the basement parking.

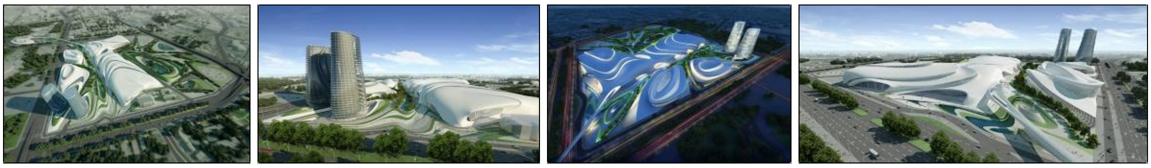

Fig. 10. Zaha Hadid & Patrik Schumacher, Cairo Expo City, project in Egypt
http://www.architectsjournal.co.uk/news/north-african-unrest-forces-hadid-to-shed-staff/8610881.article
http://desmena.com/?p=387

Cairo Expo City, multifunctional design of 2009, is planned to be constructed on the location having surface area of 450,000 m^2, between the center of the city and the airport. It has shopping malls, extremely tall administrative-office towers, hotels in the northern part of the complex, international conference and exhibition center, etc.[7]. Even though the volumes of the structures are very large, the buildings are designed as fluid, prone, horizontal, hilly structures, fitting into the surrounding landscape. The proposition for the Cairo Expo City is a homogenous urban entity with several visionary conceived functional zones, whereby the river Niles and its delta were the key inspiration in the strategic formation of the volume configuration. For this reason the horizontal expansion of communications in the structure is of primary importance, with volumes whose roof covers blend into a single rolling surface.

[7] Exhibition Hall: Footprint 132.586m^2, Floor Area: Approx 154.162m^2, Conference Centre: Footprint 11.600m^2, Floor area: Approx 38.450m^2

Conclusions

It is not difficult to conclude that the designs of the ecourbarchitectonic structures of Zaha Hadid are a new historically important city-building textbook, new city-building theory in designing of the housing of the future, a source of inspiration, an esthetic-sculptural statement at the turn of 21st century. These inspired architectonic designing, organic philosophy defines new directions towards a less conflicting city-building future. It is our impression that the archisculpturality of future forms will increasingly be in organic relation with the nature and its forms, and that the world in general will have a better comfort in the interior and exterior spaced. It is important to recognize new, diverse identity of ambient entities, with the focus on decreasing of contrasting geometrical relations and tensions in the dialogue of physical structures in space. We live with a belief that the increased presence of archisculptural ecourbarchitectonic forms, where the priority is given to natural structures, with new building technologies and materials, will be serve as a corrective architectonic factor.

REFERENCES

[1] Patrik Schumacher, Zaha Hadid complete works, ISBN:0500342008, ISBN: 9780500342008. Publisher: Thames & Hudson, 2004.

[2] Zaha Hadid, Patrik Schumacher, Steiermärkisches Landesmuseum Joanneum, Latent utopias: experiments within contemporary architecture, ISBN-10: 0892073462, ISBN-13: 978-0892073467. Publisher: Guggenheim Museum, August 15, 2006.

[3] Kathryn B. Hiesinger, Zaha Hadid: Form in Motion (Philadelphia Museum of Art) ISBN-10: 0300179820, ISBN-13: 978-0300179828. Publisher: Yale University Press, December 27, 2011.

[4] Zaha Hadid, Aaron Betsky, Zaha Hadid: The Complete Buildings and Projects, ISBN-10: 0847821331, ISBN-13: 978-0847821334. Publisher: Rizzoli, October 15, 1998.

[5] Florian Kobler, Zaha Hadid. Updated Version Hardcover, ISBN-10: 3836542838, ISBN-13: 978-3836542838. Publisher: Taschen; Mul Upd edition, December 15, 2013.

[6] Philip Jodidio, Zaha Hadid: Complete Works, 19792009, ISBN-10: 3836502941, ISBN-13: 978-3836502948. Publisher: TASCHEN America Llc; Mul edition, September 8, 2009.

[7] Joseph Giovannini, Iwan Baan, MAXXI: Zaha Hadid Architects: Museum of XXI Century Arts by Zaha Hadid Architects, ISBN-10: 0847858006, ISBN-13: 978-0847858002. Publisher: Skira Rizzoli, September 14, 2010.

[8] James F. Eckler, Language of Space and Form: Generative Terms for Architecture, ISBN-10: 0470618442, ISBN-13: 978-0470618448. Publisher: Wiley; 1 edition, February 7, 2012.

[9] Vitra Design Museum, Isamu Noguchi: Sculptural Design, ISBN-10: 3931936325, ISBN-13: 978-3931936327. Publisher: Vitra Design Mus; First English Language Edition edition, October 1, 2002.

III. GEODESY.
GEOTECHNICAL ENGINEERING.
ROAD & RAILWAY ENGINEERING.
TUNNELLING.
HYDRAULIC ENGINEERING

THEORETICAL SOLUTION OF THE FOUNDATION SLAB DEFLECTION USING FINITE DIFFERENCE METHOD

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Abstract: *The paper provides a partial non-homogeneous differential equation of the foundation slab bending which is of the fourth order and presented by the double Laplace operator. The solution is provided by the finite difference method by transformation into a system of algebraic equations using a corresponding scheme of coefficients through which the cross-section forces are displayed.*
Interaction of the foundation slab and foundation soil is presented in a matrix form. For different ratios of the sides and the thickness of the compactable layer, relative rigidity and Poisson’s coefficient, the non-dimensional parameters of coefficient I are calculated, and it was used to provide the deflection and sectional forces. For the square and rectangular slabs, the values are provided in the form of a diagram.

Key words: *differential equation, finite differences method, sectional forces, coefficients.*

1. Introduction

Bending of the foundation slab submitted to the transversal load *p (x, y)* is governed by the partial inhomogeneous differential equation of the fourth order which follows:

$$\frac{\partial^4 W}{\partial x^4} + 2\frac{\partial^4 W}{\partial x^2 \partial y^2} + \frac{\partial^4 W}{\partial y^4} = \frac{p(x,y) - q(x,y)}{K} = \frac{Z}{K} \tag{1.1}$$

where: - W is an unknown function of the vertical displacements (deflections) of the foundation slab;
- q is an unknown function of reactive stress;
- h is the thickness of a slab;
- E is the modulus of elasticity of a slab;

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- v is Poisson's ratio;
- $K = \dfrac{Eh^3}{12\left(1-\nu^2\right)}$ is the flexural stiffness of a slab.

Equation (1.1) expressed by the double Laplace's operator looks like:

$$\Delta\Delta W = \frac{p-q}{K}. \tag{1.2}$$

Equation (1.1) with the appropriate boundary conditions can be solved relatively readily using the finite difference method, which reduces a differential equation to a system of linear algebraic equations. So, the discrete values of displacements W are determined, and then cross sectional forces are calculated. In order to apply finite difference method, the middle surface of a plate is to be covered by rectangular grid with raster $S_x = L_x/n$, $S_y = l_y/m$, (Fig. 1) and then the deflections of nodes are calculated.

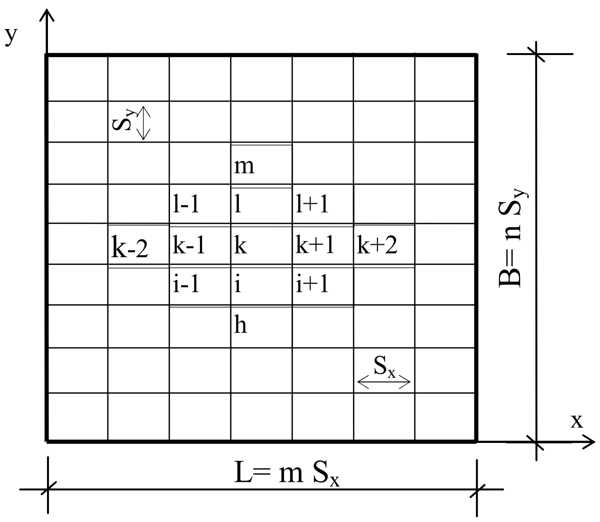
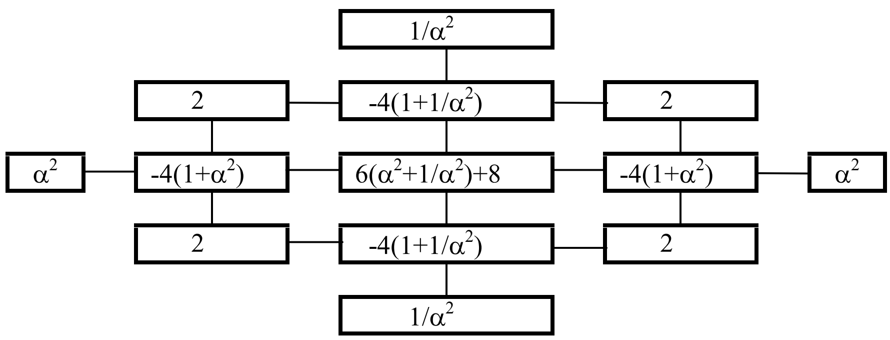


Fig. 1. The grid of finite difference method

In order to convert the differential equations into the system of algebraic equations, the following pattern of coefficients is formed:

(1.3)



Constant term in any equation is calculated according to the expression:

(1.4) $$W_{0,k} = \frac{Z_k \alpha^2 S_x^{\ 4}}{K}$$

where $\alpha = S_y/S_x$, and Z_k is the average load on the rectangle of area $S_x S_y = \alpha S_x^{\ 2}$ around the *k* point of the mesh (the node *k*).

2. Cross sectional forces

As the values of deflections *W* are obtained in the points of the grid, the internal forces in the cross-sections are computed using the following expressions:

(2.1) $$M_x = -K\left[\frac{\partial^2 w}{\partial x^2} + \nu \frac{\partial^2 w}{\partial y^2}\right]$$

(2.2) $$M_x = -K\left[\frac{\partial^2 w}{\partial y^2} + \nu \frac{\partial^2 w}{\partial x^2}\right]$$

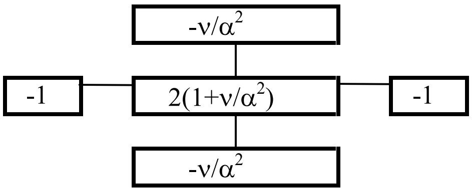
(2.3) $$M_{xy} = -K(1-\nu)\left[\frac{\partial^2 w}{\partial x \partial y}\right]$$

(2.4) $$T_x = -K\frac{\partial}{\partial x}\Delta W = -K\frac{\partial}{\partial x}\left[\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2}\right] = -K\left[\frac{\partial^3 w}{\partial x^3} + \frac{\partial^3 w}{\partial x \partial y^2}\right]$$

(2.5) $$T_y = -K\frac{\partial}{\partial y}\Delta W = -K\frac{\partial}{\partial y}\left[\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2}\right] = -K\left[\frac{\partial^3 w}{\partial x^2 \partial y} + \frac{\partial^3 w}{\partial y^3}\right]$$

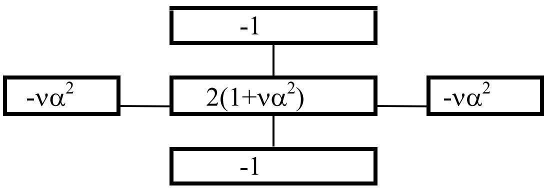
The previous expressions can be expressed in the finite differences method, by use of the coefficients given in the following schemes:

(2.6)



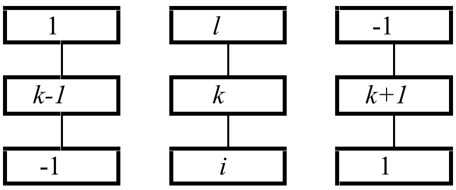
$\}* K/S_x^2 = M_{x,k}$

(2.7)



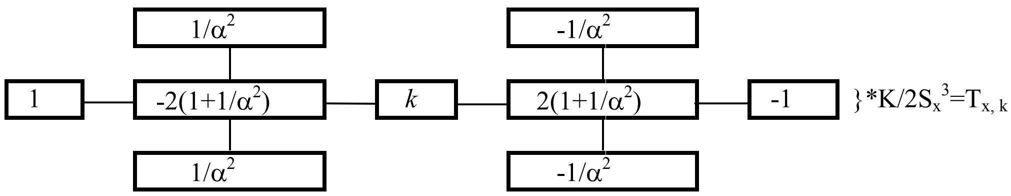
$\}* K/S_y^2 = M_{y,k}$

(2.8)

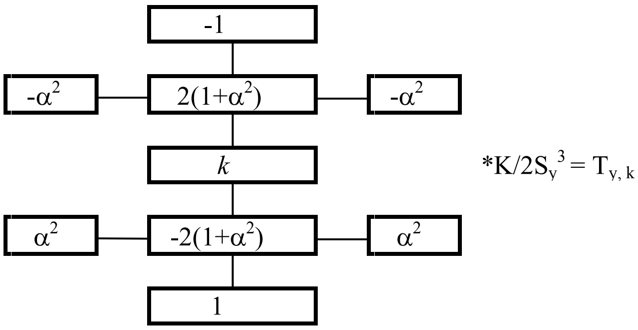


$\}* K(1-\nu)/4\alpha S_x^2 = M_{xy,k}$

(2.9)



(2.10)



3. Interaction of the foundation slab and the soil

Interaction of the slab and the soil is shown in matrix form as follows:

(3.1) $$[A]\{W\} = \frac{\lambda_x^{4}}{\alpha^2 D}\left[\{p\}-\{q\}\right]$$

where $[A]$ is a matrix of the coefficients of the system of linear algebraic equations;
$\{W\}$ is one-dimensional matrix of vertical displacements of grid nodes;
$\{p\}$ is one-dimensional matrix of external load acting on the nodal points;
$\{q\}$ is one-dimensional matrix of reactive load acting on the nodal points.

To minimize the number of unknowns, the ratio between the unknown vectors $\{W\}$ and $\{q\}$ is introduced and it is expressed in a matrix form:

(3.2) $$\{W\} = [F]\{q\}$$

where $[F]$ is the square matrix representing the influence functions of deflection of observed point on the foundation plate.

Equation (3.1) can be written in the form:

(3.3) $$[[A][F] + t[E]]\{q\} = t\{p\}$$

Where $[E]$ is the unit matrix and $t = \dfrac{\lambda_x^{4}}{\alpha^2 D}$.

Dimensionless coefficients I are calculated for multiple values L/B, H/B, K and ν, so that the expressions for deflection w, contact stress q, bending moments M_x and M_y, torsion moments M_{xy}, shear forces T_x and T_y can be written in the following form:

$$W = \frac{pB}{E} I_w \tag{3.4}$$

$$q = pI_q \tag{3.5}$$

$$M_x = pB^2 I_{M_x} \tag{3.6}$$

$$M_y = pB^2 I_{M_y} \tag{3.7}$$

$$M_{xy} = pB^2 I_{M_{xy}} \tag{3.8}$$

$$T_x = pB^2 I_{T_x} \tag{3.9}$$

$$T_y = pB^2 I_{T_y} \tag{3.10}$$

where *p* is applied load and B is a plate width.

The relative stiffness of the foundation K is defined by the following expression (Fraser and Wardle, 1976):

$$K = \frac{4E_c\left(1-\nu_s^{\,2}\right)h^3}{3E_s\left(1-\nu_c^{\,2}\right)B^3} \tag{3.11}$$

where E_c is modulus of elasticity of concrete; E_s is modulus of elasticity of the soil; N_c is Poisson's ratio of concrete; ν_s is Poisson's ratio of soil; h is thickness of the foundation plate; B is width of the foundation plate.

For the purpose of illustration, some of the obtained results are shown in Fig.2. The influence coefficients I_w for calculation of the central and corner points deflection of the rectangular foundation slab for various stiffness values *K*, while the ratio length to width is L/B=1 and L/B=2, for various ratios of the compressible layer H and edge length B (H/B = 0.5; 1.0; 2.0) are presented in the form of diagrams.

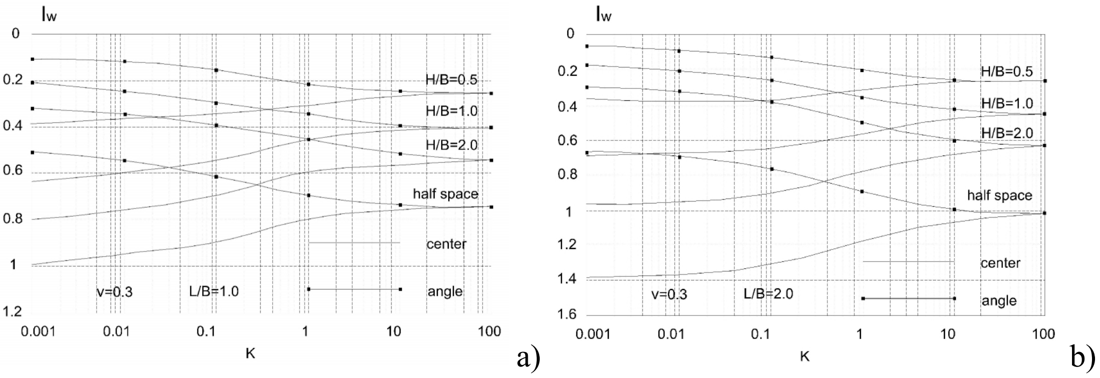


Fig.2. Coefficients I_w for foundation with ratio length to width: a) L/B=1, b) L/B=2

4. Numerical example

Calculated component of the deflection of middle plane of foundation slab for various values of relative stiffness K is shown in Fig. 3. Allowable load of soil is σ_{doz} = 320kPa, ratio L/B=2.5, the ratio between compressible layer H and edge length B is H/B=0.5.

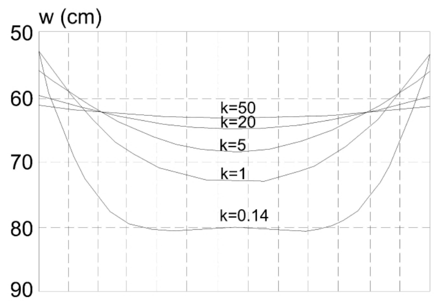


Fig. 3. The magnitudes of the elastic component of deflection

Based on the obtained solution by finite difference method, for given foundation slab of L/B = 2.5, given deformable layer thickness and the magnitude of applied load, elastic deflection component is calculated as W_i = 63.3cm, which is in very good agreement with the deflection obtained applying solution in the form of Fourier series, which amounts W_i = 60.9 cm,.

Conclusion

On the basis of the above presented it can be concluded that the use of finite difference method is very suitable and reasonable for solving the fourth order non-homogeneous partial differential equation of the foundation slab bending, which is converted into a system of algebraic equations. Unknowns in these equations are the values of deflection *W* in some discrete points of the plate. So, the discrete values of deflection *W* are defined, and then forces in the cross sections are computed.

Interaction of the foundation plate and the foundation soil is shown in a matrix form. Deflection *W*, contact stress *q*, bending moments M_x and M_y, the torsion moment M_{xy} and internal forces T_x and T_y are expressed in terms of dimensionless coefficients *I.* Solution obtained by the finite difference method for the plate ratio L/B = 2.5 differs from Fourier series solution less than 1%.

Acknowledgment

This research is supported by the Ministry of education, science and technological development of the Republic of Serbia for project cycle 2011-2015, within the framework of the project TR36016 -“Experimental and theoretical investigation of frames and plates with semi-rigid connections from the view of the second order theory and stability analysis” and TR36028 -“Development and improvement of methods for analyses of soil-structure interaction based on theoretical experimental research” of the research organization The faculty of civil engineering and architecture of University of Nis.

REFERENCES

[1] Milović D., M. Đogo. Problems of interaction soil-foundation-structure, Serbian Academy of Sciences and Arts, Department in Novi Sad, 2009. (in Serbian)
[2] Zdravković S. Theory of plates and shells - collection of solved problems with excerpts from the theory, The Faculty of Civil Engineering and Architecture, University of Niš, AGM knjiga, Belgrade, 2010. (in Serbian)
[3] Hajdin N. Theory of plates and shells: I) bending of plates, II) disks, Naučna knjiga, Belgrade, Civil Engineering Faculty, 1996. (in Serbian)
[4] Fraser R.A., L.J. Wardle. Numerical analysis of rectangular rafts on layered foundations, Grotechnique, vol.26, No4, 1976, pp. 619-630.

IMPORTANCE OF THE INTEGRAL BEHAVIOUR OF THE SOIL-FOUNDATIONS-STRUCTURE SYSTEM

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***Abstract**: The paper analyses behaviour of soil-foundations (substructure) – structure (superstructure). Achieving and provision of an integral behaviour of all the main parts of the system, i.e. substructure and superstructure so that they act as a single entity is of special importance. Usage of basic system isolation, that is, application of means for energy dissipation contributes to a better asesismic designing. Aseismic designing of foundations is of utmost importance, if the structure is built on a weak, loose soil.*

***Key words**: soil, foundation, structure, system, integral behaviour.*

1. Introduction

As for aseismic design of foundation, i.e. substructure, in particular, the following two directions are to be kept in mind: 1) Select the base of the foundation as the substructures system to be as simple as possible; 2) Connect to each other different elements of the substructure as much as possible to act integrally. This is particularly important in the case when the building is constructed on the site with a weak, loose soil, where moderate or strong vibrations of the ground, with strong accelerations which exceed about 0.15 g, just after a few strokes can cause permanent effective displacement due to lateral spreading and/or soil settlement.

In a technical sense, some strains and deformations in the foundation soil under the pressure occur even in the case of solid soil. Satisfactory connection is achieved and integral acting of the system soil-foundation-structure is provided by adequate coupling of structure and foundation. In the designing on seismically active areas of greatest importance is that the form of the structure, i.e. building is conceptually properly based. Earthquakes impose to the designers in general, and especially to architects and structural engineers, several different design criteria and prerequisites atypical in the standard design. Hence, it is essential to focus attention to a reliable seismic behaviour of a building and reducing seismic risk on time, already at the level of conceptual design, i.e. just the first

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and decisive phase of design. In general it is considered that the best is conventional foundation on a slab. Types of foundations that are commonly used in construction practice for residential buildings, silos, storage tanks, bridges, hotels and other facilities are the direct foundation on a slab or foundation on piles.

2. Foundation on a slab or piles

At the foundation on the slab, square, rectangular or circular in shape, there is a interactions of foundation and foundation soil, and therefore to certain geostatic problems, such as determination of the limit and permitted load on foundation soil, the determination of the expected total and differential subsidence, determination of the possible inclination and determination of the static influences due to the load. Of particular importance is the occurrence of significant differential subsidence in the case of uneven loads, which in conditions of the heterogeneous composition of the foundation soil is increased causing inclination and endangering the serviceability of the structure, and even causing its destruction (Fig. 1.).

Fig.1. A silos after the ground cracking due to lateral spreading in the foreground

Until recently it was believed that the foundation on piles is without problems. However, thanks to the experience about behaviour of piles due to static and dynamic loads gained in recent decades, numerous problems are identified that occur when structure is based on piles in relatively poor soil. In addition to these problems, it is necessary to analyze the possibility of buckling of piles, deviations from verticality during their setting-up, behaviour due to seismic forces and phenomena of liquefaction.

In the last decade tremendous progress was made in understanding seismic impact on the soil, primarily as a result of outstanding theoretical and experimental efforts, as well as the experience gained by observed phenomena on the ground, and damaged structures as well. Notwithstanding the aforementioned big improvement of knowledge about the behaviour of soils during earthquakes, we are far from the final realization, which inevitably brings certain conservatism in design decisions. The subsoil does not only affect the structural behaviour during the earthquake, but this influence is present throughout the whole life of a structure. If this influence is not properly anticipated and appropriate measures are not taken, i.e. the interaction with the ground is not taken into account, the structure could be stressed over the allowable limit.

The occurrence of motion, liquefaction, subsidence, slippage and faulting may be phenomena that are related to each other, and the structure itself may affect them, and the study of these phenomena is the task of the dynamics of the soil. During an earthquake seismic waves triggered the ground directly below the building and excite its dynamic response. Some structural elements are subjected to significant cyclic stresses and therefore the effect of interaction is higher. Generally, during the earthquake carrying structure is subjected to accelerations in all directions, but the most unfavourable are horizontal accelerations, which can cause severe damage or even collapse.

Fig.2. The building tilted by 20 º is leaning on neighboring one, Adapazari, Turkey, 1999

Fig.3. Sinking of the entire building block, Adapazari, Turkey, 1999

Structures, such as buildings, are primarily designed so that they can transfer the load applied vertically which is visible and " tangible " and the necessity of adequate carrying elements is clear even to less qualified persons, and the interaction with the ground is not very noticeable. It could be often heard unqualified opinion on the (no) need of some vertical carrying elements in order to takeover the impact of the earthquake or generally horizontal loads, where the importance of the integral operation of the system soil-foundation-structure is dominant. Hence seismic load can be easily neglected as is not very visible to the naked eye, which may result in the demolition of building. Magnitude of seismic load depends on the dynamic properties of the structure and character of its response which is directly related to the interaction with the ground, i.e. the integral operation of the facility as a whole. Bearing structures must be designed and constructed to withstand without destruction the strongest referent earthquake for the area on which they are built. Reference return period of such earthquake is 475 (500) years, or the probability of exceeding of 10% in 50 years. After such an earthquake, integrity of carrying structure and sufficient carrying capacity would have to be preserved.

Another basic requirement according to Eurocode 8 is that calculation of earthquake-resistant structures is related to limit of the damage. The foundation structure should ensure that the building act as a whole when exposed to seismic excitation, which should be achieved depending on the type of foundation. The foundation slab has an important role in achieving this aim, and because of that it is recommended the footings or piles to be connected by the slab or by coupling beams in two main directions.

Fig. 2 and Fig. 3 show the effects of the Turkey earthquake (1999), where it is evident leaning of a building or sinking of whole blocks of buildings due to the loss of soil strength. Greater or smaller damages are evident, but primarily has happened a displacement of a building as a "rigid body" (Fig. 3), and could be got the impression that most of the building is undamaged. Certainly, it should not be forgotten that probably the building suffered damage inside, especially partition walls and other non-carrying elements.

Bearing in mind that we are destined for the ground we must always take into account integral operation of the system soil-foundation-structure, i.e. must avoid the occurrence shown in Figures 1, 2 and 3 or similar that could endanger human lives. People's lives are unrepeatable, unique and irrecoverable that we must always have in mind.

Conclusion

In aseismic foundation, for the purpose of an integral acting soil- foundation structure it is needed to select as simple as possible base of the foundation which should interconnect the various elements, which is especially important in locations with weak, loose soil where even moderate vibration can cause lateral spreading and/or subsidence of the soil. Earthquakes impose to architects and structural engineers conditions which are not usual in the standard design. The interaction of foundations and foundation soil and the specific geostatic problems occur in the case of foundation on the slab, especially due to uneven load. It was thought until recently that there are no significant problems in the case of foundation on piles; however, significant problems were observed especially in poor soil. Although advances have been made in the understanding of the behaviour of soil during the earthquake, we are far from knowledge about final solution to the problem and hence research in this field is still necessary. The study of all of these phenomena is the task of the dynamics of the soil, and the most precious experience should be from the analysis of impacts on the buildings after past earthquakes.

It should be borne in mind that the structures are primarily designed to transfer vertical loads, while during an earthquake the horizontal loads are dominant. Integral acting of both the vertical and horizontal structural elements can be achieved only by proper concept of their development in the frame of a system.

Acknowledgment

This research is supported by the Ministry of education, science and technological development of the Republic of Serbia for project cycle 2011-2015, within the framework of the project TR36016 “Experimental and theoretical investigation of frames and plates with semi-rigid connections from the view of the second order theory and stability analysis" and TR36028 "Development and improvement of methods for analyses of soil-structure interaction based on theoretical and experimental research" of the research organization The faculty of civil engineering and architecture of University of Nis.

REFERENCES

[1] Milović D., M. Đogo. Issues of interaction soil-foundation-structure, Serbian Academy of Sciences and Arts, Branch in Novi Sad, Novi Sad, 2009. (in Serbian)
[2] Pavićević B. Non-seismic design and management of earthquake risk, University of Montenegro, Podgorica, 2000. (in Serbian)
[3] Zdravković S., D. Zlatkov, P. Petronijević. The most common manifestation on the ground due to strong earthquakes, 2nd International Scientific Meeting, GTZ 2012, Tuzla, 2012.
[4] Aničić D., P. Fajfar, B. Petrović, AS-Nossan, M. Tomažević. Earthquake Engineering-Buildings, Gradjevinska knjiga, Belgrade, 1990. (in Serbian)
[5] Romić N., S. Zdravković, V. Prolović, B. Mladenović, A. Šutanovac. Wave propagation through the ground during an eartquake, Procedings, 13th International Scientific Conference, VSU '2013, Vol.1 VI-90-95, Sofia, Bulgaria, 2013.

COUPLED APPROACH IN SIMULATION OF SOIL CONSOLIDATION

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***Abstract**: The aim of this paper is to present a mathematical framework and its corresponding coupled finite element discretization for fully saturated porous media. The model is developed as a coupled displacement-pressure formulation in which the porous medium is composed of a soil skeleton and water in the pores. The considered problem in this paper is the consolidation of a saturated soil layer subjected to uniform pressure at the top. The coupled mathematical model addressed in this work considers both drained and undrained boundary conditions in the consolidation problem. The consequent mathematical model involves equations of mass and momentum balance for the whole system. Interesting outcomes are achieved from the numerical simulation and results are discussed thoroughly.*

***Key words**: Consolidation, finite elements, porous media*

1. Introduction

In geotechnical problems the geo-materials are considered by taking into account both the mass transport and flux equations. This part of geomechanics considers the transport problems in aquifers, displacements due to soil consolidation, design of safe containers etc. Simulation of such problems using the finite elements includes the full interaction of the pore pressure with the soil skeleton. It is to be stated that these models based on fully coupled formulation require the simultaneous solution of fluid flow equation and equilibrium equations in terms of displacements. Thus the degrees of freedom per node correspond to both displacement and pore pressures. The soil medium has various components such that it can be also called a multiphase body. It follows that observed at a macroscopic scale soil media can be considered as mixtures [1]. A detailed description of the porous media is not the scope of this paper although consolidation problem has been taken into consideration. The consolidation problem of a soil layer is known since the work of Terzaghi[2] and Biot [3]. In classical fully saturated consolidation the boundary

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conditions are drained during the entire calculation while the flow of water out of the region of interest is considered. In the work of Zienkiewicz [4] it is shown that any constitutive relations of the soil skeleton can be defined incrementally since it is assumed that changes in the pore pressure do not cause any strain change in the porous solid material. In the literature different versions of effective stress principles are proposed [5]. Therefore, the effective stress principle in saturated soils is considered following the work of Verruijt [6].

In the present work, the analysis of water flow through saturated soil, coupled with the mechanical behavior of the soil skeleton is considered. A mathematical framework assuming porous medium in which the voids of the medium are filled with water is considered and the solution of the partial differential equation system is solved using the finite element method. The numerical model involves both momentum and mass balance equations.

2. Governing equations

In saturated porous media the governing equations considering the dynamic problem are the mass balance and the momentum conservation equations. Following the work of Oettl [7] the momentum balance and mass conservation equations of fluid saturated medium are combined yielding the following two equations.

(2.1) $$\nabla \cdot \dot{\mathbf{u}} + \left(\frac{1-n}{K_s} + \frac{n}{K_f} \right) \dot{p} + \nabla \cdot \mathbf{v} = 0$$

(2.2) $$\rho \ddot{\mathbf{u}} = \nabla \cdot \boldsymbol{\sigma} + \rho \mathbf{b}$$

In equation 2.1 the term $\dot{\mathbf{u}}$ stands for the solid velocity, K_s and K_f denote the bulk modulus of solid and fluid phases. In equation 2.2 the term $\ddot{\mathbf{u}}$ is the acceleration of the solid phase, **b** is the body force and $\boldsymbol{\sigma}$ is the Cauchy stress tensor. The term ρ denotes the density of the medium and can be written as

(2.3) $$\rho = (1-n)\rho_s + n\rho_f$$

In equation 2.3. the terms ρ_w and ρ_s denote the densities of water and solid phases. The effective stress tensor is given as:

(2.4) $$\boldsymbol{\sigma}' = \boldsymbol{\sigma} - p\mathbf{I}$$

The relative fluid velocity **v** is governed by the Darcy's law and can be written as:

(2.5) $$\mathbf{v} = -\frac{\mathbf{k}}{\rho_f g} \cdot \left(\nabla p - \rho_f \mathbf{b} + \rho_f \ddot{\mathbf{u}} \right)$$

where **k** is the permeability tensor, g is the gravity and ∇p is the gradient of pressure.

In order to derive the finite element matrices the weighted residual method is applied to the formulas above. The displacement vector **u** of the solid skeleton and the pore pressure **p** are chosen as the basic variables of the problem. The finite element discretization in space is presented by the following system of equations:

(2.6) $$\begin{bmatrix} 0 & 0 \\ \mathbf{C}_{\mathrm{sw}}^{\mathrm{T}} & \mathbf{P}_{\mathrm{ww}} \end{bmatrix} \begin{bmatrix} \dot{\mathbf{u}} \\ \dot{\mathbf{p}} \end{bmatrix} + \begin{bmatrix} \mathbf{K} & -\mathbf{C}_{\mathrm{sw}} \\ 0 & \mathbf{H}_{\mathrm{ww}} \end{bmatrix} \begin{bmatrix} \mathbf{u} \\ \mathbf{p} \end{bmatrix} = \begin{bmatrix} \mathbf{f}_{\mathrm{u}} \\ \mathbf{f}_{\mathrm{w}} \end{bmatrix}$$

In the equation 2.6 the matrix $\mathbf{C}_{sw}$ stands for coupling between solid and water phases. The matrix **P** stands for compressibility, matrix **H** for permeability. More detailed explanation for the derivation of the constituent matrices can be found in the work of the author [8].

3. Numerical examples

The coupled finite element method has been implemented into the finite element software ANSYS [9]. As a verification example a consolidation problem for water saturated soil is simulated. Similar investigations concerning the consolidation of a saturated soil layer have been done in the works of other authors such as Hwang [10], Fredlund [11], Oettl [12] etc. The application of the proposed model is tested in a problem of elastic consolidation for which two different initial boundary conditions are defined. The model used in this example is taken from the work of Oettl [12]. In this example a consolidating soil layer with a height of 8.0m is taken into consideration. In the horizontal direction the model has a width of 40.0m. The length of the loaded area is long as the depth of the soil layer. The lower boundary is fixed while on the side boundaries the horizontal displacements are impeded. Considering the coupled analysis, the water flow is not allowed on the bottom and side boundaries. The contact of soil layer and the applied stress on the top boundary is considered as a) drained and b) undrained boundary conditions. The boundary and initial conditions are given in the figure below:

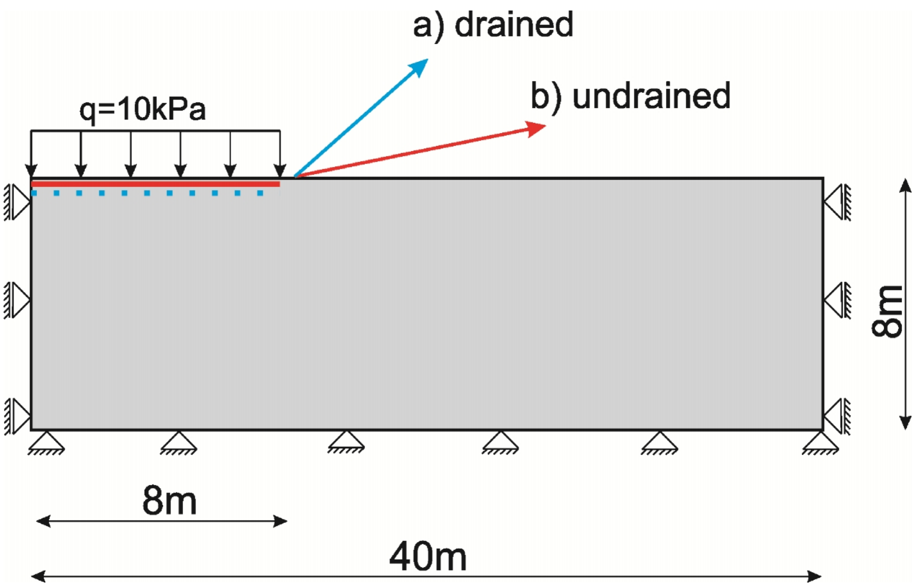

Fig. 1. Model of soil layer with boundary conditions

The initial stress that is applied on the soil layer is a uniform stress of 10 kPa. The consolidation analysis of the soil layer is done until the water has flowed out totally from the soil layer. In the numerical simulation the consolidation analysis is performed for 1000 seconds. The soil layer parameters are given in the table below.

Two cases of analysis are performed. In the first case a drained boundary is considered at the top layer.

In the second case the same domain is simulated by applying undrained boundary conditions on the region where force is applied. In both cases analysis has been performed beginning from time t=0.001seconds. The results concerning the pore pressure for both cases are given in Fig. 2 below. As can be seen from the Fig. 2 in the case of drained boundary there is sudden increase in the pore pressure at the mid height of the soil layer. On the other hand, in the undrained case the sudden increase in the pore pressure is hindered although there is an increase in the pore pressure. This clearly shows that in the case of drained boundaries the load is carried by the water in the pores totally. In the undrained case the load carrying is shared between the solid particles and water in the pores.

Table 1. Material properties for analysis of soil consolidation

Young’s modulus of elasticity	E = 5000 kPa
Poisson’s ratio	$\nu = 0.1$
Density of solid phase	ρ=2.7ton/m^3
Density of water	ρ= 1.0ton/m^3
Initial porosity	$n = 0.5$
Permeability	$k = 1.5 \times 10^{-13}$ m/s

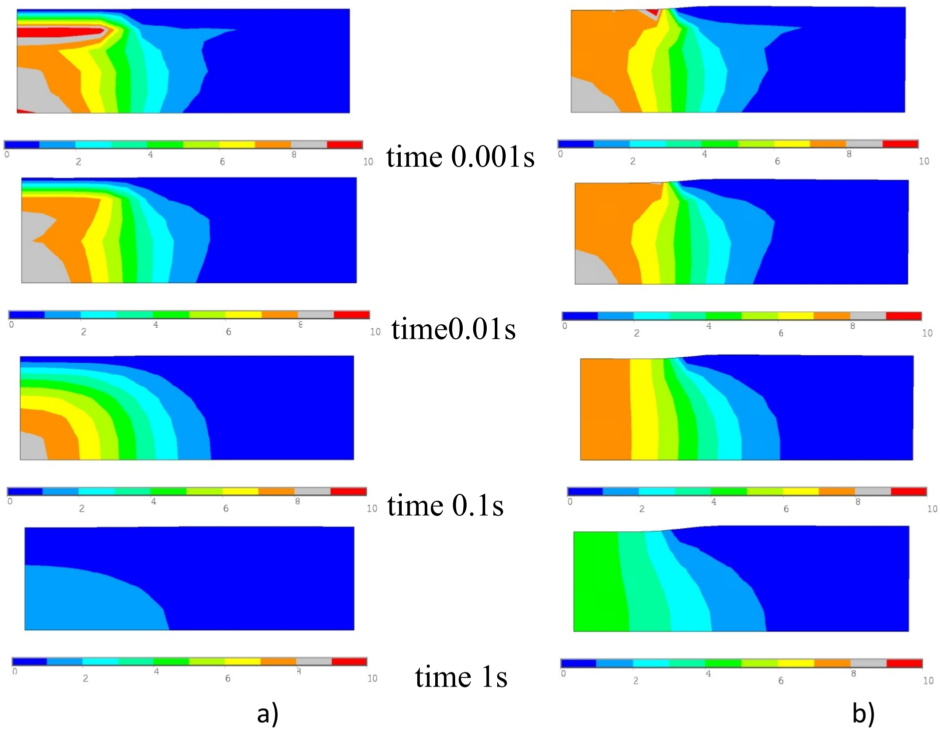

Fig. 2. Development of pore pressure in consolidation process

When concerning the effective stress development during the consolidation stage the effective stress development through time takes longer than in the case of drained boundary conditions.

From Fig.3 it is seen that the effective stress in consolidation stage of drained and undrained boundary conditions reveal the same end result although the time to reach the final effective stress is different. This is due to the boundary conditions of the consolidation process. In the first case of drained boundary condition the time needed for total consolidation is 2 seconds. On the other hand, in the case of undrained boundary conditions the time needed for total consolidation is 10 seconds. The stress distribution is in correlation with the deformation during the consolidation process.

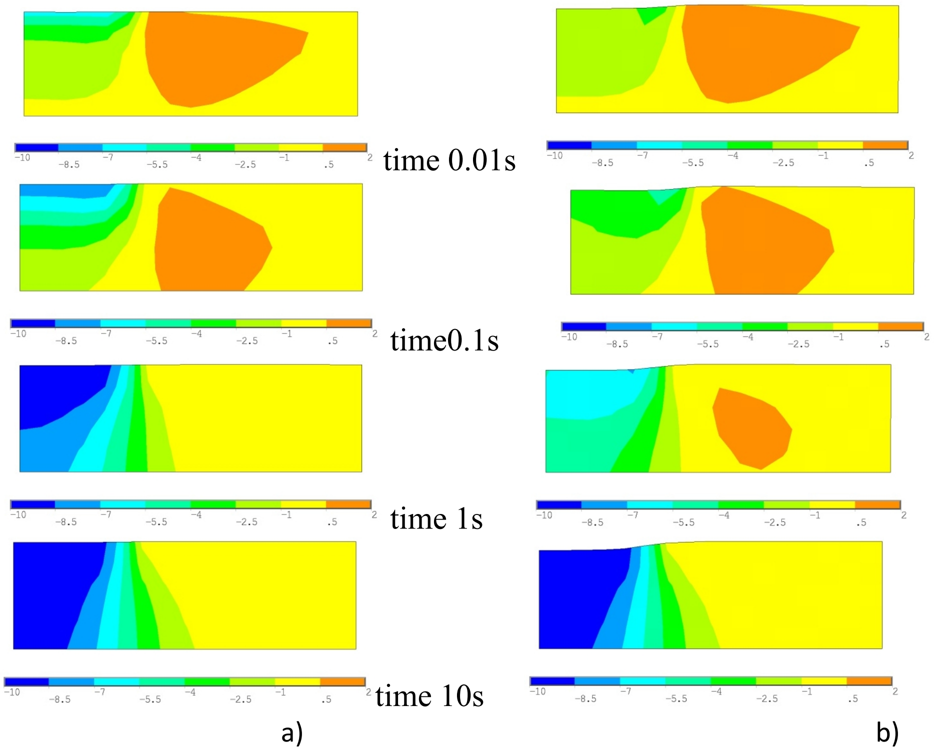

Fig. 3. Development of effective stress in consolidation process

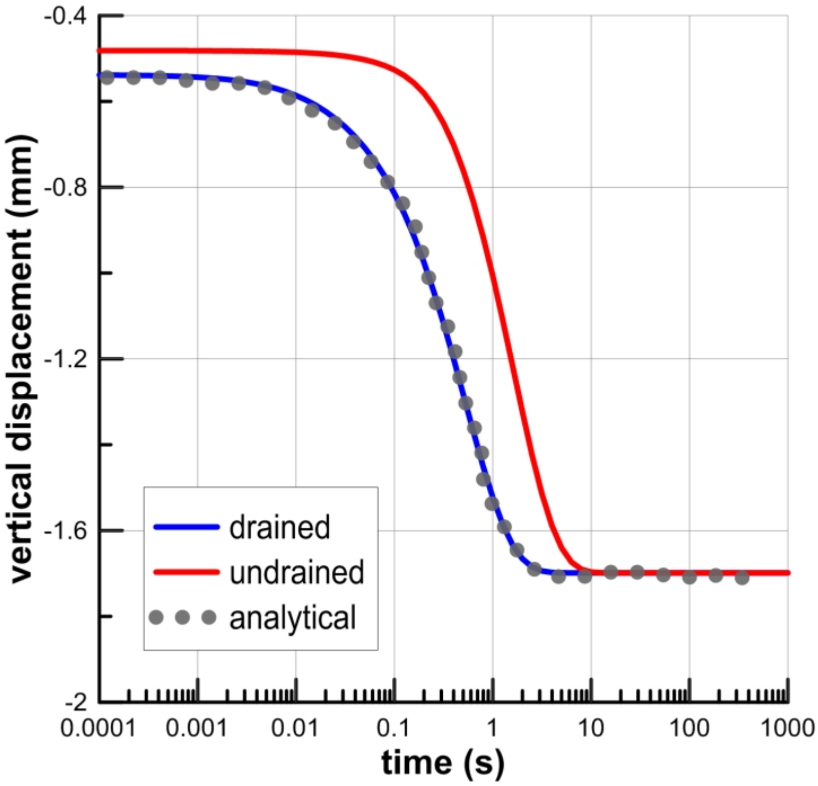

Fig. 4. Comparison of vertical displacement in drained, undrained and analytical results

As can be seen from Fig. 4 the consolidation at the end time has the same value in both cases of drained and undrained boundary conditions. The difference is in the time to develop the final consolidation. The obtained values correspond with the analytical results as given in the work of Lewis et. al [13]. Thus it can be stated the model predicts the analytical values in a good manner. The difference in vertical displacement development time proves the correctness of the applied numerical model.

Conclusion

In this paper a numerical model concerning the porous medium is presented by considering the interaction between the solid displacement and pore pressure in porous medium. The model is applied to a plane strain consolidation of a saturated soil layer subjected to uniform loading at the top of the soil layer. The investigation in this particular paper has shown that the boundary conditions do play an important role in defining the consolidation of the soil layer. As can be seen from the results the drained boundary at the contact with the applied force consolidates faster when compared with the undrained boundary condition. Although the end results are same the development of the effective stress development at a point in a saturated medium depends on the pore pressure at that particular point. A conclusion section is not required, although in the conclusion the main points of the paper may be reviewed. Do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

REFERENCES

[1] Alcoverro, J., The effective stress principle. Mathematical and Computer Modelling, 2003. 37(5–6): p. 457-467.
[2] Terzaghi, K., Theoretical soil mechanics. 1943.
[3] Biot M.A., Theory of elasticity and consolidation for porous anisotropic solid. Journal of Applied Physics, 1955. 26(2),: p. 182-185.
[4] Zienkiewicz, O.C., C. C.T., and P.Bettess, Drained, undrained, consolidating and dynamic behaviour assumptions in soils. Geotechnique, 1980. 30(4): p. 385-395.
[5] Boer, R. and W. Ehlers, The development of the concept of effective stresses. acta mechanica, 1990. 83(1-2): p. 77-92.
[6] Verruijt, A., Consolidation of Soils, in Encyclopedia of Hydrological Sciences2006, John Wiley & Sons, Ltd.
[7] Oettl, G., R. Stark, and G. Hofstetter, Numerical simulation of geotechnical problems based on a multi-phase finite element approach. Computers and Geotechnics, 2004. 31(8): p. 643-664.
[8] Edip, K., Development of three phase model with finite and infinite elements for dynamic analysis of soil media, 2013, Ss. Cyril and Methodius: Institute of Earthquake Engineering and Engineering Seismology.
[9] ANSYS. Fem Software. 2006.
[10] Hwang, C., N. Morgenstern, and D. Murray, On solutions of plane strain consolidation problems by finite element methods. Canadian Geotechnical Journal, 1971. 8(1): p. 109-118.
[11] Fredlund, D.G. and J.U. Hasan, One-dimensional consolidation theory: unsaturated soils. Canadian Geotechnical Journal, 1979. 16(3): p. 521-531.
[12] Oettl, G., A Three-Phase FE-Model for Dewatering of Soils by Means of Compressed Air, 2003, Universitaet Innsbruck.
[13] Lewis, R.W. and B.A. Schrefler, The finite element method in the static and dynamic deformation and consolidation of porous media,1998: Second Edition, Wiley Verlag.

COMPARISON OF COLUMN FOOTINGS PUNCHING RESULTS OBTAINED BY CALCULATION ACCORDING TO THE REGULATIONS AND THE RESULTS OBTAINED IN THE EXPERIMENT

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***Abstract**: The paper presents a review of calculation of punching shear according to actual Regulations and review the experimental tests in the field of punching shear of reinforced concrete column footings worldwide. Punching shear of column through the slab is usually related to flat slabs, and less for slabs of the column fotings. Calculation models for these two issues often are not separated. The deficit of experimental results on column footings causes using of models for flat slabs. Also, the experiments on footings have been rare so far, and they were performed in laboratories, where soil was simulated in various ways. The goal of this research is to perform the punching shear experiments in the circumstances which are as close as possible to real conditions both in terms of the footings, and in terms of the soil. In the paper, the fundamental concept of preparation of experimental tests that were carried out on the test specimens – column footing on the real soil under ultimate load has been presented. The test specimens have been described, as well as the applied materials, preparation of the subgrade soil, measuring equipment, and planned testing method.*

Obtained results were compared with the calculation results according to different Regulations. Recommendations and directions for future research were outlined.

***Key words**: punching, shear stresses, foundations, codes, experiments, comparative analysis*

1. Introduction

In statical sense column reinforced concrete footings are slabs loaded by dead-weight, by pressure forces from the structure, and by reactive distributed load of the soil. Bending of the footing due to reactive load leads to emergence of cracks in concrete and in case of heavy loadings to extrication of a body whose form is something between the truncated pyramid and the truncated cone from the footing. In the literature it is said that

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there was punching of footing. Checking of security of footings to punching is an obligatory part of footing design and focuses on control of the shear stress in the control cross-section. Factorized shear force should be determined by subtracting the part of soil reaction within the control cross-section. The subtracted value differs depending on the methods of calculation, adopted position and shape of control cross-section, and varies in the regulations of individual countries. Most codes do not distinguish between punching of the flat slabs and of the footings .

Previously presented overview indicates the need for comparative provision analysis of certain regulations themselves and with experimental results. This paper gives a brief overview of some of the experimental results realized on column footings, and provisions of different regulations for their comparative analysis. The comparative analysis included the Code for technical norms for concrete and reinforced concrete BAB'87 which until recently was used in the countries of our region and it is implemented in a large number of objects; American ACI 318-02 [1]; British BS 110-1-1997 [16]; German DIN 1045-1 [12]; European EN 1992 EC-2 [5] and Russian regulations SNiP-84 [14]. In this paper, a modified model based on the Model Code (*fib*) [4, 7] and EN 1992-1: 2004 and Eurpoean Concrete Platform from 2010. [6] was proposed.

Mutually comparison of these regulations is carried out based on the results of experimental tests of the column footings punching on a subgrade of gravel.

2. Review of conducted experiments

According to the scientific literature data, only a few experiments with footings in real soil were performed until now [9], [10]. Main reason for that is considerable material cost and complex organization of the experiment, so in the majority of other experiments natural subgrade soil under footing simulated by springs (Talbot, 1913), [15], by small hydraulic jacks or by simple line load on the contact surface of the footing (Hallgren et al., 1998), [8]. Punching testing based on realistic subgrade practically implemented only Hegger and others [9], [10] - in a box of sand and Rivkin [13] - on clay and sand *in situ*. Dates about geometric characteristics, the number of tested footings, and way of resting are clearly arranged and presented in Table 1.

Table 1. Properties of tested column footings (literature data)

Author	Year	Type of support	Number of footings	Geometry of footing		
				Shape	Dimension [mm]	Effective depth [mm]
Hegger and Ricker	2005	Sand in the box	5	quadratic	900	150 to 250
Timm	2003	Line	10	quadratic	760 to 1080	172 to 246
Hallgren	1998	Line/Surface	14	quadratic and circular	850 to 960	273 to 278
Dieterle and Rostasy	1987	Surface	13	quadratic	1500 to 3000	320 to 800
Kordina and Nölting	1981	Surface	11	rectangular	1500 to 1800	193 to 343
Dieterle and Steinle	1981	Surface	6	quadratic	1800 to 3000	700 to 740
Rivkin	1967	Surface /clay and sand	6	quadratic	650 and 1000	120
Richart	1948	Spring	149	quadratic and circular	610 to 3000	200 to 740
Talbot	1913	Spring	20 (in punching)	quadratic	1520	250

In the following a brief overview of the punching calculations of column footings in some current technical regulations is given and thus described methods are used in the original experimental tests of footing punching [2, 3].

3. Overview of calculation methods according to the technical regulations

The fact that none of calculation models is generally accepted has led to considerable variation in the recommendations of actual international and national codes. In most of the them semi-empirical method of critical cross-section in calculation of capacity of slabs or foundation is represented. This method is based on the assumption that the footing is punched when a vertical fracture cross-section throughout the perimeter of penetration body is formed near the column. This cross-section is called a critical or control section with length of perimeter *u*.

Based on this, the punching calculation comes down to the control of shear stress in the critical section, and compare the shear calculating stress in the control section τ_{cal}, at some distance from the edges of the column, with the the punching shear resistance v. If the requirement $\tau_{cal} < v$ is fulfilled there is no danger of punching, otherwise shear reinforcement should be mounted to prevent punching.

Calculation shear stress at punching into the critical section τ_{calc} for column footings is calculated according to

(1) $$\tau_{calc} = \frac{P_{u,red}}{O_{cs} \cdot d}$$

where:

O_{cs} – perimeter of critical (control) section

d – effective cross section depth (mean value of two perpendicular directions).

Regulations permit the normal boundary force in column P_u reduces for the part of soil reaction beneath the punching body according to the expression

(2) $$P_{u,red} = P_u - A_0 \cdot \sigma_n$$

where:

σ_n – net reactive soil pressure at the contact surface (without dead weight of footing)

A_0 – surface area of a basis of punching body in the plane of reinforcement

Regulations for calculating boundary shear stress at punching in the control section are very varied as illustrated in Table 1. In addition, the regulations are very different from each other when determine the position and shape of the control section as presented in Figure 1. Control sections from different regulations are used for comparative analysis.

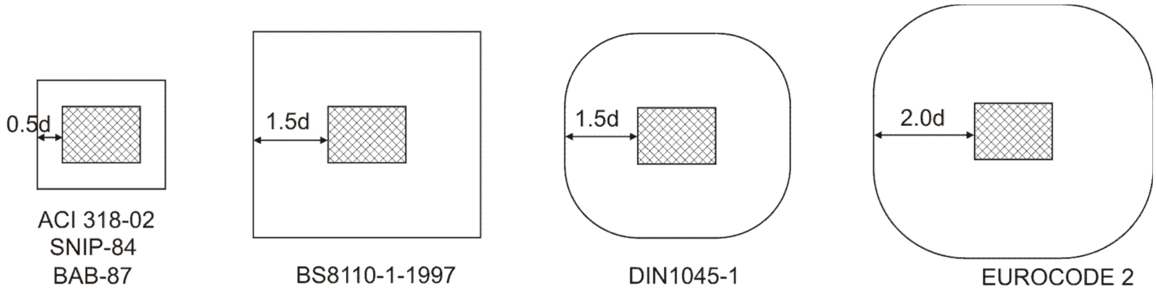

Fig. 1. The control section in some Regulations depending on the effective footing depth *d*

Table 2. Calculation methods of boundary shear stress according to different Regulations

Eurocode 2 [5]	**ACI 318-02 [1]**
$v = C_{Rd,c} \cdot k \cdot (100 \cdot \rho_t \cdot f_c)^{1/3} \dfrac{2d}{a_{EC2}} \geq v_{min} \dfrac{2d}{a_{EC2}}$ (3) $C_{Rd,c} = 0.18 / \gamma_c$ γ_c - material resistance factor for concrete $k = 1 + \sqrt{\dfrac{200}{d}} \leq 2.0$ ρ_t - flexural reinforcement ratio a_{EC2} – distance from the loaded area to the control perimeter	$v = min \begin{cases} 0.083(2 + \dfrac{4}{\beta_c})\sqrt{f_c} \\ 0.083(2 + \dfrac{\alpha_s \cdot d}{b_0})\sqrt{f_c} \\ 0.332\sqrt{f_c} \end{cases}$ (4) $\alpha_s = 40$ for interior column $\alpha_s = 30$ for edge column $\alpha_s = 20$ for corner column
BS 8110-1: 1997[16]	**SNIP-84 [14]**
$v = \dfrac{0.79}{\gamma_m}(100\rho_s)^{\frac{1}{3}}(\dfrac{400}{d})^{\frac{1}{4}}(\dfrac{f_{cu}}{25})^{\frac{1}{3}}$ (5) γ_m - parcijalni koeficijent sigurnosti ρ_s - flexural reinforcement ratio f_{cu} - characteristic cube compressive concrete strength	$P_{u,red} = \alpha \cdot R_{bl} \cdot u_m \cdot d$ (6) α - coefficient of conrete characteristics (1.0 for normal weight concrete) R_{bl} - calculation strength of concrete to axial tension u_m - mean circumference of the upper and lower bases of the punching pyramid/cone $u_m = 2(b_c + l_c + 2d)$ b_c, l_c - dimensions of the column at basis
BAB 87 [17]	**DIN 1045-1 [12]**
$v \leq \dfrac{2}{3}\gamma_1 \cdot \tau_a$ (7) $\gamma_1 = 1.3 \cdot \alpha_a \cdot \sqrt{\mu}$ μ - mean value of flexural reinforcement ratio of two perpendicular directions α_a – coefficient depends on the type of reinforcement τ_a - limits of permissible main tensile stresses	$v_{Rd,ct} = \left(\dfrac{0.21}{\gamma_c}\eta_l \cdot k(100\rho_l \cdot f_{ck})^{1/3}\right)$ (8) γ_c - material resistance factor for concrete (1.50) $\eta_l = 1.0$ for normal weight concrete ρ_t - flexural reinforcement ratio

d – effective depth of footing; f_c - characteristic cylinder compressive concrete strength; b - perimeter of critical section

4. Conducted experimental investigations

Schematic of the experimental setup for the implementation of the experiment which consists of the test frame, a test specimen – column footing, hydraulic jack and prepared the subgrade is shown in Figure 2. Experiments were conducted during 2009-th year.

The test frame was placed in the bottom of the prepared footing pit with dimensions 4.0x5.0 in base and 3.0 m deep. Over the bottom of the frame, 3.5x3.5 m in base, gravel layers of 30cm are poured and compacted by plate vibrator to the required values of the

Modulus of compressibility. Compaction of each layer was controlled by circular plate test. The measured mean values of the Modulus of compressibility in layers were in the range of 43.3 to 66.7 MPa, corresponding to normal compaction of subsoil. Compaction of subgrade is controlled before each footing testing and it was between 39.5 MPa and 76.7 MPa.

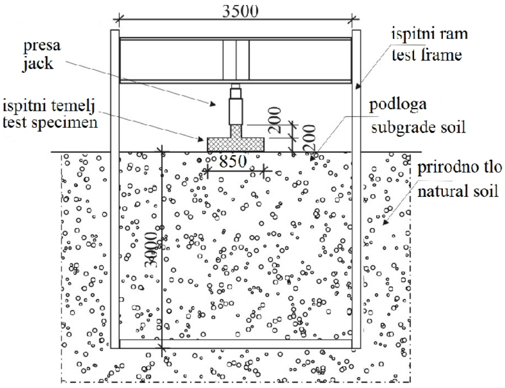

Fig. 2. Schematic of experimental setup

Fig 3. Experimentally testing in situ

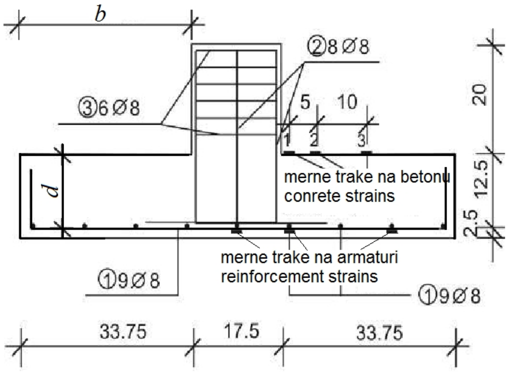

Fig 4. Dimensions and reinforcement of some foootings

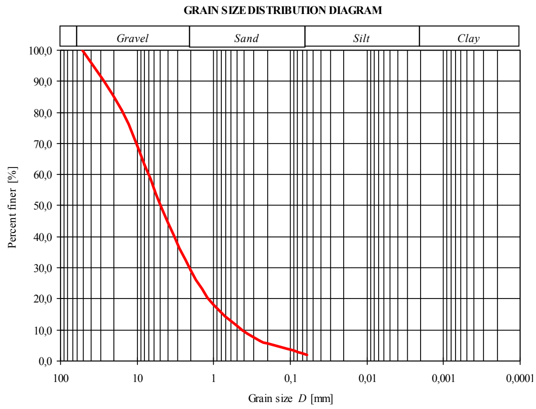

Fig. 5. Particle size distribution of gravel

Truss structure of the frame, as well as its dimensions provided undisturbed formation of sliding surfaces in the soil beneath the foundations, in the course of loading, the soil failure preceded the punching shear. This setup allowed footings testing with completely realistic boundary conditions in terms of soil and also comparison and verification of earlier testing results in laboratories with testing *in situ*.

Adopted footing dimensions are 85x85cm in basis and correspond to Kinnunen and Hegger's experiments and others [3-4], because of mutually comparing of results and also correspond to capacity of available measuring equipment (approximately 1000kN). The dimensions and characteristics of the footing are given in Table 3 and shown in Figure 4.

Concrete compressive strength at the time of testing was obtained from the cube specimens with edges of 15cm and standard cylinders and their averaged and calculated values for the cube with edge of 15cm are given in Table 3.

For reinforcement of the footings, 8 mm diameter steel bars were used, and the percentage of reinforcement was approximately 0.4% for all footings. The characteristics of used steel were determined on three samples of used reinforcement. The obtained mean values were: tensile strength f_{su}=653 MPa, yield point f_{sy}=570 MPa and corresponding yield strain $\varepsilon \approx 2.7‰$.

Table 3. Characteristics of tested footings (test specimens)

Footing N°	Footing depth h [cm]	Effective depth d [cm]	Concrete strength fc,cube [MPa]	Bar size [mm]	Reinforcement ratio [%]	Failure force [kN]
TI	20	17.5	38.37	8	0.40	1001/906*
TII	15	12.5	38.37	8	0.40	1050
TIX	12.5	10.0	21.25	8	0.40	430
TX	17.5	15.0	21.25	8	0.40	656
TXI	15	12.5	19.29	8	0.40	451
TXII	15	12.5	10.0	8	0.40	440

* During the first test, the column failed at the load of 1001 kN. After a new column was constructed, the footing was punched through at the load of 906 kN.
** TIII-TVIII were not broken, as their bearing capacity was higher than the capacity of the equipment (1000 kN).

Experimental testing is conducted by placing of footing on the soil surface and loading by vertical centric force which is applied by a hydraulic jack positioned between the steel cross-beam and the footings (Figure 3). For footing loading, a hydraulic jack with the capacity of 1000 kN was used, applying the load in load steps of 50 kN. The load was kept constant at every load step until total consolidation of the ground at that load was achieved. The consolidation was registered by observing the process of vertical displacements of points at the footing corners and on the column of the footings. During the experiment, the following parameters were measured every second: strains in the reinforcement and in the concrete of the footings, vertical displacements of the points at the footing corners and on the column of the footings, intensity of the applied force during loading, and value of contact pressures beneath the footings. More detailed data and test results are given in [2].

5. Implementation of regulations in the calculation of tested specimens

In order intercomparisons, as well as for comparisons between the results obtained by applying the regulations to the results of conducted experimental investigations the boundary axial force in the column for the tested footings from Table 3 are calculated.

Calculation of the boundary axial force in the column is made with the actual characteristics of the material and it is assumed that the safety factors relating to the material (concrete) are equal to one.

For the tested footings based on boundary axial force in the column after the transformation, based on equation (2) can be determined according to the formula:

$$(9)\qquad P_u = P_{u,red}\,\frac{A}{A - A_0} = \frac{P_{u,red}}{1 - \dfrac{A_0}{A}}$$

where A is area of footing basis.

All regulations defines the shape and position of the control section, which is bounded surface A_0, so the capacity of control section can be calculated as follows:

$$(10)\qquad P_{u,red} = v \cdot O_{cs} \cdot d$$

where:

v – boundary shear stress at punching of the control section of the chosen Regulation,

O_{cs} – perimeter of the control section of the chosen Regulation,

d – effective depth of footing.

In this way, the boundary axial force in the column are calculated for the tested footings with the application of rules and Regulations mentioned in introduction and given in Table 4.

The values in parentheses in Table 4 are safety coefficients i.e, ratio of experimentally obtained and calculated failure load (with actual material properties) $Fs = P_{um} / P_{uc}$. When the value of this ratio is greater than 1.0 Rules/Regulation is conservative and underestimates the bearing capacity of footings, while value is less than 1.0 Rules/Regulations overestimate the bearing capacity of footings.

Table 4. The boundary normal force in the column for some Standards/Regulations in kN

Design method	TI-3	TII	TIX	TX	TXI	TXII
EC2 a_{crit}=2.0d	5013	539(1.95)	195(2.21)	914(0.72)	429(1.05)	345(1.28)
EC2 based on ECP [6]	811	570(1.84)	368(1.17)	531(1.24)	453(0.99)	260(1.7)
DIN a_{crit}=1.5d	584	284(3.70)	153(2.81)	317(2.07)	226(1.99)	181(2.44)
BS a_{crit}=1.5d	1200	401(2.62)	230(1.87)	583(1.13)	376(1.20)	376(1.18)
ACI a_{crit}=0.5d	540	314(3.34)	140(3.07)	311(2.11)	222(2.03)	160(2.76)
СНиП a_{crit}=0.5d	1010	487(2.16)	247(1.74)	514(1.28)	338(1.33)	249(1.78)
BAB 87 a_{crit}=0.5d	482	239(4.39)	104(4.13)	199(3.30)	146(3.08)	101(4.38)
Measured	-	1050	430	656	450	442

Conclusion

Based on the conducted analysis it can be concluded that all current Regulations give conservative results and among them the most rational is EC 2 with the use of the procedure proposed in the ECP [6]. The results clearly indicate the need for improvement - corrections of existing Regulations because, calculated values of the footing bearing capacity, based on them, significantly underestimated so the values of safety coefficients Fs are obtained up to 4.39. It is therefore necessary to examine the impact of various parameters in the calculation of punching capacity of the footings.

Number of tested footings on realistic soil is small to formulate general conclusions. For that it is the need to carry out detailed parametric study on the influence of experimentally observed stress concentration beneath the footings and other parameters that are introduced in the calculation of punching bearing capacity of the footings. This leaves wide space for further experimental research in this direction.

Taking into account the assessment of literature tests it is proposed to be adopted an approximate angle of punching cracks through the footing about 45^0. In paper [9] it was concluded that the density of the sand does not affect on the distribution of contact stresses under the footing and that the adoption of their uniform distribution provides sufficient security against column punching through footing. Also, it was found that the EN less conservative than the ACI 318 who underestimate the influence of the "shear slenderness" on the calculated values.

Some research introduce a probabilistic approach to punching analysis. Thus, punching probability of reinforced concrete footings plate was studied in [11]. Variables were studied: errors of the theoretical model for strength determination, compressive strength of concrete, reinforcing steel strength, cross-sectional dimension and apply load.

Since, in practice we use a safety factor for load 3, it is recommended that it be increased to 4 to the probability of column punching through the plate was less than $1.35x10^{-3}$.

Acknowledgements

The paper is the result of the research project TR 36028 and TR 36016 financed by the Ministry of Education, Science and Technological Development of Republic of Serbia.

REFERENCES

[1] ACI Committee 318: Building Code Requirements for Structural Concrete (ACI 318-02) and Commentary (318R-02). American Concrete Institute, Farmington Hills, Mich., 2002, 443 pp.

[2] Bonić, Z.: A contribution to the failure calculation theory by punching shear of column footings resting on deformable subgrade soil, PhD thesis, Faculty of Civil Engineering and Architecture, Niš, Serbia, 2011, p. 182 (in Serbian).

[3] Bonić, Z., Vacev T., Prolović V., Mijalković M., Dančević P.: Mathematical modeling of materially nonlinear problems in structural analyses (part II – application in contemporary software), Facta Univeritatis, Univerzitet u Nišu, Series Arcitecture and Civil engineering, Vol. 8 N^o 2, 2010, pp. 201-210

[4] CEB –FIP Model Code 1990. Comite Euro-International du beton, Thomas Telford, 1993.

[5] Eurocode 2 (EN 1992): Design of Concrete Structures, Part 1.1: General Rules and Rules for Buildings, Brussels, 2004, 226 pp.

[6] Eurocode 2 – Commentary, Eurpoean Concrete Platform ASBL, Brussels, June 2008.

[7] fib (International Federation for Structural Concrete)-Model Code 2010-Draft, Bulletins 55 and 56, 2010.

[8] Hallgren, M., Kinnunen, S., Nylander, B.: Punching shear tests on column footings, Nordic Concrete Research 21(1), 1998, p.1–24.

[9] Hegger, J., Sherif, A.G., Ricker, M.: Experimental Investigations on Punching Behavior of Reinforced Concrete Footings, *ACI Structural Journal*/July-August 2006, p. 604-613.

[10] Hegger, J., Ricker, M., Ulke, B., Ziegler, M.: Investigations on the punching behavior of reinforced concrete footings, *EngineeringStructures* 29, 2007, p. 2233–2241.

[11] Lu, W.Y.: Failure probabilities of reinforced concrete column footings, Journal of the Chinese Institute of Engineers, Vol. 29, N0. 4, 2006, pp. 733-739.

[12] Reinforced and Prestressed Concrete Design according to DIN 1045-1. InfoGraph, Dortmund, Germany, 2010.

[13] Rivkin, S.: Calculation of Foundations, Budivel'nik, 1967 (in Russian).

[14] SNiP 2.03.01-84: Concrete and Reinforced Concrete Structures Design Codes, Moscow, 1985, 77 pp. (in Russian).

[15] Talbot, A.N.: Reinforced Concrete Wall Footings and Columns under Concentrated Loads. Research and Development Bulletin D47, Illinois, 1913.

[16] Theodorakopoulos, D.D., Swamy, R.N.: Ultimate punching shear strength analysis of slab–column connections. Cement & Concrete Composites 24, 2002, p. 509-521.

[17] The Yugoslav Regulation of technical standards for concrete and reinforced concrete (1987)

EXPERIMENTAL INVESTIGATION OF THE POSSIBILITY OF USING BETONBLOCK ELEMENTS IN ROAD CONSTRUCTION

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***Abstract**: In modern construction practice, for solving of terrain instability along the road, in addition to conventional rigid retaining walls, we have been increasingly using flexible support structures of mechanically stabilized earth, gabions and precast elements. Although widely used only recently, their benefits are proven and widely accepted. The first part of the paper gives an overview of the possible ways of using of precast betonblock elements in the construction of retaining walls. The second part gives a detailed overview of the conducted experimental examination of the stability of retaining walls of precast betonblock elements. Their aim was to test the behavior of the retaining wall of precast betonblock elements due to the static impacts. The obtained results are analyzed and given recommendations for use in practice.*

***Key words**: retaining walls, precast elements, betonblock elements, experimental testing, test points*

1. Introduction

Retaining structures are permanent or temporary, solid or parsed structures whose main task is to support or prevent the collapse of the steep terrain cuts as well as material slopes in the embankment. They allow a sudden change of ground level in order to obtain available space for performing foundation pits, providing side cuts, road embankments, bridge abutments, dock walls, navigation locks, repositories, etc.. For this purpose, in addition to conventional rigid walls (stone, concrete and reinforced concrete) and flexible retaining structures (sheet piles, diaphragms, geotechnical anchors, pile walls), now

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increasingly use modern structures of reinforced earth, gabions and precast concrete and reinforced concrete elements.

2. Retaining walls of precast betonblock elements

Landslides and mudslides are frequent along the roads after the winter months, when there is snow thawing and soil unfreezing. This results in increase in the content of water in the soil and consequently increase in the soil weight, reducing the cohesion and the formation of the sliding surfaces. The most common cause of these phenomena is inadequate drainage of surface water above and below the road. The result of these processes is backfilling or abruption of road segments or disabling its basic function.

In these conditions, it is very important to choose such the measures of rehabilitation that would in a fast, efficient and reliable manner restore the road to its functional state at a low cost. Retaining structures that best meet the above requirements are retaining walls of reinforced earth, gabions and precast elements. Retaining walls of precast elements are a cheap, simple and visually attractive solution. They are based on the principle of dry construction, usually without the use of fresh concrete and the construction of the footing of the retaining wall. This significantly reduces the time and cost of construction, allowing easy construction in all weather conditions, which are important factors in selecting the type of the retaining structures.

The basic unit of the retaining walls of precast betonblcok elements is a concrete block whose dimensions can vary considerably. The "Putinženjering" from Nis produces blocks of dimensions 150 x 60 x 60 cm (Fig. 1).

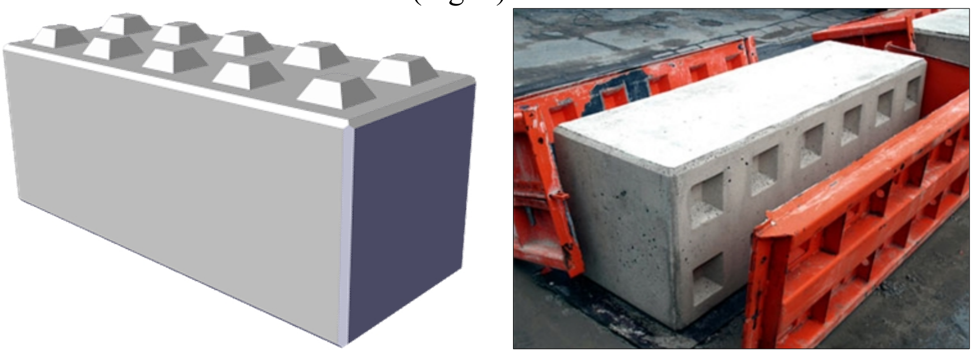

Fig. 1. The basic unit of the retaining walls of precast betonblok elements

Considering that the blocks are laid as "Lego" blocks, possibility of using bricks are very broad: in addition to retaining walls they are also used for partition walls in storages and in various temporary structures: halls, fences, barriers to block and routing traffic, flood control, etc. Some of the numerous possible applications of betonblock elements are shown in Fig. 2.

3. Experimental investigations

In order to examine the possibility of using betonblock elements in the construction of retaining walls, Geotechnical Laboratory of Faculty of Civil Engineering and Architecture, University of Nis, has conducted experimental investigations within the manufacturing plant of "Putinženjering" a.d. Niš. The aim of the conducted experimental investigations was to test the behavior of the retaining wall of precast betonblock elements due to the static impacts.

3.1. Testing of the retaining wall of precast betonblock elements

The experiment was aimed to reproduce the real situation in situ in the case of gravity retaining wall when the space behind the wall filled with coarse material, which is a common request in the case of retaining walls along the roads. Model of the wall of precast betonblock elements is made on a concrete base, in situ in the ratio of 1:1, with length of 15.00m and height of 2.40m or 4 rows of blocks. The space behind the wall is filled with coarse crushed aggregate in fraction of 0/32 mm. Material embankmented to a height of 0.90m first, when the first measurement of horizontal displacements of points on the wall was made, according to Figure 3. Horizontal displacements of characteristic points of the wall are registered by surveying instruments - total station SOKKIA Set 630R [1].

Fig. 2. Different ways of using of precast betonblock elements

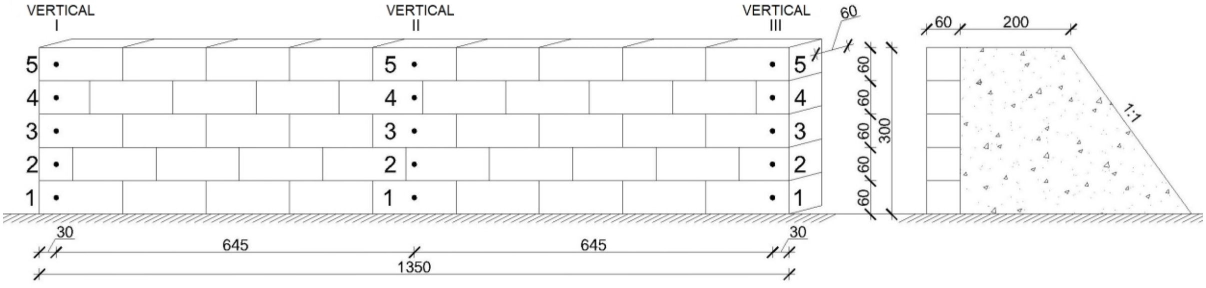

Fig. 3. Measurement points on the experimental model

After that filling the space behind the wall is continued to the height of the wall, i.e. to the height of 2.40m, when new horizontal displacements of the same points on the wall are registered. Since small displacements of the wall are registered, another row of betonblock elements is placed, i.e. the height of the wall of 3.00m is reached (Fig. 4 right).

Fig. 4. Some phases of the experiment (investigating the retaining wall on the static influences)

The space behind the wall is filled with material to the height of the wall again and new horizontal displacements are measured. Summary of measured horizontal displacements of the characteristic points of the wall is shown in Table 1, and their graphical representation is given in Figures 5 and 6. Figure 5 presents measured horizontal displacements of characteristic points of all three verticals. From Figure 5 it can be seen that the difference between the largest and smallest horizontal displacements of points at the same elevation are small as it was expected and remains approximately constant with height of the wall. Figure 6 shows the lines of horizontal displacements of points of the wall at a height 0.30 m, 0.90 m 1.50 m. It may be noted that the lines of horizontal movements of the points approximately parallel, which means that the horizontal movement of the wall uniformly increases with the height of the wall.

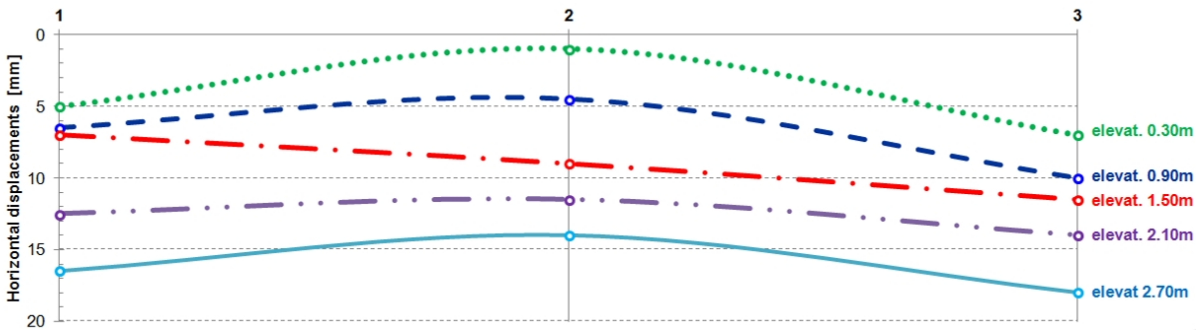

Fig. 5. Lines of points of horizontal movements of the wall at different heights

Table 1. Registered horizontal displacement of the wall

Vertical	Mark of the measurement points	Height of the measurement points [m]	Horizontal displacements [mm]
I	1	0.30	5.0
	2	0.90	6.5
	3	1.50	7.0
	4	2.10	12.5
	5	2.70	16.5
II	1	0.30	1.0
	2	0.90	4.5
	3	1.50	9.0
	4	2.10	11.5
	5	2.70	14.0
III	1	0.30	7.0
	2	0.90	10.0
	3	1.50	11.5
	4	2.10	14.0
	5	2.70	18.0

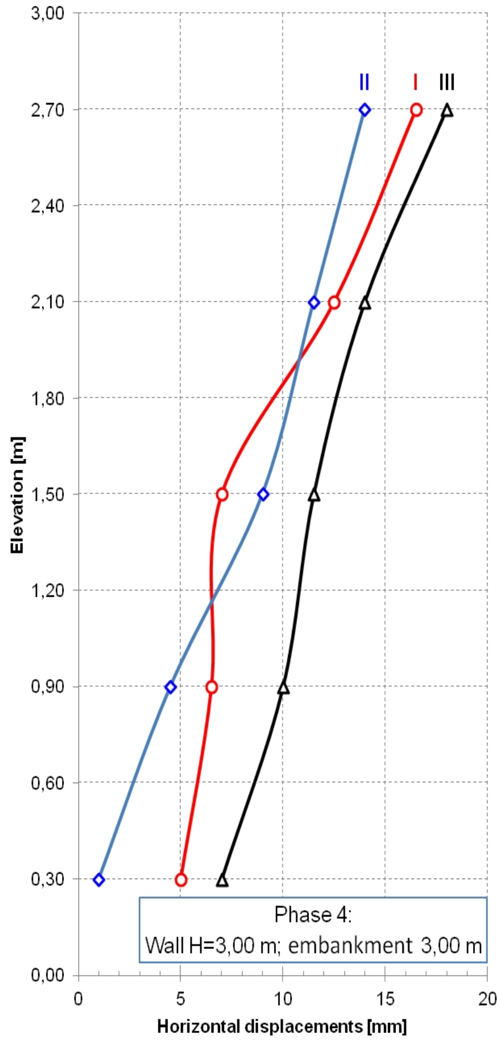

Fig. 6. Registered horizontal displacements of the wall at all measuring points

Conclusion

Experimental testing of the retaining wall in the ratio 1:1 showed that if these walls are used as partitions or retaining, in conditions where the material behind the wall is not compacted (static conditions), they can be constructed to considerable heights. The experiment has proven that the retaining wall in height of 3,00m (6 rows of blocks) is completely stable with a small horizontal displacements. Realized horizontal displacements are sufficient to relax the soil pressure on the back side of the wall from the pressure at rest to the pressure in the active state. Therefore we should not expect additional movements of the wall if you do not change the loading conditions of the wall. The dynamic effects of traffic in this experiment have been successfully involved by the movement of the loader in front of and behind the wall. The stability of the walls of larger height should be checked computationally, but also experimentally, for an appropriate model.

Betonblock retaining walls are particularly suitable for use in road construction when we can solve geotechnical problems which in some way disrupt the road function in a very fast, efficient, reliable and financially favorable manner.

Finally it should be noted that the construction of the supporting walls of betonblock elements it is necessary for the subsoil to be well prepared concerning the evenness and density (or concreted), in order to prevent their unequal settlements, both in the transverse and in the longitudinal direction.

Acknowledgement

The paper is the result of the research project TR 36028 and TR 36016 financed by the Ministry of Education, Science and Technological Development of Republic of Serbia.

REFERENCES

[1] Prolović V., Samardaković M., Bonić Z., Davidović N., Fundamentals of Soil Mechanics for a study program Architecture, Faculty of Civil Engineering and Architecture, University of Niš, 2008, (in Serbian)

[2] The study of experimental testing of retaining walls of betonblock elements - Testing of the retaining wall on the static effects, Faculty of Civil Engineering and Architecture, University of Niš, Department of Geotechnical Engineering, Niš, 2014.

[3] The study of experimental testing of retaining walls of betonblock elements - Testing of the retaining wall on the dinamic effects, Faculty of Civil Engineering and Architecture, University of Niš, Department of Geotechnical Engineering, Niš, 2012.

[4] www.betonblockusa.com/ (20.03.2014.)

INFLUENCE OF CREEP ON DEFLECTION OF BEAM RESTED ON THE UNILATERAL ELASTIC FOUNDATION

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Abstract: *Subject of offered contribution is an analysis of the elastic beam on the unilateral elastic foundation under bending loading, when materials of beam and subgrade are subjected to creep. Creep of both materials (beam and subgrade) is considered to be coresponding to Bolzmann-Volterra theory. Solution of the problem by consecutive distribution of residual tension stresses between analysed beam and elastic Winkler′s foundation is performed. The derived algorithm is verified by numerical examples.*

Key words: *unilateral elastic foundation, creep, beam, bending loading*

1. Introduction

In the present paper we deal with the influence of time factor on deformation and stress of the beam in contact with subsoil. The beam on an elastic Winkler's subsoil was analyzed which is characterized by the coefficient (c) [kNm^{-3}]. In the interaction between the beam and the subsoil is being considered with the unilateral coupling.

Material of the beam is concrete, the soil of subgrade is clay.

Creep of both materials depends on several parameters i.e. intensity of loading, speed of straining, age of concrete in time loading, property of concrete mixture, characteristics of environs - relative humidity, temperature, etc. The range of soil consolidation is also an important characteristic of the subgrade. In this contribution we consider that time response of the material of the beam and Winkler´s subgrade passes according to the linear theory of hereditary creep.

The mathematic-physical principle of the deforming bodies is the Boltzmann – Volterra´s theory. We assume that the material of the beam as well as the subgrade represent a quasi-elastic body.

2. Assumptions and solution

Boltzmann´s theory of heridarity creep suggests that loads level of concrete foundation is up to 50% of square strength and loads can be applied in steady pressure after 28 days. Creep of subgrade occurs after primary soil consolidation. Principle of Boltzmann´s theory is superposition:

$$\varepsilon(t)=\int_0^{\tau}\sigma(\tau)\frac{dD(t-\tau)}{d\tau}d\tau\,, \tag{1}$$

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where D is the function of creep.

Formula (1) we can write as product of convolution (2).

$$\varepsilon(t) = \left\lfloor D(0^+)\delta(t) + D^{(1)}(t) \right\rfloor * \sigma(t) = D^{[1]} * \sigma \tag{2}$$

where $D^{[1]}$ is first derivation of creep function.

The equation (2), represents the physical equation for the viscoelastic body.

If we keep known assumptions that apply to elastic and viscoelastic body, on the basis of an analogy we can convert physical equations from elastic to viscoelastic solution. In time t differential equation of equilibrium for a beam in interaction with Winkler´s type of subgrade can be written as follows:

$$w^{(IV)}(x,t) = \frac{1}{I_y} D_n^{[1]} * \left(q(x)H(t) - p(x,t)\right) \tag{3}$$

where

$$p(x,t) = \frac{b}{D_z^{[1]}} * w(x,t) \tag{4}$$

I_y - moment of inertia of beam cross section, b – width of beam cross section,

$H(t)$ - Heaviside function

The problem was solved by iteration - stepwise distribution of unbalanced contact tensile stresses in the foundation gap. In each iteration step differential equations (3) were solved with various right sides. In the j[th] iteration step the right sides of the differential equations (3) are as follows:

$$q_j(x)H(t) = \left(q(x) + \Delta q_j(x)\right)H(t) \tag{5}$$

$\Delta q_j(x)H(t)$ balanced of tension stress $p_{j-1}{}^{(-)}(x,t)$ on area $\Omega_{j-1}{}^{(-)}$ and create on this area of equilibrium state (6).

$$\left(\int_{\Omega_{j-1}^{(-)}} \Delta q_j(x) d\Omega^{(-)} \right) H(t) + \int_{\Omega_{j-1}^{(-)}} p_{j-1}^{(-)}(x,t) d\Omega^{(-)} = 0 \tag{6}$$

Method of approximation $\Delta q_j(x)H(t)$ and test of convergence are described in [4**]**. In the j[th] iteration step is the differential equation (3) :

$$w_j^{(IV)}(x,t) = \frac{1}{I_y} D_n^{[1]} * \left(q_j(x)H(t) - \frac{b}{D_z^{[1]}} * w_{j-1}(x,t) \right) \tag{7}$$

and boundary conditions

$$\begin{aligned} &1.\ \left\lfloor w_j''(x,t) \right\rfloor_{x=0} = 0 \quad 2.\ \left\lfloor w_j''(x,t) \right\rfloor_{x=l} = 0 \\ &3.\ \left[w_j'''(x,t) \right]_{x=0} = 0 \quad 4.\ \left[w_j'''(x,t) \right]_{x=l} = 0 \end{aligned} \tag{8}$$

We solve equations (7) and (8) using the Laplace integral transformation. The Laplace transformation eliminates the argument t and transforms the original problem defined in the time t for the associated elastic problem, which is expressed by the eq. (9).

(9) $$\tilde{w}_j^{(IV)}(x,\lambda)+\frac{b}{I_y}\frac{\tilde{D}_n(\lambda)}{\tilde{D}_z(\lambda)}\tilde{w}_j(x,\lambda)=\frac{\tilde{D}_n(\lambda)}{I_y}\tilde{q}_j(x,\lambda)$$

Equation (9) we can transform using a known procedure into the equation (10)

(10) $$\tilde{w}_j^{(IV)}(\xi(\lambda),\lambda)+4\tilde{w}_j(\xi(\lambda),\lambda)=\frac{4\tilde{D}_z(\lambda)}{b}\tilde{q}_j(\xi(\lambda),\lambda)$$

where

(11) $$\xi(\lambda)=\frac{x}{\tilde{L}(\lambda)},\quad \tilde{L}(\lambda)=\sqrt[4]{\frac{4I_y\tilde{D}_z}{b\tilde{D}_n}}$$

The solution of the equation (10) can we presented in form:

(12) $$\tilde{w}_j(\xi(\lambda),\lambda)=\tilde{A}_{1j}(\lambda)e^{-\xi(\lambda)}\cos\xi(\lambda)+\tilde{A}_{2j}(\lambda)e^{-\xi(\lambda)}\sin\xi(\lambda)+\tilde{A}_{3j}(\lambda)e^{-\eta(\lambda)}\cos\eta(\lambda)+$$
$$+\tilde{A}_{4j}(\lambda)e^{-\eta(\lambda)}\sin\eta(\lambda)+\tilde{w}_{oj}(\xi(\lambda),\lambda)$$

where

(13) $$\eta(\lambda)=\frac{1}{\tilde{L}(\lambda)}-\xi(\lambda)$$

2. Numerical solution

Creep functions $D_n(t)$ of concrete beam are in eq. (14) and of subgrade $D_z(t)$ in eq. (15).

(14) $$D_n(t)=2(1+\nu)D_d(t)\qquad \text{where } D_d(t)=\frac{1}{E_n}+C_0\left(1-B_1e^{-\gamma_1 t}-B_2e^{-\gamma_2 t}\right)$$

(15) $$D_z(t)=\frac{\left(1-\nu_z^{\,2}\right)\pi r}{2}D_{zz}(t)\quad \text{where } D_{zz}(t)=\frac{1}{E_z}\left[1+\frac{\delta_1}{\delta_2}\left(1-e^{-\delta_2 t}\right)\right]$$

Laplace´s images of the creep functions (14) and (15) are the holomorphic functions (16) and (17), which are taken from [5].

(16) $$\tilde{D}_n(\lambda)=2(1+\nu_d)\tilde{D}_d(\lambda)\text{ where } \tilde{D}_d(\lambda)=\frac{1}{E_n}\left[1+E_nC_0\left(1-B_1-B_2+\frac{B_1\gamma_1}{\gamma_1+\lambda}+\frac{B_2\gamma_2}{\gamma_2+\lambda}\right)\right]$$

(17) $$\tilde{D}_z(\lambda)=\frac{\left(1-\nu_z^{\,2}\right)\pi r}{2}\tilde{D}_{zz}(\lambda)\text{ where } \tilde{D}_{zz}(\lambda)=\frac{1}{E_z}\left(1+\frac{\delta_1}{\delta_2+\lambda}\right)$$

Solution of equation (12) we made over the Laplace´s transformation. The time variable *t* we eliminate from the equations by means of Laplace integral transformation for these selected parameters λ :

$\lambda=(0, 0.001, 0.003162, 0.01, 0.03162, 0.1, 0.3162, 1.0, 3.162, 10, 31.62, 100, \infty)$

The time dependent solution we made using Laplace´s inverse transformation $f(x,y,t)=\mathcal{L}^{-1}\{f(x,y,\lambda)\}$, that is described in [3].

Table 1. Comparison of deflection

		F=1MN			F=100kN		
	Time (day)	Bilateral bond	Unilateral bond	Difference %	Bilateral bond	Unilateral bond	Difference %
Max. deflec-tion w(l/2) (mm)	t=0	12,3	13,1	6,5	1,37	1,38	0,73
	t=5	19,3	20,2	4,6	2,17	2,19	0,92
	t=50	52,0	52,3	0,5	5,99	5,99	0,0
	t=∞	73,6	74,1	0,6	8,53	8,53	0,0
Beam edge w(0) (mm)	t=0	-2,81	-11,4	305,7	-0,127	-0,190	49,6
	t=5	-4,93	-13,2	167,7	-0,222	-0,338	52,2
	t=50	-11,3	-13,0	15,1	-0,265	-0,271	2,26
	t=∞	-12,9	-15,9	23,25	-0,0490	-0,0491	0,2

In the numeric example we show deflection $w(x,t)$ of beam. The length of beam is $l = 8$ m, cross section bxh is (0,60 m x 0,30 m).

We are considering with the load in two alternatives F=1MN, F=100kN and with the dead-weight. Parameters of creep function are: $E_n = 21 \cdot 10^3\,\text{MPa}$, $\nu_n = 0{,}15$, $E_z = 24{,}74\,\text{Mpa}$, $\nu_z = 0{,}4$, $C_0 = 0{,}28 \cdot 10^{-7}\,\text{MPa}^{-1}$, B_1=0,43, B_2=0,57, γ_1=0.0018 1/day, γ_2=0.01 1/day, δ_1=0.15 1/day, δ_2=0.2 1/day.

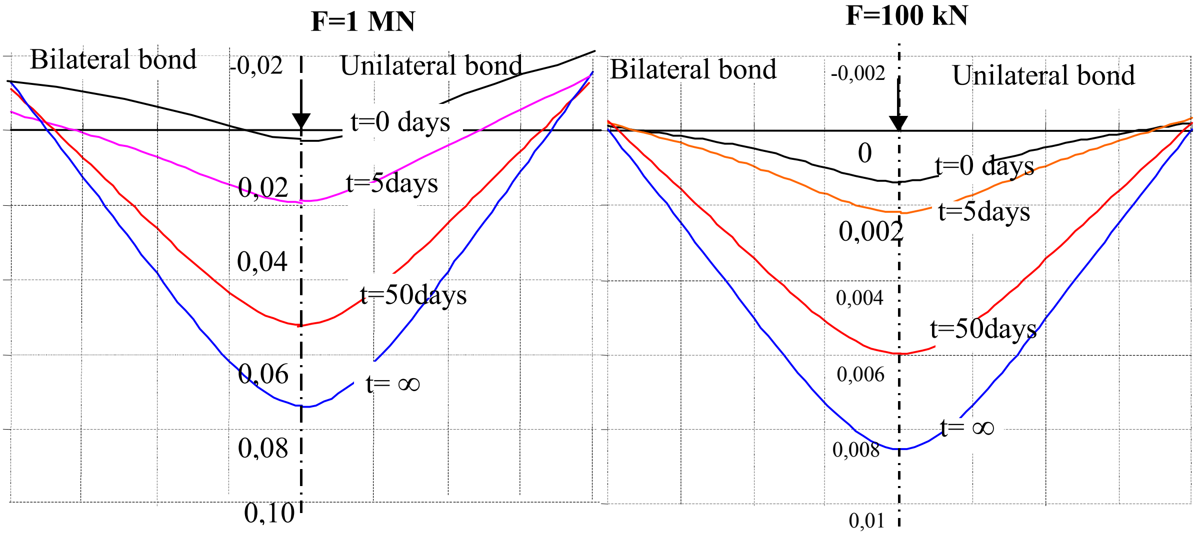

Fig. 1. Deflection w [m]

Conclusion

Graphs in Fig. 1 and numerical evaluation in Tabl. 1 show differences in deflections when considering unilateral and bilateral bonds. These differences are more pronounced in the loading of the greater intensity and in a shorter period of time. For a time t = ∞ eliminated the differences in deflection when considering a unilateral or bilateral bonds. Increase maximum of deflection at time t = ∞ opposite the t = 0 is almost 6 times.

Acknowledgement
This paper was supported by Grant Agency VEGA, project No. 1/0629/12

REFERENCES

[1] Bittnar Z. - Šejnoha J.: Numerické metódy mechaniky, Vydavatelství ČVUT, Praha 1992
[2] Kovařík V: Problémy vazkopružnosti v teorii plošných konstrukí, Studie ČSAV, ACADEMIA, Praha 1987
[3] Novotný B., Hanuška A.: Teória vrstevnatého polpriestoru, VEDA, Bratislava1983
[4] Mistrikova Z.: Excentrically loaded beam on an elastic subsoil with unilateral coupling, 13th International scientific conference VSU´ 2013. Volume 1: Proceedings. Sofia, Bulgaria, 6.-7.6.2013. Sofia: L.K aravelov Civil engineering higher school Sofia, 2013, s. 223--227. ISSN:1314-071X
[5] Kollár P.-Mistríková Z.: Spolupôsobenie ohybom namáhaných pilót s podložím s prihliadnutím na dotvarovanie materiálov pilót a podložia – pilóty voľné v päte, Inžinierske stavby, roč.39, č.12, 1991, str.416-423

CONSTITUTIVE MODELS FOR SETTLEMENT ANALYSIS OF SOFT SALT-AFFECTED GROUND

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Abstract: *A saturation of Hanoi soft soil specimens with artificial sea water to simulate saline contamination process was carried out in the laboratory. The mechanical properties of the soft soils with a different salt concentration are determined. Based on the laboratory results an investigation of the settlement deformation of the soft ground in saline conditions under an embankment is conducted. FEM analyses are performed using different constitutive models for the soft ground - linear elastic model, elastoplastic model and advanced soft soil "cap" model. Settlement-time relationships of embankment are obtained and the process of consolidation of the saturated ground is evaluated. Analyses of the results are performed and conclusions about the influence of the constitutive models on the solutions are made.*

Key words: *soft ground, constitutive models, salt-affected soil, finite element method*

1. Introduction

Global warming is being considered to be main reason of sea level rise phenomenon occurring in the world. In the low-lying plain areas along the coast, sea level rise gradually causes ground to be saturated by saline water. This process is believed to lead to significantly change in engineering properties of soils. Consequently, it will directly influence the construction and infrastructure such as dyke, embankment and traffic road foundation in those areas [3, 4].

The study of changing in engineering properties of soil intruded by saline water is firstly considered under aspect of settlement deformation property. Undisturbed soil samples that originated from shallow sea sediment in Hanoi, Vietnam, were chosen. They are located in the inland area and far from the coast, and soil layers have not been affected by saline water yet. Saline intrusion process implemented by artificial seawater in the laboratory was strictly controlled. To investigate how the relation between settlement deformation and salinity is, one-dimensional consolidation test was applied.

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2. Preparation for soil specimens

The in-situ works were aimed at collecting undisturbed soil samples and field experiment based on the deep boreholes. The soil in medium state, i.e. clay or silty clay, which their undrained shear strength, S_u, fluctuates from 25 to 50 kPa, was studied. Nine research sites are located in and around the inner city of Hanoi, i.e. Hoai Duc 1 (HD1), Hoai Duc 2 (HD2), Hoan Kiem (HK), Bach Mai (BM), Gia Lam 1 (GL1), Gia Lam 2 (GL2), Gia Lam 3 (GL3), Highway No.5 (D5), Yen So (YS) (see figure 1). To study effects of salt on the soil properties, saturation for the soil specimens to simulate saline contamination process was carried out in the lab with artificial sea water. Average salinity of the water in the East Sea of Vietnam is reported to be 33 ‰; it should be considered corresponding to salinity S_a=100%. When seawater is not rising, salinity of groundwater in inland area is 0‰; it is considered corresponding to S_a=0%. To simulate the saline intrusion progresses, soil specimens were saturated with saline water in the laboratory at four chosen salt concentrations, 0, 9.9, 19.8, 33‰, corresponding to 0, 30, 60, 100% salinity of seawater, respectively. The saline solution is a mixture of pure water and salt (sodium chloride, NaCl), or can be considered as artificial seawater. Basic chemical component and the content of salt served saturating is NaCl (≥ 92%), SO_4^{2-} (≤ 2.7%), Mg^{2+} (≤ 1.3%), Ca^{2+}(≤ 0.65%). Saturation for soil was carried out in a closed process with two phases, capillary and pressure saturation. Each saturation phase was conducted for at least 5 days to make sure the soil specimens to be fully intruded by saline water. Experiment was executed by the consolidation apparatus with automatic data acquisition. Four specimens corresponding to four concentrations of saline water were placed in each separate apparatus. Pressure ranges in the test were 25, 50, 100, 200, and 400 kPa. Each pressure stage was applied during 24 hour.

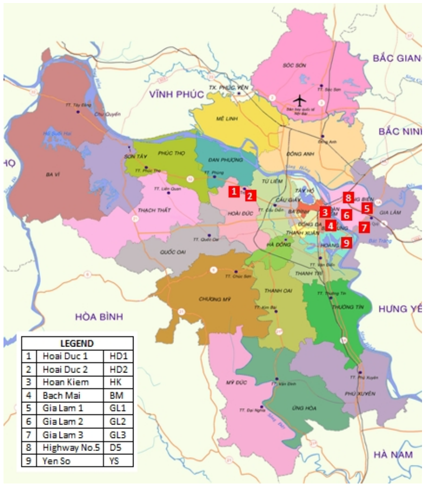


Fig. 1. Nine research sites in Hanoi area

3. Settlement FEM analyses of salt-affected soft soil layer under embankment

3.1. Input data of FEM analyses

In order to obtain a detailed research about settlement deformation of salt-affected soils, the instance of settlement calculation for an assumed embankment that ground is affected by different salt concentrations is taken and a scheme of geometry data is shown on Fig. 2. The case study is assumed that the 5 m high embankment is located on a three-layer ground. The top and bottom layers of ground are sand and the middle one is clay or silty clay layer with 2.4 m thickness. The consolidation is expected to occur in this compressible layer.

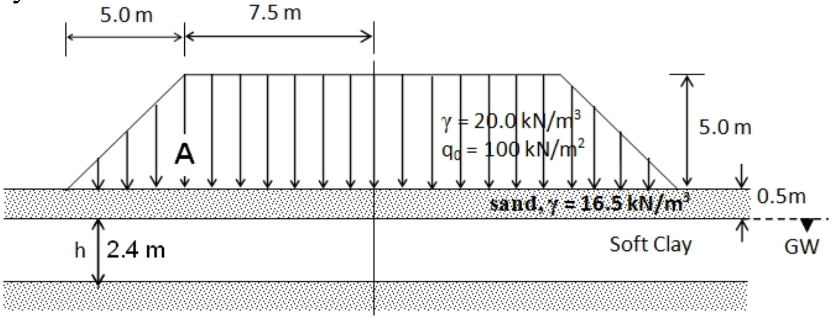


Fig. 2. Scheme of embankment and soft ground layer

In this paper, the authors take into account clayey soil silty clay at HD1 and clay at GL2 as main objects of the study. It is supposed that the ground was intruded by respective four salt concentrations as mentioned in the previous section. The geotechnical parameters of the soft soils are shown in Tabl. 1. Here λ* and κ* are modified parameters of one-dimensional compression and recompression.

Numerical FEM models of the ground are created through Plaxis program considering an embankment as a distributed load (fig.3). Coupled consolidation analysis is performed and time-settlement relationships of the ground are obtained. The following constitutive models are used for the soft clayey soil layer: Linear Elastic model of Hooke, Elastoplatic model of Mohr-Coulomb and Soft Soil model. The dilatancy angle of the soil is ψ 0 to limit the velocity of the plastic deformation increase.

Table 1. Properties of the soil at sites HD1 and GL2

Para-meter	Dimension	Silty clay (HD1)				Clay (GL2)			
		S_a=0%	S_a=30	S_a=60	S_a=100	S_a=0%	S_a=30	S_a=60	S_a=100
γ	kN/m^3	18.20	18.12	17.95	18.08	19.20	19.15	19.19	19.10
e_0	-	0.996	0.999	1.027	1.037	0.824	0.825	0.831	0.846
φ	deg	12.42	11.97	11.53	10.93	3.50	3.31	3.12	2.87
c	kPa	14.72	13.92	13.13	12.07	32.47	31.20	29.94	28.25
E_{oed}	kPa	3717	3515	3390	3234	4742	4495	4256	3992
v	-	0.35	0.35	0.35	0.35	0.42	0.42	0.42	0.42
C_c	kPa^{-1}	0.179	0.189	0.199	0.209	0.128	0.135	0.143	0.154
λ*	kPa^{-1}	0.0390	0.0410	0.0427	0.0446	0.0305	0.0322	0.0340	0.0363
κ^*	kPa^{-1}	0.0099	0.0103	0.0107	0.0112	0.0076	0.0080	0.0085	0.0091
k×10^{-5}	m/day	5.79	5.31	5.20	4.99	1.01	0.950	0.959	0.942

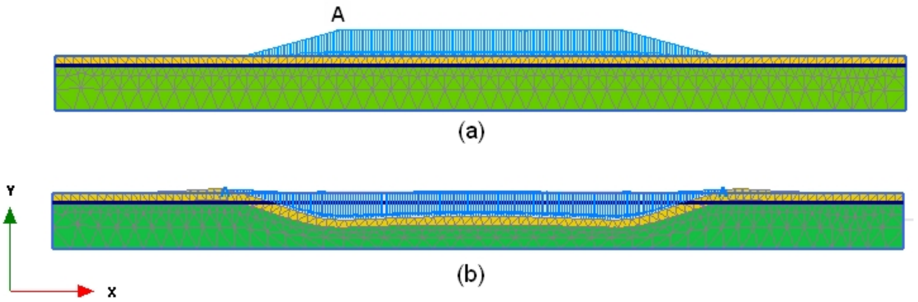


Fig. 3 Numerical model of embankment ground:
(a) FEM mesh; (b) Typical deformed scheme

3.2. Soft Soil constitutive model

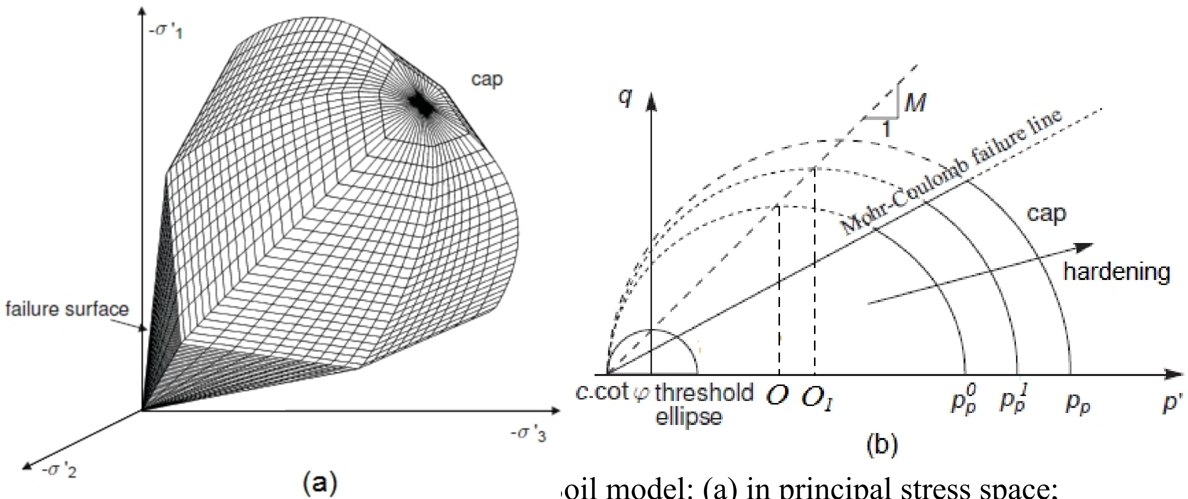
The Soft Soil model is developed in Plaxis program [2] and it is suitable for near-normally consolidated clays with high degree of compressibility (E_{oed} = 1 to 4 MPa). This model is based on the test data which are generalized by Janbu [1]. The main features of the Soft Soil model are: stress dependent stiffness; distinction between primary loading and unloading-reloading; memory for pre-consolidation stress; failure behaviour according to the Mohr-Coulomb criterion. The yield surface of the model is illustrated in fig. 4(a) in the space of the effective principal stresses. The yield curve in the plane of the stress invariants (p', q) is in shape of an ellipse, Fig. 4(b). The yield function is defined by the following expressions:

(3.1) $F = \bar{f} - p_p$,

(3.2) $\bar{f} = \dfrac{q^2}{M^2\left(p' + c\cot\varphi\right)} + p'$,

(3.3) $p_p = p_p^0 \exp\left(\dfrac{-\varepsilon_V^p}{\lambda^* - \kappa^*}\right)$,

where: p_p^0 is pre-consolidation pressure; ε_V^p is volumetric plastic strain; M is parameter used to determine the height of the ellipse, $M \approx 3.0 - 2.8K_0$; K_0 is coefficient of lateral stress.



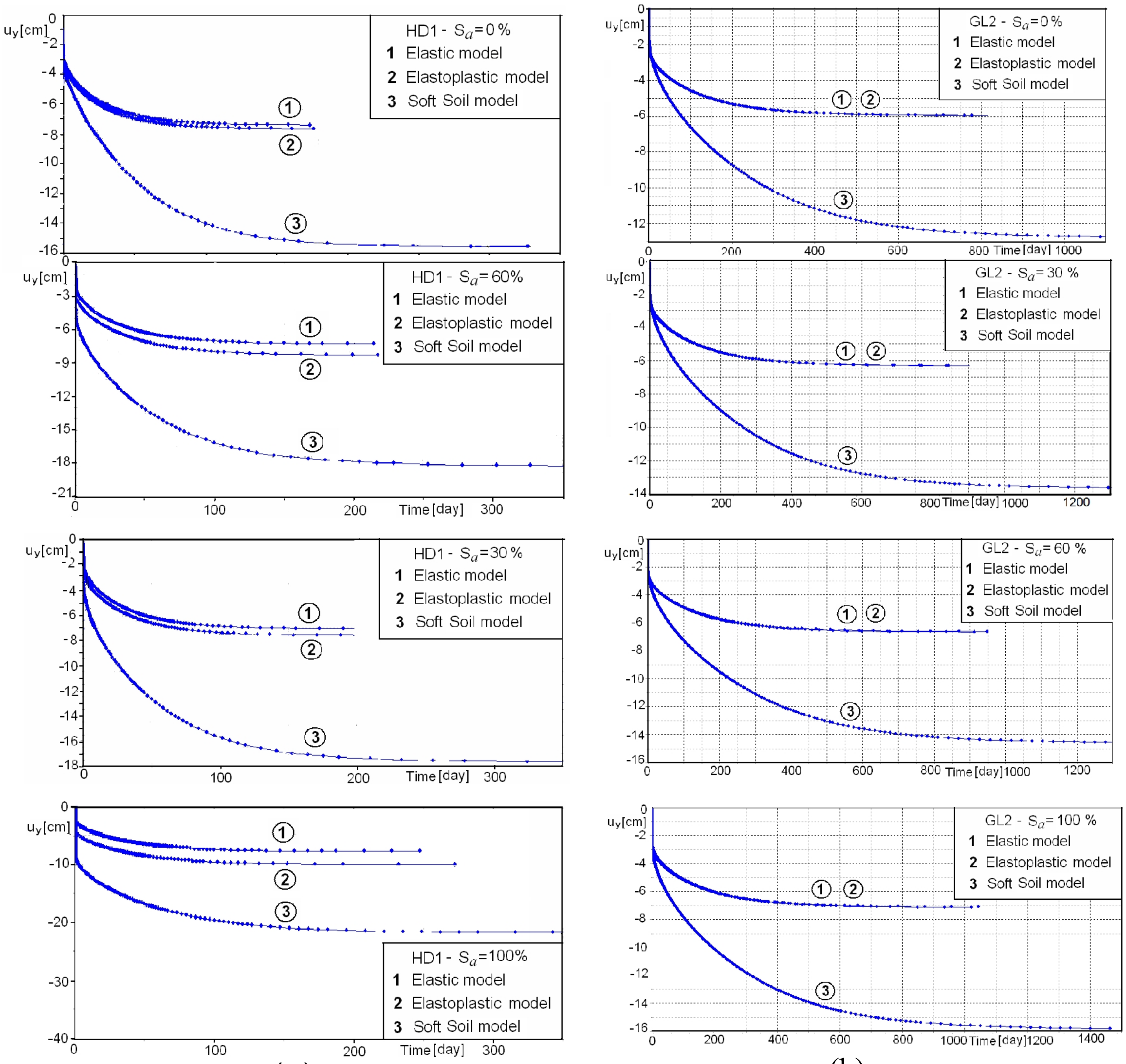
oil model: (a) in principal stress space;
(a) in plane of the normal stress p'- deviator q [2]

3.3. Results from FEM analyses

Table 2. Settlement S of point A in Fig. 3 and time t_{100} at the end of primary consolidation of saline soil layer by different constitutive models

S_a (%)	Silty clay (HD1)				Clay (GL2)			
	t_{100}(day)	$\Delta\ t_{100}$ %	S (cm)	ΔS %	t_{100}(day)	$\Delta\ t_{100}$ %	S (cm)	ΔS %
Linear Elastic model								
0	167	-	7.1	-	815	-	6.3	-
30	207	24.0	7.5	5.9	946	16.1	6.6	5.1
60	209	25.2	7.8	9.7	985	20.9	7.0	10.8
100	228	36.5	8.2	14.9	1039	27.5	7.5	18.9
Elastoplastic model								
0	175	-	7.4	-	827	-	6.3	-
30	196	12.0	8.3	11.7	913	10.4	6.6	5.2
60	227	29.7	9.2	23.0	914	10.5	7.0	10.6
100	282	61.1	11.7	57.5	1044	26.2	7.5	18.1
Soft Soil model								
0	327	-	15.4	-	1187	-	12.8	-
30	339	3.7	17.6	14.4	1350	12.1	13.9	8.5
60	351	7.3	18.7	21.2	1368	15.3	14.7	14.9
100	369	12.84	23.4	52.1	1465	23.4	15.9	24.6

The results from the analyses are given in Tabl. 2. They include the time t_{100} and the settlement S at the end of the primary consolidation, and the quantitative changes $\Delta\ t_{100}$ and ΔS from the base line. Relations of the settlement over the time are shown graphically in Fig. 5.



(a) (b)

Fig. 5. Settlement-time curves of the ground: (a) at site HD1; (b) at site GL2

4. Discussion

4.1. Ground at site HD1

The obtained results display the following features:

- The ground settlement is proportional to the salinity of the soil. The higher the soil salinity is, the larger the ground's vertical displacement gets.
- The increase of the salinity from 0% to 100% in the solution of the Linear Elastic model causes the increase of the settlement by 15%. The salinity influences the value of the vertical displacement significantly in both the Elastoplastic model and the Soft Soil model. By the Elastoplastic model, the settlement value gets 52% higher as the salinity increases from 0% to 100%, while by the Soft Soil model, the value gets 57% higher.
- The greatest values of the settlement are obtained by the Soft Soil model. The value of the settlement is 15.4 cm at salinity S_a = 0% and 23.4 cm at S_a = 100%. These values are twice greater than the corresponding values obtained by the Elastoplastic model. The value of the settlement is lowest in the Elastic model solution. The settlement varies between 7.1 cm and 8.2 cm as the salinity increases from 0% to 100%.

- The gradient of the settlement-salinity function may be evaluated by the following incremental expression: $S' = (S_i - S_{i-1}) / (S_{a,i} - S_{a,i-1})$. The gradient in the Linear Elastic model is constant at 0.013 cm. The Elastoplastic model gives higher gradient values: at 0% to 60% salinity, the gradient is 0.030 cm; at 60% to 100% salinity, the gradient increases to 0.063 cm. The Soft Soil model gives the largest values: the gradient varies between 0.036 – 0.118 cm.
- The Linear Elastic and the Elastoplastic models show similar values of the primary consolidation time t_{100}. The Soft Soil model estimates an about 1.5 times longer t_{100}. The t_{100} increases as the salinity of the soil increases. As the salinity increases from 0% to 100%, t_{100} gets 36% longer in the Elastic model, 61% longer in the Elastoplastic model, and 13% longer in the Soft Soil model.

4.2. Ground at site GL2

- Due to the higher modulus of the clay, the settlement of the clay ground at GL2 is smaller than the settlement of the silty clay ground at HD1. The time of the primary consolidation t_{100} of the clay at GL2 is significantly longer compared to the t_{100} of the silty clay at HD1, because the clay's permeability coefficient is more than 5 times lower than that of the silty clay.
- The mean conclusions made for the ground of the silty clay HD1 above are valid here. But for the clay at GL2 the increase intensity of the settlement is smaller, and all models give more close results of the ground settlement. When the salinity changes from 0% to 100%, the settlement increases by above 18.5% in the Linear Elastic and Elastoplastic models, and by 24.6% in the Soft Soil model. The gradient of the settlement-salinity function is $S' = 0.01$ cm in both the Elastic model and the Elastoplastic model, and the gradient is $S' = 0.03$ in the Soft Soil model. The increase of the salinity from 0% to 100% causes the time t_{100} to rise by about 25% in all models.

Conclusion

The Soft Soil model gives significantly different results of the ground settlement in comparison with the Linear Elastic model and Elastoplastic model. The application of the Soft Soil model requires additional investigations of the material parameters of the soil by settlement filed tests. For modelling of the consolidation of the soft soils in salt-affected conditions, the model of Elastoplasticity is more suitable than the Linear Elastic model, because it works with all parameters of the Elastic model plus the internal friction angle and the cohesion of the saline soils.

REFERENCES

[1] Janbu, N. (1985). Soil Models in Offshore Engineering. 25th Rankine Lecture. Géotechnique, 35.
[2] Plaxis. (2012). Material Models Manual.
[3] Truc, N. N. & Granie, R. J. (2008). Global Warming - Related Sea Level Rise and The Change of Some Mechanical Characteristics of Soil Foundation Due to Salty Intrusion, Case Study: Thai Binh Formation Sediment in The Red River Delta, Vietnam, Proceedings of International Symposium on Climate Change and the Sustainability, Hanoi, pp. 131-140.
[4] Truc, N. N. & Hung, D. N. (2007). The Issue of Sea Level Rise Due to Global Warming and Its Impacts on The Coastal Zone of Vietnam, Proceedings of International Symposium on Hanoi Geoengineering, Hanoi, pp. 124-130.

ASSESSMENT OF LIQUEFACTION POTENTIAL BY IN-SITU METHODS AND LABORATORY EXPERIMENTS

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***Abstract**: The study presents the investigations and the results on the evaluation of the potential of liquefiable soil layers at the location where a new industrial complex is planned to be built in the southern part of the Republic of Macedonia. The investigations combine the results from different in-situ methods, site response analysis and laboratory cyclic triaxial undrained tests. The results from the performed tests and experiments provide valuable data for assessment of the liquefaction hazard at the location with medium to high seismicity and non-homogenous soil conditions. The methodology applied in this study pointed out the necessity of attention and precaution in drawing the final conclusions about the potential of liquefaction in complex geological conditions with a high degree of soil heterogeneity.*

***Key words**: Liquefaction, dynamic triaxial tests, SPT, CPT*

1. Introduction

Assessment of the likelihood of initiation of liquefaction is the necessary first step of most projects involving potential seismically induced liquefaction. Concerning the liquefaction as one of the geotechnical instabilities, which increased damages during strong earthquakes, there are different approaches and methods available for evaluation and assessment of its potential. Two general types of approaches exist: (1) use of empirical relationships based on correlation of observed field behavior with various in-situ "index" tests (2) use of laboratory testing of samples. In-situ tests namely SPT and CPT with appropriate empirical formulas are a very good starting point for estimation of the liquefaction potential in a quite short period. For the purpose of the new industrial complex, which is planned to be built, preliminary evaluation of the liquefaction potential has, first of all, been done by use of the SPT and CPT methods. The results indicated that soil layers whose cyclic resistance ratio is lower than the expected cyclic stress ratio could behave as liquefiable. The geological conditions and particularly the soil heterogeneity of the site were very complicated to rely only on SPT and CPT tests since there was no clear presence of soil layers composed purely of sands and the stratification of the sandy soil layers was far from regular. Therefore, extensive laboratory tests were conducted at the Laboratory for Dynamics of Soils and Foundations, Department for Geotechnics and Special Structures at the Institute for Earthquake Engineering and Engineering

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Seismology. Disturbed soil samples were taken from the boreholes of the site and cyclic undrained triaxial experiments were done. The results from the performed tests and experiments provide valuable data regarding the assessment of the liquefaction hazard at the location with medium to high seismicity and non-homogenous soil conditions. The methodology applied in this study which combines the results from different in-situ and also laboratory tests pointed out the necessity for attention and precaution in drawing final conclusions about the liquefaction potential of complex geological conditions with high degree of soil heterogeneity.

2. Site conditions

The site is located near the city of Bitola in the southwestern part of Macedonia. The industrial complex includes an industrial hall, an associated administrative and support buildings and access platforms and roads (Figure 1).

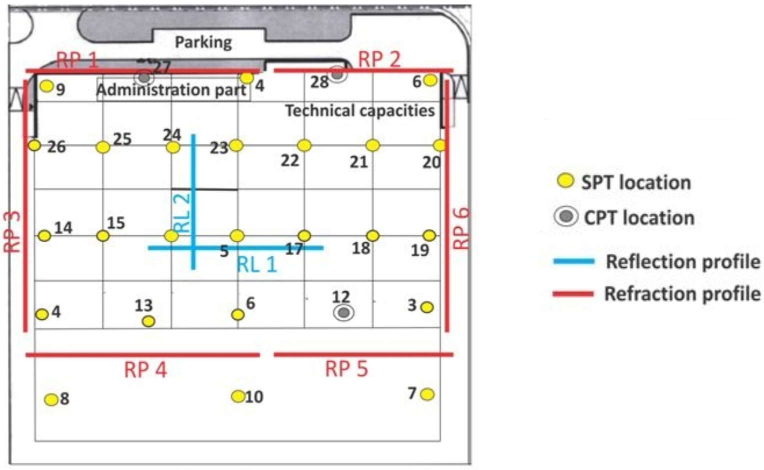

Fig. 1. Plan of the site and site location

The field investigations, which are presented in figure 1, for the project included boreholes, seismic cone penetration testing (CPT), standard penetration test (SPT) and in order to define the subsurface amplification soil layers parameters (H-height, Vs- seismic shear wave velocity and T- predominant periods) seismic refraction and seismic reflexion testing has been performed. Figure 2 shows a simplified soil profile and a summary of the site conditions located on the analysed industrial complex.

In general, the soil has a heterogeneous structure. The location consists of silty and clayey sand, then clayey and silty sand to different depths, but most at the depth >10-11.0m to the investigation depth. Underground water has been detected at two, three and four water bearing levels and it makes aquifers with an intergranular porosity and a subarterian character. Underground water level has been detected in all the boreholes at depth of 1.3 to 1.8m.

Based on the results of the field investigation, the proposed facility is located on a site with complex soil conditions, consisting of around 30 metres of alluvial deposits – predominantly layers of medium-dense sand and soft, low-plasticity silt. Significant portions of soil deposits are compressible and there are zones within the upper part that are estimated to be liquefiable. The bedrock elevation (Figure 2) was assumed, as it was not detected during the field exploration down to around 30 metres depth.

Given that the site is underlain by more than 30 metres of predominantly soft alluvial materials and considering the strong ground motions, the industrial complex is designed to be supported by pile foundations with round improvement in the upper 3-5 metres below the ground surface.

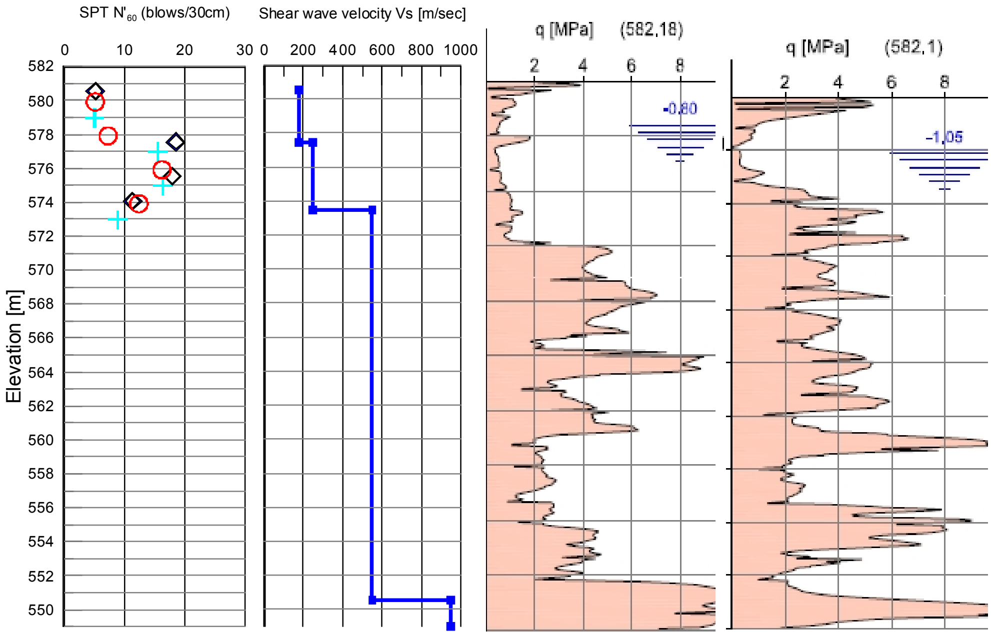

Fig. 2. Summary Site Soil Profile

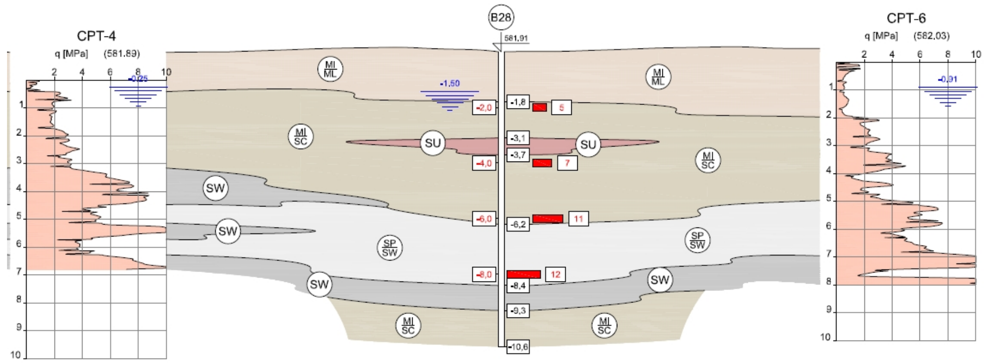

Fig. 3. Soil profile formed on the basis of boreholes and CPT data

3. Seismic site response

The region where this industrial complex is planned is characterized by medium to high seismicity. A site-specific seismic hazard study estimated bedrock peak ground accelerations for different return periods and for near and far earthquake events respectively.

The results based on site response analysis of two representative geodynamic models show the value of the predominant period of the site in the range between T=0.32 s to 0.36 s. Figure 4 presents the maximum acceleration values versus depths for site response analysis with 10 representative earthquakes for the region with input acceleration at bedrock of a_{max}=0.15g (return period of 200 years), for model 1 and 2, respectively

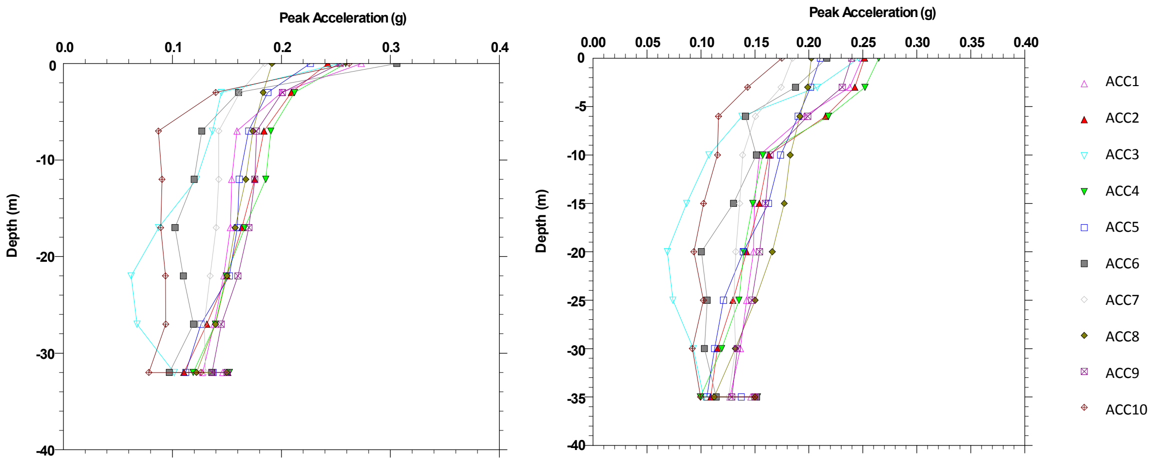

Fig. 4. Maximum accelerations versus depth model 1(left) and model 2 (right)

4. Evaluation of the liquefaction potential

4.1. SPT and CPT Procedure Method

The first preliminary analyses for the liquefaction potential using the SPT and CPT procedures explained in Youd et al. (2001) have been done and the results in the format of CSR (Cyclic Strength Ratio) versus CRR (Cyclic Resistance Ratio) are given in Figure 3 and Figure 4, respectively. On the basis of these analyses, it can be noticed that the majority of the zone between 6-8 meters depth is potentially liquefiable.

In the area between 6- 8 metres, the standard penetration test (SPT) corrected blow counts (N'60) values calculated for the site indicate that the majority of the values are around 12. The granulometry of this sandy material shows fines content value of around 10 %. Given the large heterogeneity of the soil profile, the high level of the water table, an in-depth site-response and seismic performance evaluation was conducted for these layers by cyclic triaxial laboratory testing.

This evaluation was particularly connected with this project and the seismic performance requirements for the pile foundations.

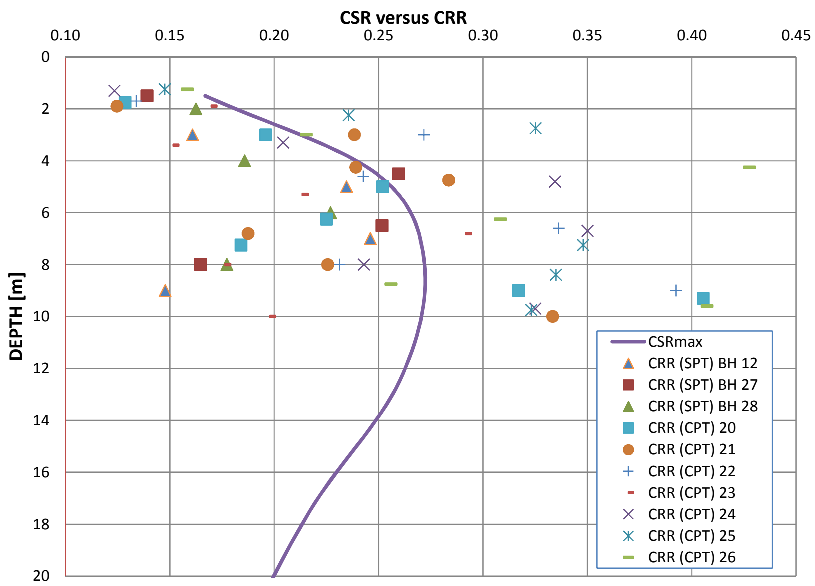

Fig. 4. Liquefaction potential by SPT and CPT method (Youd et. al., 2001)

4.2. Laboratory Testing – Dynamic Triaxial Tests

The liquefaction potential for the observed soil layers was evaluated by cyclic liquefaction triaxial tests in the Laboratory for Geotechnics and Special Structures at IZIIS. Two specimens were tested under different levels of cyclic stress ratio in order to define the liquefaction versus number of cycles. The specimens were cyclically loaded at 0.5 Hertz. The test conditions for the specimens are presented in table 2. The results from the liquefaction test under cyclic stress ratio of 0.10 are given below.

Table 2. Test conditions for the specimens

Borehole	Depth	Test No.	Initial density [%]	Confining ratio [kPa]	CSR
BH 28	6.2-8.4	1	44.0	100	0.08
		2	41.8	100	0.10
		3	39.8	100	0.15
BH 12	5.0-8.0	1	41.8	100	0.08
		2	40.1	100	0.10
		3	40.5	100	0.15

In order to give a better insight into the liquefaction potential of the site, the following figure show the dependence of the cyclic stress ratio CSR on the number of cycles necessary to initiate liquefaction. As can be seen from the Figure 5, the number of cycles necessary to initiate liquefaction at both boreholes BH12 and BH28 is quite small.

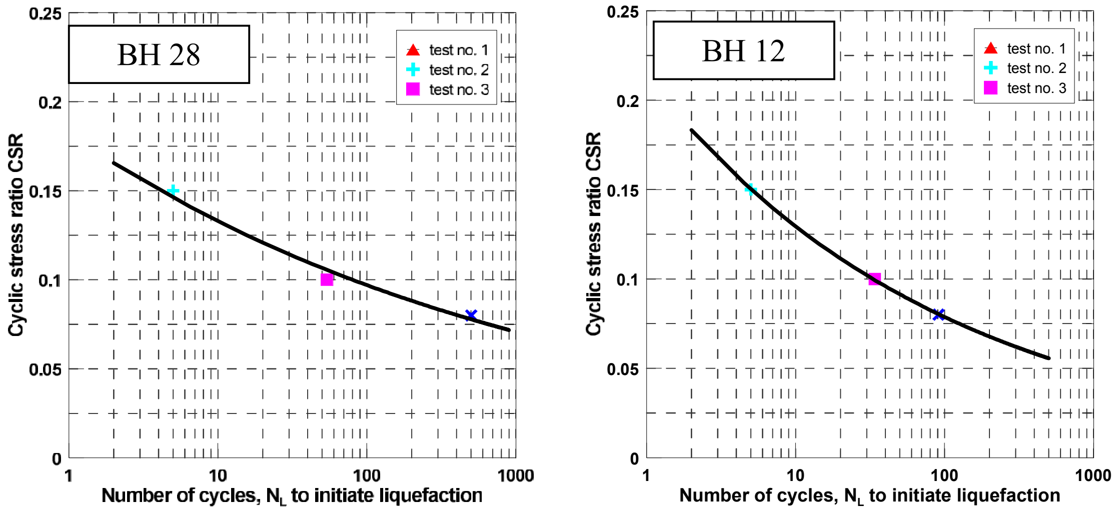

Fig. 5. Cyclic stress ratio CSR versus number of cycles to initiate liquefaction

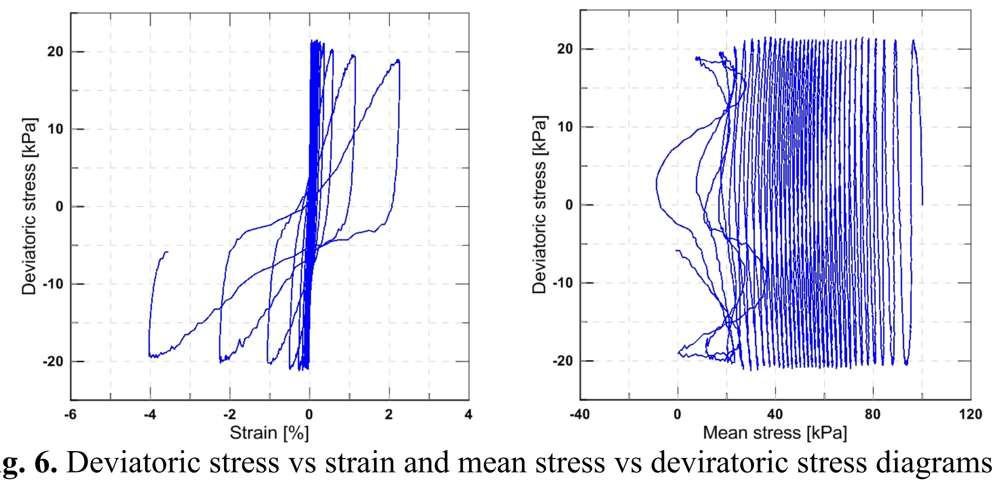

Fig. 6. Deviatoric stress vs strain and mean stress vs deviratoric stress diagrams of CSR=0.1 of BH12

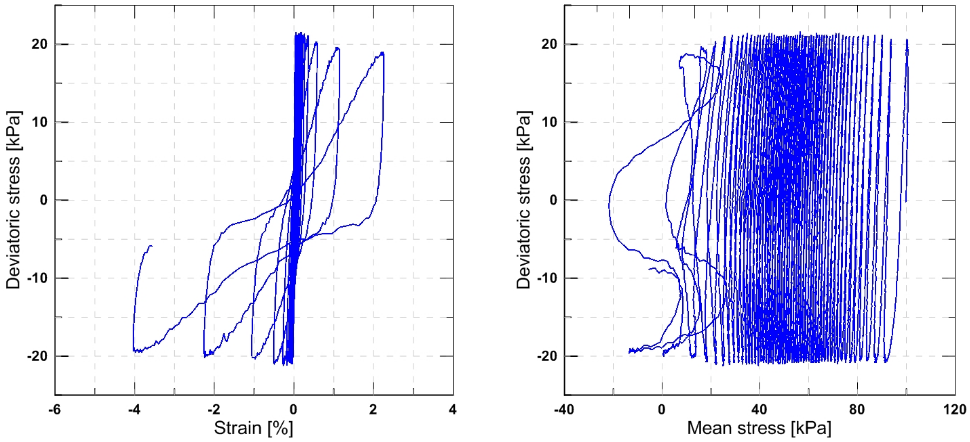

Fig. 7. Deviatoric stress vs strain and mean stress vs deviratoric stress diagrams of CSR=0.1 of BH28

As can be seen from the diagrams in Figure 6 and Figure 7, the mean stress has been reduced considering its initial value, which proves the liquefaction initiation. On the other hand, the stress strain diagram shows that, in the first few cycles, the slope of the diagram is quite bigger than zero while at the last cycle, the slope of the diagram approaches a straight line, increasing the strain value enormously. As can be seen from both figures, the liquefaction initiation is present even at low cyclic stress ratio such as CSR=0.1 thus pointing out that the liquefaction phenomenon should be taken into the analysis for the evaluation of the site.

5. Conclusions and recomendations

In-situ tests namely SPT and CPT with appropriate empirical formulas represent a very good starting point for estimation of the liquefaction potential in quite a short period. For the purpose of the new industrial complex which is planned to be built, a preliminary evaluation of the liquefaction potential has, first of all, been done by use of the SPT and CPT methods. The results indicate the soil layers whose cyclic resistance ratio is lower than the expected cyclic stress ratio and might behave as liquefiable. Disturbed soil specimens have been taken from the boreholes of the site and cyclic undrained triaxial experiments have been done. The results of undrained triaxial experiments reveal the fact that the soil can behave as liquefiable considering the low cyclic stress ratio needed to initiate liquefaction as it is shown in the figures above. Further investigation is needed in order to evaluate possible liquefaction occurrence at the site.

REFERENCES

[1] Cullough, N.J. et al., Seismic Site Response for an LNG Facility – Analyses and Lessons Learned. TCLEE 2009: Lifeline Earthquake Engineering in a Multihazard Environment, 2009 ASCE

[2] Geoing, Geomechanical report on the location for construction "warehouse for storage cables for cars" Zhabeni-bitola, 2011 (in Macedonian).

[3] Sesov et al., Definition of design seismic paramteres for the Industrial complex Zhabani, Bitola. IZIIS Report No. 2011/40

[4] Youd T. L., I. M. Idriss, "Liquefaction resistance of soils: Summary report from the 1996 NCEER and 1998 NCEER/NSF workshops on evaluation of liquefaction resistance of soils." Journal of Geotechnical and Geoenvironmental Engineering 127(Compendex), 2001, 297-313.

AN INTERACTION BETWEEN A BENDED PILE AND THE LAYERED SUBSOIL

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***Abstract**: This paper presents an analysis of a pile loaded in its head by a horizontal force. The pile crosses subsoil layers of a low bearing capacity and the bearing gravel layer below it. Further an analysis of displacements and internal forces of a bended pile in interaction with the layered subsoil, having various physical properties, is performed.*

***Key words**: Interaction, Bended Pile, Layered Subsoil*

1. Introduction

The basement on piles is usually used, if there is either the bedrock under the structure of the object a little bearable or soil is strongly squeezable, mainly if the depth of bearable layers is more than four meters. Soft clays, peat soils and rammed embankments are mostly little bearing layers, when their deformation is greater than the permissible value of building squeezing. Supported piles ensure low values of vertical load to the foundation, consequently when setting up the pile base, therefore there are no larger differences in the settlement of the object.

One of the major problems in design of pile bases is the determination of the necessary length of the pile. Therefore, the design needs as closely as possible the results of the engineering-geological survey, in particular under the bottom of a pile. The length of a pile is often variable, since the surface of bearable layer tends to be wavy or inclined [2].

2. Bearing capacity of subsoil

The task is to determine as precisely as possible the depths of the individual layers of the foundation, the establishment of the geological model using profiles and detailed determination of the properties of soils. The most important in this case are the strength and strain properties, which are used in the determination of the bearing capacity and the deformation of the foundation.

2.1. Horizontal bearing capacity of a pile

Laterally loaded piles may be designed by several computational models. They are usually situated vertically and are proposed to load the horizontal load. In case that it is sufficient to know the horizontal bearing capacity only approximately, some practical tables are used for the design in order to fulfill the condition:

(2.1) $U_{h,tab} \geq H_d$,

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where $U_{h,tab}$ is the value of the horizontal bearing capacity given in table due to ČSN 73 1004 standard,
H_d is the horizontal coordinate of the extreme load.

When using the design model according to [2] a pile is considered to be a beam fixed to the elasto-plastic subsoil, which may be in some special cases analyzed by the theory of beams rested on elastic foundation. Its background is the assumption of a linear relationship between stress and strain given by Winkler hypothesis

(2.2) $\sigma = k_h . y$,

where k_h is the modulus of horizontal compressibility [kN. m^{-3}]
y – horizontal displacement of a pile.

The value of the k_h modulus depends on the type of soil and the progression of deformation along the pile may vary. When the horizontal load occurs, the pile can behave either as rigid (only the shift or rotation occurs) or flexible (some deflections occurs after the load) [7].

2.1. Bedding of subsoil

The composition of the foundation underneath the base is usually a non-homogeneous, i.e. it consists of two or more layers. When we take into account the foliation, we may build the foundation model that better captures the real structure and, consequently, gives more precise results of deformations and stress.

3. Model of the structure

We dealt with a pile of the length L = 8.0 m. with a circular cross-section of a diameter of ∅ =0.42 m made of reinforced concrete. Modulus E = 20000 MPa. The foundation consist of a little bearable subsoil with the modulus E = 1.0 MPa, Poisson´s number for soil should be the value of ν = 0.35. Two different states of loads were used for the design: the first was the pile loaded by a horizontal force Fx = 100 kN applied in its head, the second was the pile loaded by a couple head bearing the moment M_y = 100 kNm.

In the next step the same pile was located in the layered foundation, whose composition and material properties are given in Fig. 1.

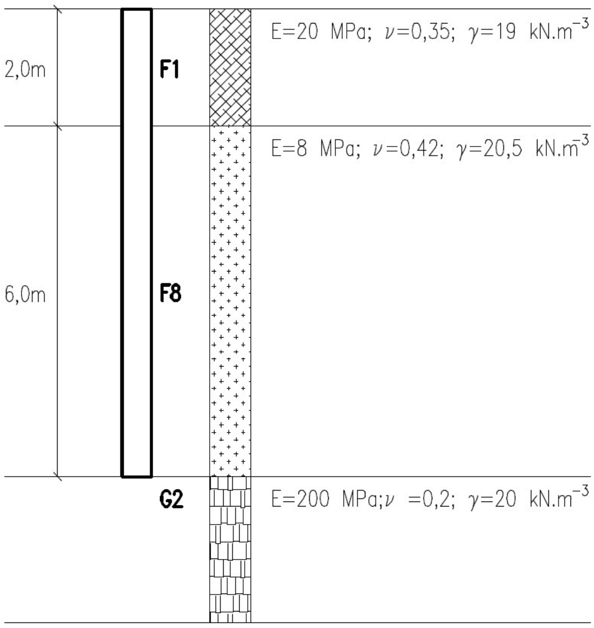

Fig. 1. The composition of layers and an intersection of model

A pile having a bottom, supported to the layer with a good bearing capacity, was used for the analyzed model. The structure was modeled as a 3-D model in ANSYS. The pile´s body was modeled using elements of SOLID65 and the foundation surrounding by natural elements SOLID45. The following elements were subsequently assigned to the properties of the subsoil layers according to Fig. 1. The contact between the pile and foundation was modeled using the contact elements TARGE170 and CONTA173. [1]. A more detailed explanation of modeling process was presented in [5]. The problem of interaction structure-foundation was analyzed in [3], [4] and [6].

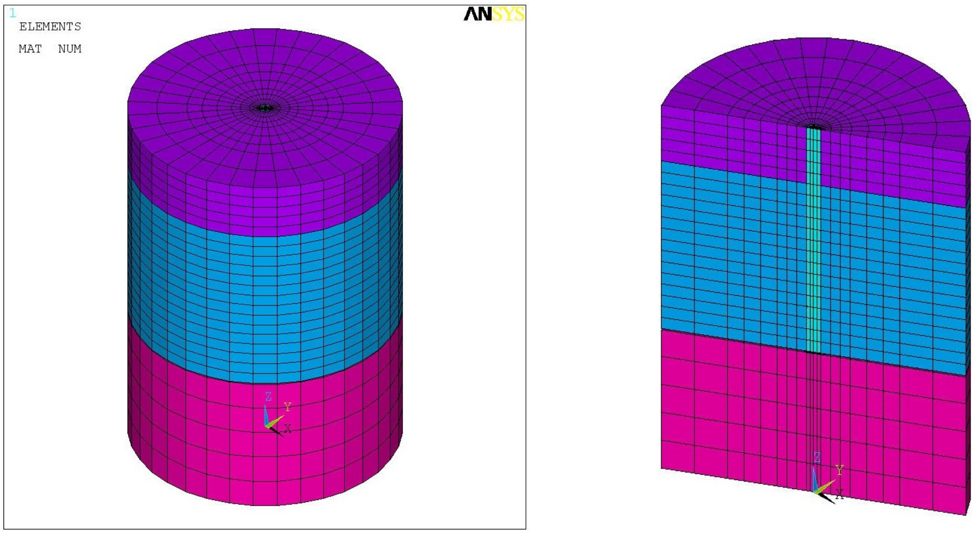

Fig. 2. 3D model a and its intersection

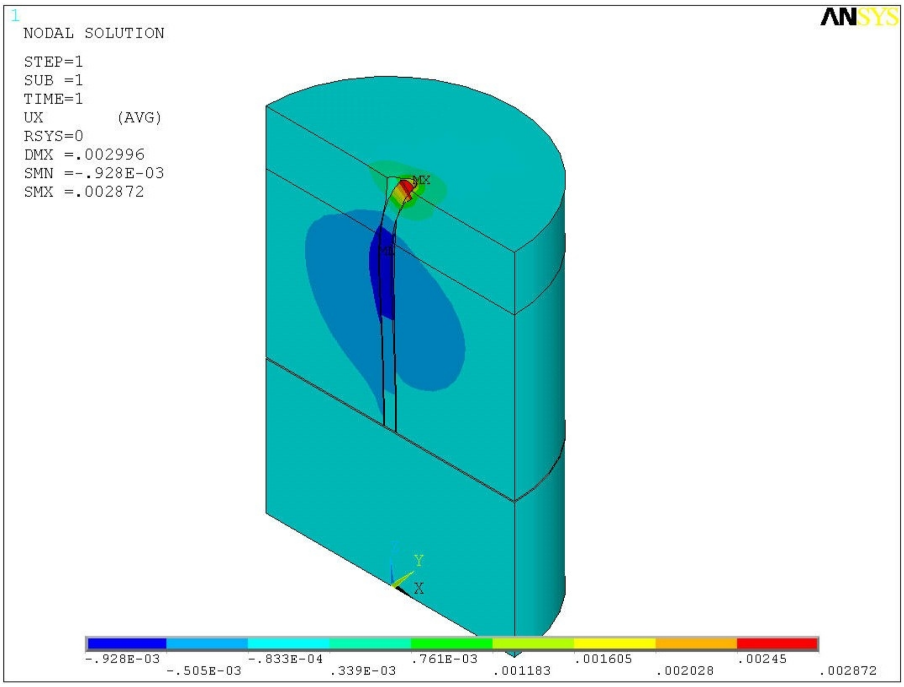

Fig. 3. Horizontal deformation of pile in layered foundation

From the results, given in Fig. 3 and Fig. 4 it is clear, that horizontal deformations of the pile in homogeneous environment made of incohesive subsoil are bigger in order than these of the pile in layered environment. This fact results from the lower value of the modulus of elasticity of incohesive subsoil.

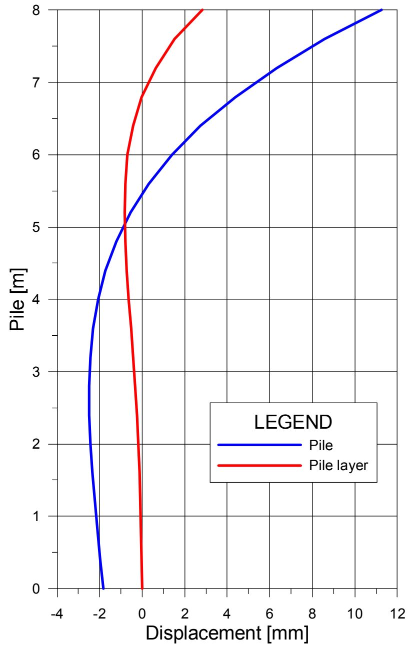

Fig. 4. Deformations of the pile in homogeneous and layered foundation

Conclusion

Modeling of the layered foundation better captures the real action of the pilots in the subsoil, which is much better and is close to the real conditions on the construction site. It is therefore appropriate to pay due attention to it.

Acknowledgement

This paper was supported by Grant Agency VEGA, project No. 1/0629/12.

REFERENCES

[1] ANSYS ® User's Manual for Revision 12, Swanson Analysis Systems, Inc.
[2] Bažant Z. Problémy zakládaní staveb, Academia Praha, 1966.
[3] Čajka, R. – Burkovič, K. – Buchta, V. – Fojtík,R.: Experimental soil – Concrete plate interaction test and numerical models. In. 12th Inter. Conference on Fracture and Damage Mechanics, FDM 2013 Sardinia, Italy, September 2013, Vol. 577, 2014, pp 33-36, ISBN 978-303785830-1 (in SCOPUS)
[4] Čajka, R. – Burkovič, K. – Buchta, V.: Foundation slab in interaction with subsoil. In. 2nd Globa Conference on Civil, Structural and Enviromental Engineering, GCCSEE 2013 Shenyhen, China; September 2013, Vol 838, 2014, pp 375-380, ISBN 978-303785926-1 (in SCOPUS)
[5] Jendželovský, N., Prekop, Ľ., Grmanová, A.: Analysis of Pile Foundations. In: 13th International Scientific Conference VSU 2013, Sofia, Bulgaria, June 6-7, 2013. Vol.I–10. pp. I-185-188. ISSN 1314–071X.
[6] Kuzma, J. - Hruštinec, Ľ.: Interaction between Spread Foundations and Subsoil. In: Proceedings of the *13th Europan Conference on Soil Mechanics and Geotechnical Engineering*. Praha, Czech Geotechnical Society CICE, 2003. ISBN 80-86769-04-6, p. 239-244.
[7] Turček, P., Slávik, I. Zakladanie stavieb, Vydavateľstvo STU v Bratislave, 2002, ISBN 80-227-1699-5.

PERFORMANCE OF SELECTED PAVEMENT SERVICEABILITY PARAMETERS AND SURFACE DETERIORATIONS

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Abstract: *The surface properties of pavements are a basic factor of their serviceability and an important factor of their safety. For the prediction reasons by incoming reconstructions, repairs and services is very important to know the development particular parameters of surface properties in dependence on the traffic load and time. An important factor of the road quality is a transverse evenness expressed by ruts depth and skid resistance expressed by friction coefficient. In order to determine the development these factors were analysed the measurements of test sections on the highway and selected roads I. and II. class every year. Constantly exchanging values of data, deficiencies in data collection, but also in the process of evaluation suggest to the need for further research.*

Key words: *pavement, ruts, skid resistance, 3D scanner, serviceability*

1. Introduction

A requirement for quality and safe road infrastructure resonates at present more frequently considering the obligations of EU member states to reduce the number of accidents and fatalities on the roads. Continuous growth of transport needs and the consequent effect to the increasing the share of freight transport is a major concern sustainability of roads quality. Globally the pavement serviceability describes the qualitative characteristics of roads as a summarizing the properties, ensuring the fast, smooth, economical and safe ride of motor vehicles. Monitoring the progress and development of serviceability parameters is important due to optimal maintenance and appropriate chosen time of renewal or reconstruction. Monitoring is oriented to the qualitative parameters values decrease as a result of several factors_ mainly traffic volumes and climate impacts. This process is characterized as a development of parameter, respectively its degradation. After detailed analysis the development functions_ describing the deterioration of the parameter depending on the observed effects (time or transport loads) are developed using the mathematical and statistical methods.

2. Transverse evenness

The evaluation of evenness road in transversal direction consists in measurement of transverse evenness as aberrance from theoretical condition. From this reason is in terminology important to differentiate these two basic terms. Transverse road evenness is unevenness of road surface in vertical direction on the traffic direction. It expresses as the difference between existing and theoretical transversal profile of road. The measurement

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and evaluation of transverse evenness is realised because of determination quality of road pavement from the aspect of permanent deformations, which are well-known as road rut.

By measurement of transverse evenness are valuating these parameters:

- *rut depth /RD/* – vertical distance between connection of apex wave and the lowest point of wave,
- *permanent deformations /PD/* – vertical distance between first and last point of measured profile and the lowest point of wave (fig.1),
- *water depth /WD/* – vertical distance between horizontal flat ground in the position the lowest point of wave and the lowest point of wave (fig.1).

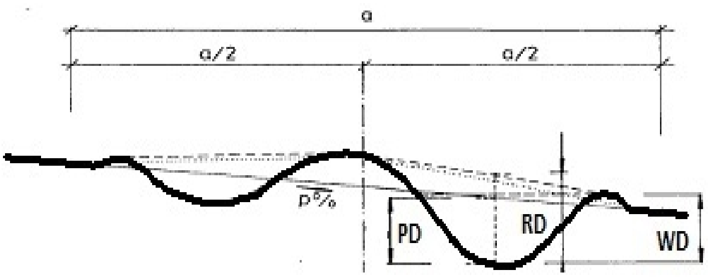

Fig. 1 Elementary characteristics of transverse evenness [8]

From the aspect of pavement serviceability parameters and their influence on road operation ability is the conclusive evaluating factor rut depth, which is also the elementary factor of water depth [1].

The creation of well-known road ruts is as a result of mostly two dominant aspects; in first case overlimited traffic load and excessive traffic density and in second case parking and staying heavy trucks on unassimilated surface of pavement – especially inappropriately elected surface (Fig.2).

Fig. 2. Pavement rut in traffic lane [1]

The similar problem accrues on bus way point in the cities (Fig. 3), but in this time are the pavement surfaces on this bus way points exchange for cement-concrete or cobble stone.

Very important assignments by assessment optimal current maintenance, reconstruction but also recovery have the prediction of several pavement serviceability parameters. The prediction of transverse evenness analyse we on the base the creation and analysing predictions functions these parameter.

By reason of constantly increasing tendency of count the heavy trucks and load on our pavements along with the important location of Slovakia, is very considerable to create the breach model and consequently the forecasting pavement conditions. For that reason is the determination of degradation models and functions actually and important issue in the pavement diagnostic not only in Slovakia but also in foreign countries.

Fig. 3 The cement-concrete surface on the bus way points in Žilina (Veľká Okružna St.)

3. Skid resistance

A skid resistance of the road surface is a characteristic, which provides interaction between vehicle wheel and road surface. It can be defined as a power emerging from the contact area of tyre with roadway. Actually, it is the power which inhibits slipperiness and reduces the braking distance in critical driving moments. The skid resistance as such has two basic components - adhesion and hysteresis. Adhesive component originates from an ability of molecular adhesion i.e. the particles of the tyre´s rubber get into close contact with roadway. Hysteresis component originates from the consequence of energy loss inside the tyre´s rubber passing through projections of the road´s surface. The aforementioned characteristics are directly related to the basic characteristics of roadways which are microtexture and macrotexture. Microtexture is directly related to the surface of individual grains. It says how smooth or rough the grains are. Microtexture affects mainly adhesive properties. Macrotexture represents inequalities on the road´s surface and describes how the gravel aggregate individual grains are arranged on the surface. Macrotexture directly influences hysteresis qualities. Therefore, it is important for quick draining of water from wet road surface [1].

The consequence of this is a limiting formation of aquaplaning while the tyre contacts with the road surface. Skid resistance of roadway can be evaluated subjectively e.g. by touching the surface with hands. To determine this quality many experiences are necessary. However, it is still considered to be quite inaccurate. Objectively, we can clearly specify the antiskid properties only by a proper measurement. Skid resistance, as such, is mostly defined by using the coefficient of friction. Over the world, there exist a lot of methods to stipulate the magnitude of sliding friction, as well as for the detection of the macrotecture. Results of these measurements are coefficients and parameters that represent the skid resistance of the road´s surface.

Nowadays, there exist more than twenty devices for measuring sliding friction. Although, some of these devices are of the same type. However, they may vary from each other by marginal conditions when measured. The best device to detect the macrotexture of the road´s surface is a profilometer [4]. To conclude it, evaluating skid resistance of the road´s surface depends on the type of devices used and on the method used. These methods are divided to direct and indirect. The difference is that indirect methods use for evaluating the skid resistance auxiliary variables of the surface´s macrotexture. On the other hand, direct methods are directly expressing to the coefficient of longitudinal friction or coefficient of the lateral friction.

In Slovak Republic we use Profilograph GE for this measurement. The result is called a Mean Profile Depth (MPD). Another method used for measuring rests in spreading out a specified volume of glass microspheres on the surface of the road. This provides us with Mean Texture Depth (MTD).To measure the resistance of the road´s surface against sliding we use a pendulum test (TRRL). This test is based on a kinetic energy loss of the rubber heel of pendulum, after passing a wet road surface. Its output is PTV (Pendulum Test Value). A high-capacity measuring device called Skiddometer BV11 is used, too. The output is a coefficient value of longitudinal friction $M_{u.}$

For measurement of rutting, longitudinal unevenness and also macro-texture of pavement surfaces is currently used in standard way the profilometers. Systems for mobile laser scanning do not yet have sufficient resolution for continuous measurement of unevenness for the next calculation of the parameters of IRI and MPD. In between the biggest advantages of laser scanning includes the possibility of creating a 3D model of a larger ground space, allowing for a variety of applications, where the lower resolution is not very limiting (identification of ruts, cross fall of pavement, gradient, superelevation, or passportization of pavement and its ambient) [6].

In spite of the mentioned facts and drawbacks, is resolved comprisal the integration of laser scanning methods to more standards at national level and also at European level.
Laser scanning technology allows to focus in detail the pavement surface and the local ambient in a coordinate system. In many cases, it is a more detailed focus than provided by other technologies, as it is intended only selected sections or selected parts of the pavement. In between of additional advantages of this method is a self-moving machine, which does not need any other external mechanisms, that make it difficult to scan the surfaces and thereby negatively affect the measurement itself [8]. The system allows free movement of the object during scanning, and also can be traced image of the scanned surface in real time. On the experimental field (Fig. 4) were realized the measurements using a smaller type of hand-held 3D scanner - ZScanner 600 (Fig. 5) with a maximum resolution of 0.1 mm. The disadvantage of handheld equipment, is time consuming of measurement itself and the next evaluation. For more accurate measurements are used specially designed network comprising positioning points through which the laser beam is recorded pursued the pavement surface and its texture. After processing the results we therefore assess the quality of the surface in terms of its macro-texture (Fig. 6)

Fig. 4 Experimental field with testing pavement

By reason of the time consuming and especially relatively small recorded area, was realized measurement of surface and pavement texture by using another type of 3D scanner - measuring station Leica ScanStation with a resolution of 1 mm. The method consists in creating a terrain model with the details required measuring points on the pavement. Technology Smart X-Mirror allows using a rotating mirror to scan the entire area up to the zenith in few minutes. The disadvantage is relatively big measurement sensitivity of the lighting conditions and in particular in the reflected light.

Fig. 5 Measurement of 3D hand scanner - ZScanner 600

The output of measurement ZScanner (Fig. 6) is the recording of the pavement surface and its texture. Before the measurement can be setup the accuracy, i.e. set the number of recorded points on the analyzed surface. Obviously, with more points directly related significantly higher time-consuming measurement and evaluation. On the Fig. 5 is recorded tested pavement surface field with a specified profile which, as seen on the right side of the figure, can be further focus. The measurements was realized on the field of approximately of 10 m^2 with an accuracy of 0.5 mm, which is for this type of scanner quite big and its further monitoring would be very time consuming.

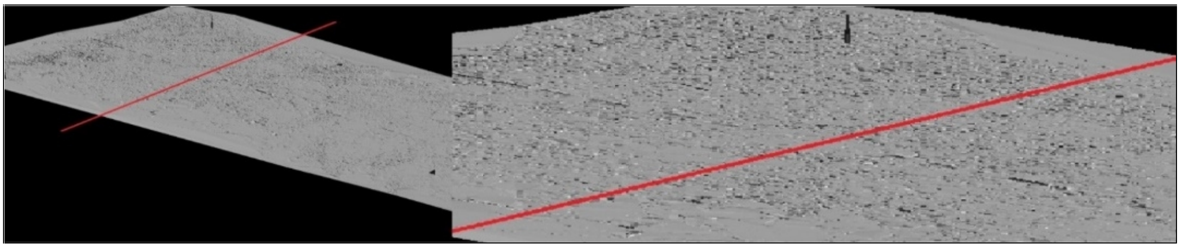

Fig. 6. Records of the pavement surface on experimental field by using the experimental field ZScanner (author: doc. Ing Kováč, PhD.)

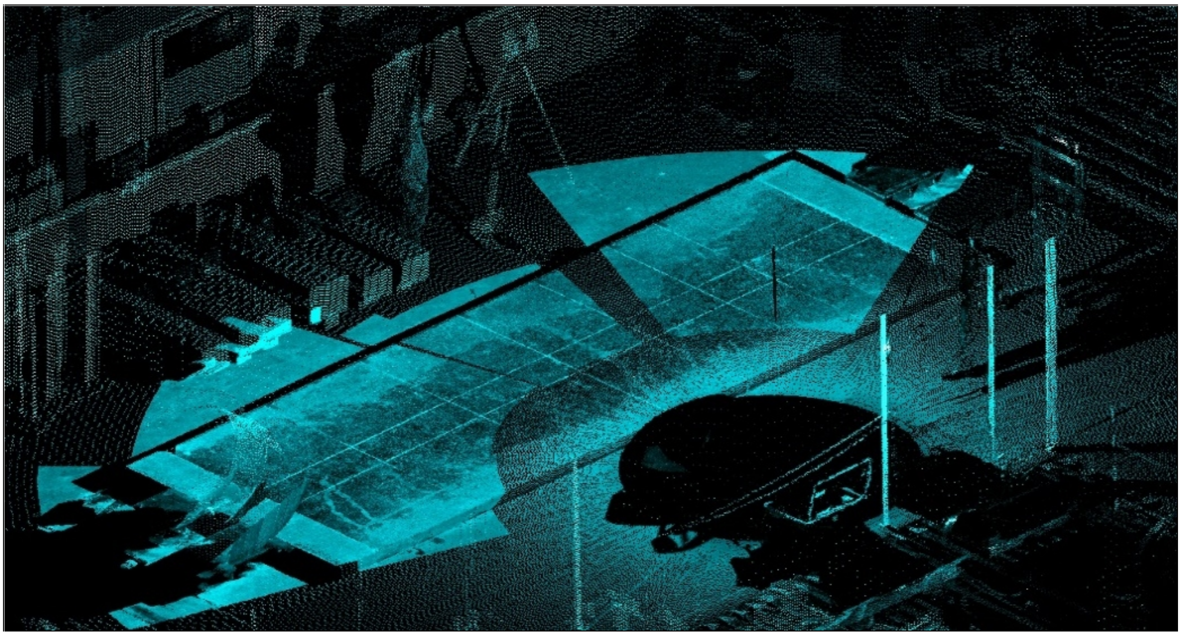

Fig. 7. 3D model of the experimental field with the environment 3D realized with 3D station Leica (author: Ing. Villim)

Mainly due to reduced time demands seem appropriate scan method using a Leica 3D scanner. The most significant step in this method is the surface treatment of clouds of points (Fig. 6). This evaluation of the surface terrain (pavement) takes place in several successive steps. The individual measured points are transformed into the coordinate system x, y, z; carry out the removal of noise from the measurement and delete unnecessary objects (pedestrians, vehicles, vegetation, etc.). On Fig. 7 are processed point cloud into a 3D model Application of this method will be to further research, which will be given to "behavior" the pavement surface and the structure of pavement loading with repeated truck wheel load [5].

Conclusions

One of the most important and the most significant factors which directly influences economic factors as well as safety traffic on the roads is a parameter of serviceability. It is important not only from the perspective of properly elected maintenance, reconstruction, or planned road restoration. Constant road´s monitoring and analysing helps overall diagnostics of the road network.

This article introduces basic characteristics and two important parameters of serviceability and skid resistance. It also points out on the necessity of the further monitoring and analysing the above mentioned parameters. They will create features and models that will later play an important role in the future predictions and thereby directly help to develop and attempt to improve our road network.

Acknowledgement

The research is supported by the European Regional Development Fund and the Slovak state budget for the project "Research Centre of University of Žilina", ITMS 26220220183.

REFERENCES

[1] Čelko J. a kol.: The surface properties of pavements, in Slovak: Povrchové vlastnosti vozoviek (Prevádzková spôsobilosť vozoviek), EDIS Žilina, 2000. ISBN 80-7100-774-9.

[2] Chang J.-R., S.-J Chao: Development of a .Rutting Prediction Model through Accelerated Pavement Testing Using Group Method of Data Handling (GMDH). Department of Civil Engineering, National Ilan University, I-Lan, Taiwan, 1999.

[3] Molenaar, A.: Principles of Pavement Management Systems, Planning on Network and Project Level. Basic Steps in Pavement Management Systems, TU Delft, 02/1992. 7-92-411-1..

[4] Pederson Neil J.: Pavement Lessons Learned from the AASHO Road Test and Performance of the Interstate Highway System. Transport Research Board, 2007.

[5] Přikryl, M., Kutil, L., žák, J.: 3D měření technologií laserového skenování, švédsko, silnice 41 (väg 41) bergham–gullberg. konferencia asfaltové vozovky 2011, české budějovice.

[6] Timm, D. H., Mcqueen, J. M.: A Study of Manual vs. Automated Pavement Condition Surveys, Highway Research Centre, Alabama 2004.

[7] von Quintus., B. M. Kilingsworth, M. I. Darter: Catalog of Recommended Pavement Design Features. TRB National Research Council, Washington D.C. 1997.

PROGRESSIVE QUALITY ASCERTAINMENT METHODS OF THE SURFACE AND STRUCTURAL LAYERS OF A PAVEMENT

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***Abstract**: Pavement data collection is of paramount importance in Pavement Management Systems (PMS), where it fulfils an important advisory role in selection of an appropriate repair or reconstruction technology. Consecutively, by appropriate diagnostic method, we are able to choose optimal material for repair, which entails a positive effect not only from the economic viewpoint but from a time viewpoint as well. Concurrently, a fairly large emphasis is put on diagnostic methods, which are non-invasive, simple, safe, time efficient and non intrusive from the viewpoint of interference with traffic flow of particular road. These policies largely conform to the methods of measuring with ground penetrating radar (GPR) and 3D laser scanner measurement.*

***Key words**: diagnosis of pavements, 3D scanner, GPR, test field*

1. Introduction

Pavement diagnostics is, together with the collection of traffic data and updating process of current database of the road network, the main input of pavement management processes. It is the most challenging process of the entire PMS in terms of financial, time, technological and personnel resources. This issue was addressed by a number of research teams around the world [1-3, 6] and each progressive automated data collection method tends to be very marketable. The issue of the level of quality was also engaged in a number of studies, for example. [5, 6] in principle, they are showing that the automation of data collection does not necessarily distort the measured data. An overview of current methods and automation procedures of data collection was process by the American Association of State Highway and Transportation Officials (AASHTO) in its publications [1, 2].

As new technologies arise, they entail not only the simplification the data collection process but also increase in quality of measurement results and even measurement of data which were previously possible to obtain only through destructive methods.

The ability to measure more parameters, measure them faster, more accurately and safely, enables us to obtain the desired volume of data needed for complex PMS decision-making processes - estimation of optimal intervention time and choosing of optimal technology for maintenance repair and rehabilitation.

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If the measured data are archived thoroughly, they may serve as a basis for the creation of important advisory models which are known as degradation or prediction models. We comprehend the deterioration of the pavement as gradual degradation of individual properties deteriorating under a variety of influences. The aging of the material and its fatigue characteristics have considerate impact on deterioration. For surfacing materials in particular, it is the transition from a flexible to a plastic state continuing until reaching the limits of the infraction.

Degradation model characterizes supposed changes of particular parameter or characteristic pavement condition index in relation to time, or repeated loading. Standard practice for estimation of pavement degradation and definition of such model is to repeatedly measure and asses pavement characteristics in given time intervals on particular road section, and, after their statistical processing, ascertainment of their relationship, in most cases, with traffic load, time, or other factors affecting a given parameter. The implementation of accelerated tests on pavement test field (Fig. 1) is currently a priority objective of the research activities in the immediate future.

This article is focused on the collection of data regarding pavement structure using the interpretation of the radargrams and collection of data regarding the quality of road surface by scanning its surface with a laser beam.

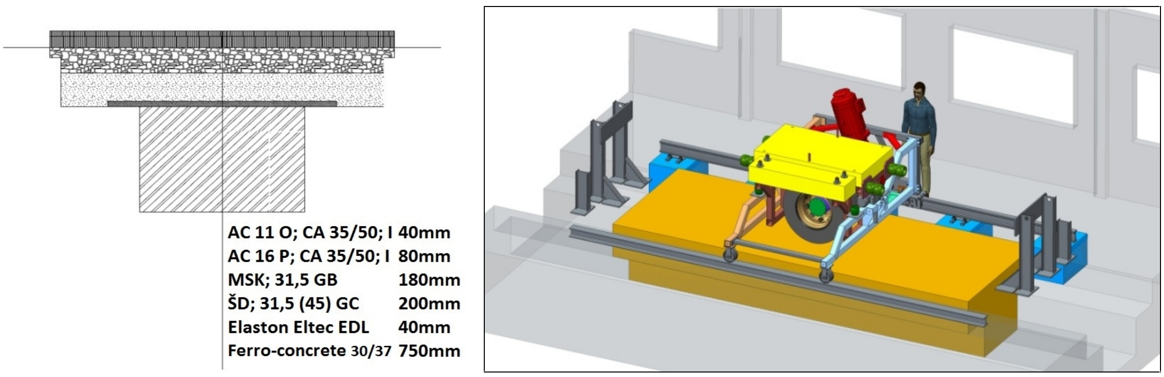

Fig. 1. Accelerated Pavement Testing Facility of the University of Zilina - cross section of pavement test field and design of the facility

2. Practical application of advanced data collection methods on the pavement test field

For evaluation of a measurement method, measured subject has to be thoroughly known and measured data has to be collated with known reality. In the context of PMS research, an experimental pavement test field in scale of 1:1 was constructed. This test field is part of the pavement accelerated testing facility. The research links up with pavement research performed by company VUIS-roads in the 90's. The general principle of APT testing is to apply artificially inducted load similar to real life traffic load in a compressed time period, thus providing an expedited means of evaluating factors associated with traffic-pavement interaction.

The test field has a length of 6 meters and a width of 2.2 meters. The pavement structure was designed as a pavement for a road with traffic load class TLC III. It is a flexible pavement with bitumen concrete surfacing. The wearing base layer is made of asphalt concrete (AC) 11; CA 35/50; 40 mm thick. The base course layer is made of asphalt concrete (AC) 16 P, CA 35/50; 80 mm thick. These layers are connected by penetrating coating PS; 0.5 kg/m^2. The road base is a mechanically bound aggregate MSK 31.5 GB; 180 mm thick. Sub-base is gravel ŠD; 31.5 (45) GC; 200 mm thick. Conformity of all supplied materials has been confirmed by tests affirming the quality elaborate supplied by the constructor; quality of particular layers was confirmed through quality tests performed during the construction as prescribed in the test plan.

3. Diagnosis road construction layers using GPR (Ground Penetrating Radar)

Among current methods of geophysical survey, the most effective, in terms of diagnostics road construction (except of FWD), is GPR method. The reasons for growing popularity of the GPR method are its non-destructive nature, high resolution, ideal depth range (depending on the transmitting antenna), low cost and high speed of a survey. Moreover, it can be carried out in full traffic. Data acquisition is performed in situ by GPR device, consisting of transmitter and receiver antenna, control unit and a computer. The measurement is carried out directly on the surface of a studied structure. In our case, it was used the device from GSSI - SIR 20 with Horn - type antenna (center frequency of 2 GHz). Transmitter and receiver antenna is hanged above surface at a distance of about 0.45 m.

3.1. Principles and methodology of measurement GPR

GPR is a relatively fast method of geophysical survey. It is based on emitting of a high-frequency electromagnetic signal in regular time impulses into the rock, soil or anthropogenic environment and its subsequent registration of passing and reflected waves from bodies and interfaces. The position system (e.g., GPS, odometer) is an important part of the measurement system that identifies the position of each measurement within the measured distance.

Several GPR time records (A - scan) at regular intervals along specified profile form B - scan or a radargram. A radargram shows continuous record of measurements along a profile. Data processing is carried out in a specialized software system. Modified data is then interpreted and graphically processed in the end. Thicknesses of layers, possible delamination, also built objects, inhomogeneities and other hidden faults can be calculated from the resulting travel times.

3.2. Measuring of the road shape and its texture by a laser scan method.

The profilometers are currently used for measurement of rutting, longitudinal unevenness and also macro-texture of pavement surfaces. Systems for mobile laser scanning do not have yet sufficient resolution for continuous measurement of road unevenness for the further calculation of the IRI and MPD parameters. The biggest advantage of laser scanning includes the possibility of creating a 3D model. It allows various applications, where the lower resolution is not very limiting (identification of ruts, cross fall of pavement, gradient, super elevation, or passportization of). Despite of the mentioned facts it works on the integration of laser scanning methods to more standards not only at national level, but also at European level. The laser scanning technology allows focusing in detail on the pavement surface and its near surroundings in a coordinate system. In many cases, it is a more detailed measurement than it is provided by other technologies. Among other advantages of this method a self-moving machine can be included, which does not need any other external mechanisms, that can make difficult to scan remote surfaces and thereby negatively affect the measurement itself [4]. The system allows free movement of the object during scanning. It is also possible to see an image of the scanned surface in real time. On the test field (Fig. 1) were realized the measurements using a smaller type of hand-held 3D scanner - ZScanner 600 (Fig. 2) with a maximum resolution of 0.1 mm. The disadvantage of handheld equipment is time consuming measurement and the evaluation. For more accurate measurements a specially designed network was applied therefore the laser scan can records studied pavement surface and its texture. Based on processed results the quality of the surface in terms of its macro-texture can be determined (Fig. 2)

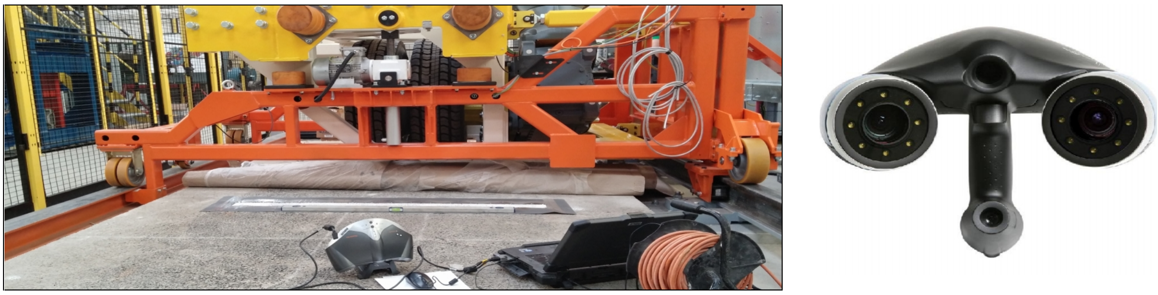

Fig. 2 Measurement of 3D hand scanner - ZScanner 600

4. Processing and results

The output of measurement with the ZScanner (Fig. 2) is recording of pavement surface and its texture. Before the measurement, the accuracy can be setup up, i.e. setting up the number of recorded points on the analyzed surface. It is obvious that with increased number of points is directly related also significantly higher time-consuming measurement and evaluation. On the Fig. 3 is shown the surface of the test field with a studied profile which can be further focus. The measurements was carried out on the field of approximately of 10 m^2 with an accuracy of 0.5 mm, which is quite big for this type of scanner and its further monitoring would be very time consuming.

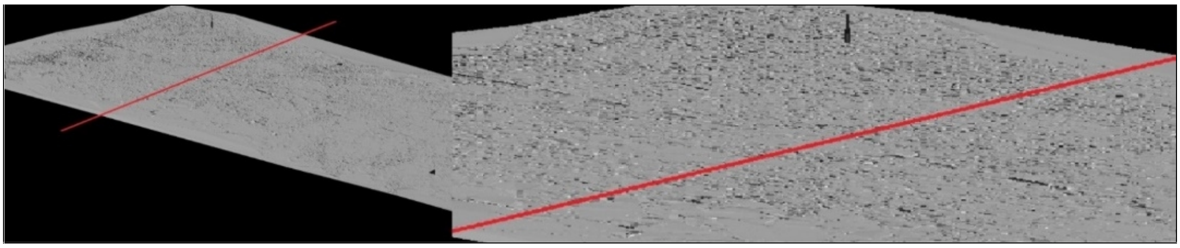

Fig. 3 Records of the pavement surface of the test field using the ZScanner (photo: doc. Ing Kováč, PhD.)

5. GPR results

The before mentioned test field was measured by the GPR system SIR-20 (GSSI) in a transverse profile. In this case, it was applied an antenna Horn type with centre frequency of 2 GHz. The step of measurement of 0.01 m and time record length of 20 ns was used. The total measured length of the profile was 1.4 m. Manufacturer's specified depth range for this type of antenna is about 0.75 m, which is sufficient for diagnosing of road condition and layers construction. Radargram was treated by special software package ReflexW designed by Sandmeier Scientific Software.

The raw data were firstly processed in the following manner; 1 Static correction - setting of the 0 value (the surface of the test field). 2 1D filtration - dewow , correction of the time travel record deformation caused by low-frequency noise 3 Butterworth filtration 4 Selective amplification of the signal 5 2D filter - running average . The treated radargram was converted to depth section. Every pavement interface was determined by analysis of the amplitude in the time travel section (Fig. 4) and on this basis it was converted into the final depth section (Fig. 4). The resulting GPR interpretation of the test field is almost identical with the project documentation (Fig. 4). It can be observed intact subhorizonal layers of the experimental road section (Fig. 4). The values of the layers thicknesses, as well as the velocity of propagation of the electromagnetic signal in the studied environment and calculated values of the dielectric constant are shown in the table (Tabl. 1).

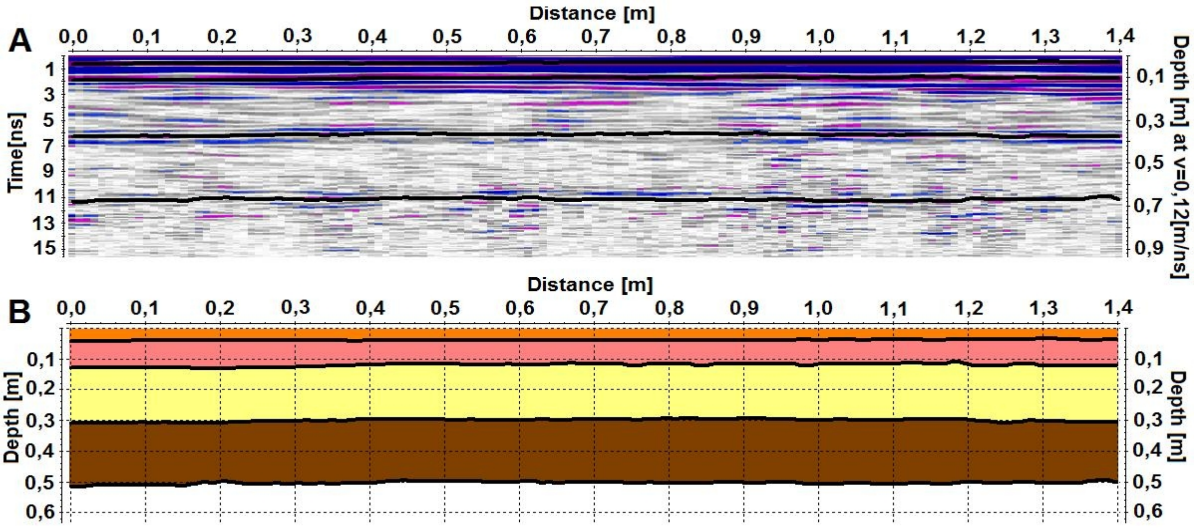

Fig. 4. A. The resulting radargram, black line indicates boundaries between the layers of the test field. B. The resulting depth section of the test field.

Table 1 Thicknesses of the test field layers with trigger interval of 0,1 m, their average value and dielectric constant.

Profile	**AC 11 O**	**AC 16 P**	**MSK**	**ŠD**
distance [m]	thickness [m]	thickness [m]	thickness [m]	thickness [m]
0.00	0.044	0.085	0.18	0.20
0.10	0.041	0.088	0.18	0.20
0.20	0.041	0.086	0.18	0.19
0.30	0.041	0.085	0.18	0.20
0.40	0.041	0.080	0.17	0.21
0.50	0.041	0.077	0.18	0.20
0.60	0.038	0.082	0.18	0.20
0.70	0.038	0.078	0.18	0.21
0.80	0.036	0.091	0.17	0.21
0.90	0.038	0.083	0.18	0.21
1.00	0.038	0.078	0.18	0.21
1.10	0.036	0.086	0.18	0.21
1.20	0.036	0.086	0.18	0.20
1.30	0.033	0.089	0.18	0.20
1.40	0.036	0.091	0.18	0.20
average	**0.039**	**0.084**	**0.18**	**0.20**
dielectric value	**4.6**	**4.9**	**13.3**	**13.7**

Despite of above mentioned, methods of GPR and 3D laser scanning have not yet become a standard tool for the road administrators in the diagnosis and maintenance of roads. It is also obvious that these methods, when they are used in proper manner, can save some financial expenses for a road repairing.

Conclusion

Progressive methods for the assessment of road surface quality described in the article, are meant to facilitate the fulfilment of one of the central objectives of the research activity 3.1 – "research and development in the field of monitoring and assessment of transport infrastructure" in the framework of the Research centre founded under the auspices of the University of Zilina.

One of the main subjects of this activity is the development and verification of new condition diagnostic and monitoring methods of the transportation infrastructure. The comprehensive output of the research project will be a development of infrastructure diagnostic systems and methodologies for automated data collection. Consequently, it will therefore be possible to objectively evaluate variables and in-variable parameters of a road.

On the basis of evaluation of serviceability - its individual parameters, it will be possible to create degradation models and trend lines in order to predict the future development of road network's technical parameters; this will ensure the safety of traffic and fluid traffic flow while minimizing the cost during the whole life cycle of the road.

Acknowledgement

The research is supported by European regional development fund and Slovak state budget by the project "Research centre of University of Žilina", ITMS 26220220183.

REFERENCES

[1] AASHTO. Standard Practice for Quantifying Cracks in Asphalt Pavement Surfaces from Collected Images Utilizing Automated Methods, 2010.

[2] AASHTO. Standard Practice for Collecting Images of Pavement Surfaces for Distress Detection, 2010

[3] Decký M. Dynamická interakcia vozidla s vozovkou z aspektu jej pozdĺžnej rovnosti. Habilitačná práca, KCS, SvF, Žilinská univerzita, 2003.

[4] Přikryl M., Kutil L., Žák J. 3D měření technologií laserového skenování, Švédsko, silnice 41 (väg 41) Bergham–Gullberg. Konferencia Asfaltové vozovky 2011, České Budějovice.

[5] Sivaneswaran N., Pierce L.M. and Mahoney J.P. Transition from Manual to Automated Pavement Condition Surveys: Washington State's Experience, 6th International Conference on Managing Pavements (2004)

[6] Timm D. H., McQueen J. M. A Study of Manual vs. Automated Pavement Condition Surveys, Highway Research Centre, Alabama 2004.

ELESHNITSA LANDSLIDE: CURRENT CONDITION AND CONSIDERATIONS

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***Abstract**: The present study concerns the geological and hydrogeological features of a landslide, developed in Paleogene sediments next to Eleshnitsa village, Blagoevgrad region, SW Bulgaria. A detailed characteristic of the area has been made, including data for the seismic situation, water table, and seasonal rain values. Fieldwork included sample collecting, low-scale geological mapping, and core boring. Laboratory analyses were performed on the collected samples for mineralogical phase identification as well as for rock and soil strength. As a result, detailed low-scale 3D GIS maps of the landslide were produced.*

***Key words**: landslide, landslide mitigation and prevention, Blagoevgrad region*

Introduction and geological setting

This study is part of the European Territorial Cooperation Programme "Greece-Bulgaria 2007-2013" within the project RISKLIDES (RISK management of natural and anthropogenic landsLIDES in the Greek-Bulgarian cross-border area). RISKLIDES is a project aiming at the assessment and management of landslide risk caused by natural or anthropogenic causes in the area adjacent to the roadline Lailias-Serres-Kato Nevrokopi-Koprivlen-Gotse Delchev-Bansko, covering a total road length of 160 km, from which 92 km in the Greek and 68 km to Bulgarian territory (Fig. 1). Several landslides have been established during the project and here we present a detailed geological and hydrogeological characteristic, as well as a risk mitigation strategy, and risk management of a landslide next to Eleshnitsa village, Blagoevgrad region, SW Bulgaria.

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Fig. 1. Map of the area, concerning RISKLIDES project.
Point 11 marks the landslide at Eleshnitsa.

The landslide is situated about 1 km south from the crossroad for Eleshnitsa village, in point with coordinates N 41° 49' 15.8" / E 23° 36' 49.7" (Fig. 2). Geomorphologically, the landslide is located in the Momina klisura gorge in the right slope of the River Mesta Valley. The lay of the region is hilly with 715-750 m altitude. The landslides' slope surface is inclined toward the flood plain of Mesta River. The valley erosion and accumulative slopes to the south of the landslides are also subjected to gravitational processes; however, they do not impact the road directly.

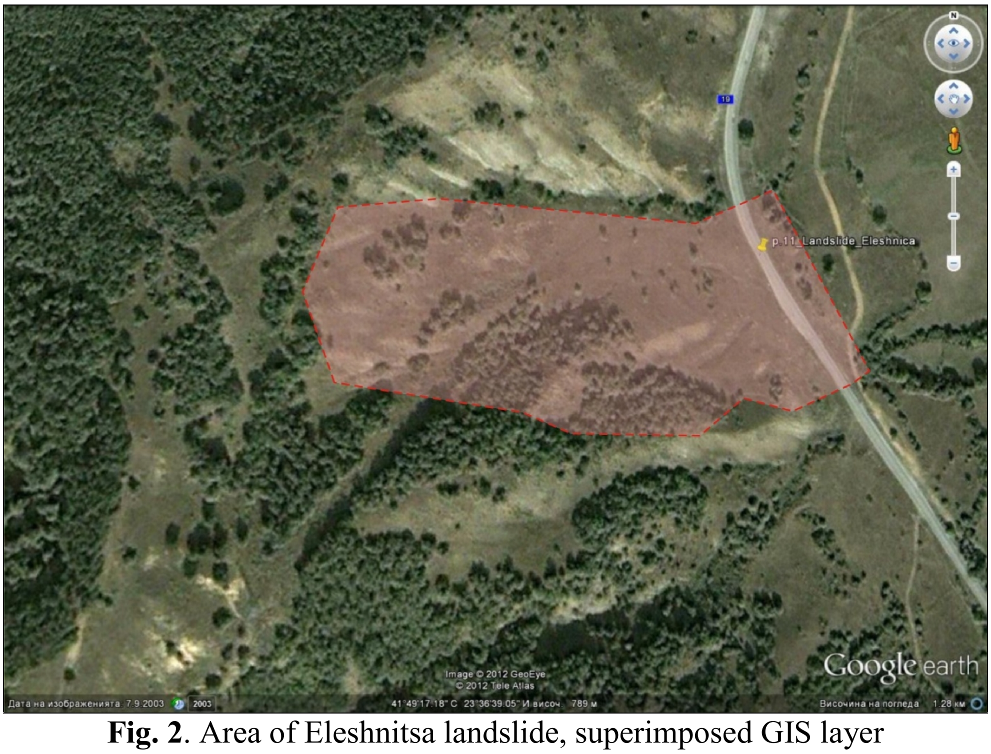

Fig. 2. Area of Eleshnitsa landslide, superimposed GIS layer
over a Google maps orthophoto.

The landslide is developed in Paleogene sediments presented by a breccia-conglomerate formation [1, 2]. The latter is built up of irregular alternation of slices of polymictic breccia-conglomerates, sandstones, silt shales, and silt shale argillites aged Late Eocene – Early Oligocene. Polymictic breccia-conglomerates intercalated by couple of sandstones and silt shale layers of about 0.7 m thickness predominate on the surface within the frames of the landslide. The Breccia-conglomerate slices thickness varies from 2-3 up to several dozens of meters. They dip (50-55°) to the northeast. Their boundary with the metamorphosed rocks runs along a fault striking at 140°. The metamorphites are presented by biotite and two-mica diaphthoresised gneisses characterized with abundant pegmatoid injection included within the Ograzhden Lithotectonic Unit. Main tectonic reason for the landslide arising are the movements along the 140° striking fault which is a right lateral normal strike-slip fault which northeast flank has sunk. The fault is later with respect to the Mesta Depression setting and most probably is of Neogene age. A number of local landslides and rock-falls are related with it.

Methods and materials

For the purposes of this study, extended number of materials have been collected and tested in situ and in the lab. The following field survey and laboratory tests were carried out to establish the geological conditions within landslides, clarify the scope and dynamics of sliding, and to obtain a sufficient amount of reliable data of these slopes: geotechnical mapping of landslides; drilling of exploration boreholes located in one representative profile in the central part of the landslide; optimal number of soil samples were collected and a set of laboratory tests were performed for determination of mineralogical, physical and mechanical properties of the soils, including X-ray diffraction and peak and residual shear strength (minimum of 3 pcs. samples of every engineering geological layer).

All field and laboratory data were processed and presented in a final engineering geological report including drawings of engineering profiles as well obtained computational values of engineering geological layers. Design values of physical and mechanical properties have been determined from laboratory tests data, and they have been reduced by correction coefficients according to Ordinance № 12/03.07.2001. The method of Janbu in “effective stress” has been used. Several options have been considered - stability of the slopes in the natural state with deep groundwater levels, after rising of groundwater levels and earthquake influence. Software program Slope W has been used. Factors of safety for more than 1,000 slip surfaces have been calculated and most adequate of them have been selected (Tabl. 1, Fig. 3).

Table 1. Factors of safety F_s of slip surfaces under different load conditions

Slope condition	Slip surface number	Factor of safety, F_s
Dry slope	393	2.107
High ground water table	501	1.103
High ground water table + earthquake	388	0.887

Excited resistance measurements have been conducted along a profile with northeast direction crossing the central part of the landslide body. Detailed mapping included development of GIS layers superimposed over a geological map of the area. All 3d models are built in Autodesk AutoCad. 3D surfaces in the model are made of triangular faces which are taken from the geodesy drawings. These faces are extruded to get the volume of the part of the landscape that we need to model. Autodesk 3dStudioMax was used to make a landslide animation. The simulation of the movement is achieved through MORPHER modifier. All results from the study are available upon request.

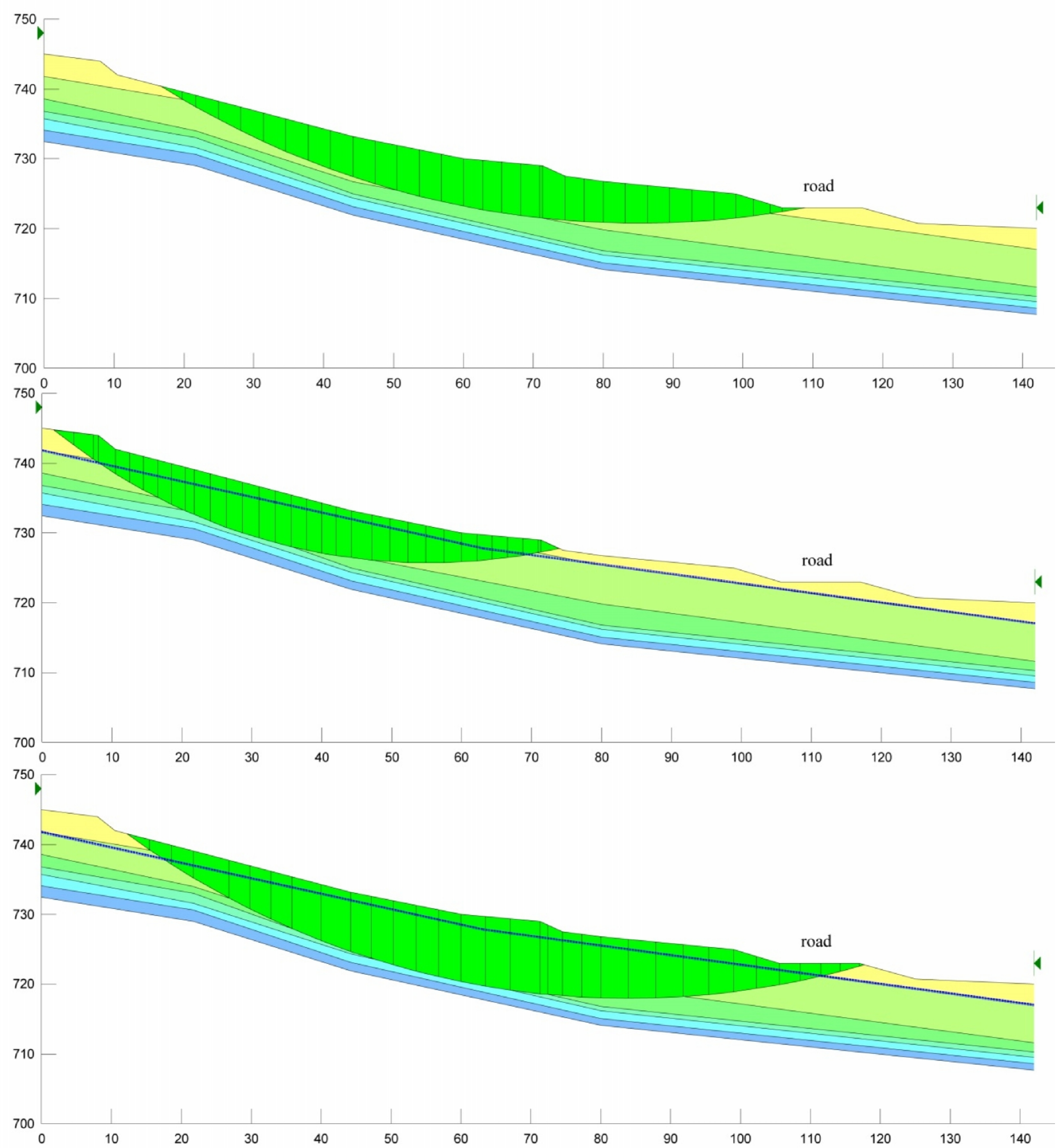

Fig. 3. Different load conditions for Eleshnitsa landslide: dry (top), high ground water table (middle), and High ground water table + earthquake (bottom).

For slope stability studies, the following tasks have been performed: Preparation of 2D geomechanical model of the landslide, including the location of the most possible slip surface, groundwater level, verification of computing values of physicomechanical properties of soils; Determination of the factor of safety (F_s) of the landslide in different conditions - actual slope stability, slope stability after uprising of groundwater level, slope stability during an earthquake, slope stability in heavy traffic and a combination of relevant factors; Following the geotechnical slope stability analysis adequate preventive measures have been proposed to increase slope stability and to prevent activation of the recorded landslide.

Results and discussion

Several GIS layers have been produced for the project, including layers with points of interests, geology, types of geohazards, etc. These layers are combined with a geological map of the area. The scale of the maps does not allow for their proper representation in this paper but all files and maps are available upon request from the authors. The produced 3D model of the landslide is presented on Fig. 4.

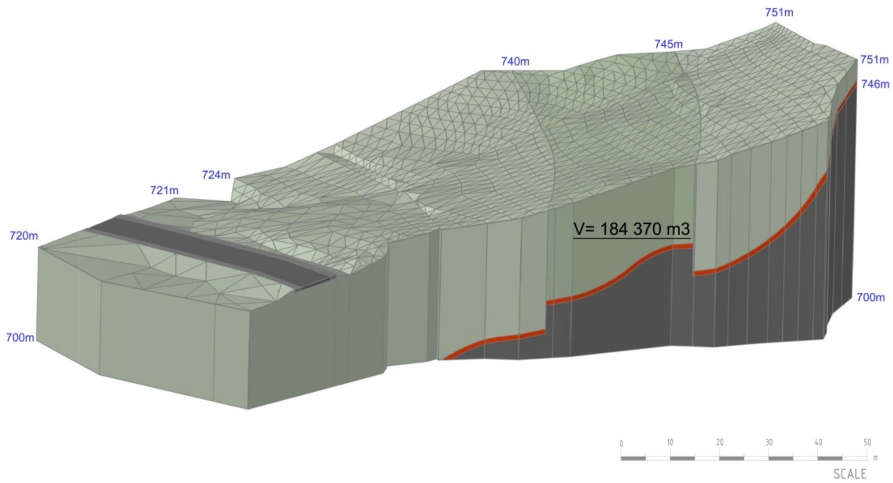

Fig. 4. Three dimensional model of Eleshnitsa landslide.

The main reason for the landslide occurrence is the post-Neogene motion along a fault which strikes at 140° delimiting the Paleogene sediments from the metamorphites of the Ograzhden Lithotectonic Unit. The fault influences the gravitational processes manifested by small landslides and rock-falls in southern and south-eastern direction.

The main landslide process that has formed the landslide body has originated in the end of the Lower and the beginning of the Upper Pleistocene as the depth of the slid earth mass ranges between 15 m in the upper part to 26 m in the lower part of the landslide, correspondingly. The landslide body is over 260 m long and 170 m wide and part of it (about 60 m long) is situated below the roadway.

At the end of Pleistocene the landslide consolidated and during the Holocene, a 10 m thick talus has piled in its head. Subsequently, starting from the Lower Holocene up to present days, the talus has been subjected to a number of activations manifested as secondary landslide bevels of 1.5-3 m height which separate three landslide terraces along the slope. One of them is nearby the road and the other two – below it.

According to its geological and tectonic characteristics the landslide is consequent – the sliding occurs along a surface of separation between heterogeneous layers and along seams without cracks. The mechanism of the land sliding process defines its detrusive nature – it starts in the upper part of the slope from the fault as the slid earth mass forms “landslide dome” as a result of the pressure from above.

The reasons for the landslide formation are mainly the neo-tectonic movements along the fault. The climate and the anthropogenic contributions are less markedly expressed (the track of the road from checkpoint “Ilinden” to Bansko crosses the landslide body) but in time can be crucial for its activation.

Based on electrotomographic data, two contrast media have been distinguished separated by an inclined surface that marks the boundary between the metamorphites and the Paleogene sedimentary rocks. The metamorphosed rocks from the basement are characterized with a very high resistance of 2365 Ωm while the values for sediments range between 100-400 Ωm. The depth of this boundary surface is about 30 m in the base station of measuring and 5-6 m southwest.

An interruption of the metamorphic section is observed about 15-20 m to the northeast of the base station and next up to 80 m in depth only water-saturated sediments have been established. The interruption has been interpreted as a northwest-southeast striking normal fault which north-eastern part has sunk. The movements along it are facilitated by the gravity forces arising due to the great thickness of the sediments and their sliding along their water-saturated lower part.

According to genesis, the lithological characteristics and physical and mechanical properties following engineering geological layers have been established (Tabl. 2).

Table 2. Computing values of physical and mechanical properties of rocks from Eleshnitsa landslide

Layer	Specific weight, γ	Angle of internal friction, *f*	Cohesion, *c*
	kN/m^3	°	kN/m^2
Layer 1	20.4	12	8.0
Layer 2	20.2	14	3.0
Layer 3	21.5	29	0.0

Landslide retaining structures

Landslide Eleshnitsa which threatens the Bansko - Gotse Delchev - Ilinden is characterized by a deep slip surface determined by the local erosion basis. Numerous shallow slip surfaces in the body of the landslide have appeared. More of the soil structural bonds in landslide body have broken. Deep landslide is largely exhausted its capacity. New total activation of ancient landslide can be caused by sudden acceleration of fault movements. This scenario is not excluded, but is unlikely. Local activation of landslides can be expected along secondary slip surfaces within the ancient landslide. Particular attention during this survey is paid to shallow landslides that may occur in the foreseeable future and could have a real impact on the road.

Layers 1 and 2 are included in landslide processes and layer 3 remains under the slip surface within the scope of the road. Ground waters are porous and they are accumulated in the gravel and sand lenses and layers. They are fed by infiltration of precipitation and drained in the alluvial deposits of Mesta River.

To protect the road from hazards due to landslide ground movement following preventive and earth retaining systems have been designed to be constructed: Drainage of the terrain by surface-panelled ditches. They should be positioned over the main landslide slope. Their main purpose is to take over runoff away from the landslide and prevent infiltration into the landslide body. This can be done by strengthening the road section with drilling piles in two rows and unifying by reinforced beam with low retaining wall. Retaining structure is designed to take the landslide pressure. Arranged in this way reinforced concrete piles in diameter of 100 cm and in depth of 5.0 m under the slip surface satisfies the requirements for all checks made according to actual norms. Schemes of reinforcements and retaining maps are available upon request.

Conclusions

The collected data and materials have been successfully implemented in RISKLIDES project. The results have been described in detail in several work report packages. Combination of high ground water table + earthquake puts the slope in an unstable environment. Adequate preventive measures and retaining structures have been developed to increase slope stability and to avoid activation of recorded landslides based on geotechnical slope stability analysis. The drainage of the pitch with a surface lined ditches and drainage of surface runoff away from landslides prevent the water saturation and cause positive impact on landslide stability. Drilling piles in two rows with unifying reinforced beam, a flexible retaining wall of gabions and concrete reinforced retaining wall anchored with injection anchors have been proposed.

REFERENCES

[1] Sarov, S. (ed.). Geological map of the Republic of Bulgaria, scale 1: 50,000, sheet Dobrinishte. MEW, BNGS - Apis 50 Ltd, 2010, 72 p.

[2] Sarov, S. (ed.). Explanatory note to the geological map of the Republic of Bulgaria, scale 1: 50,000, sheet Dobrinishte. - MEW, BNGS - Uniscorp Ltd, 2010, 72 p.

IV. BUILDING MATERIALS. TECHNOLOGY, MANAGEMENT AND ECONOMICS OF CONSTRUCTION. CONSTRUCTION LAW

MATERIALS AND EQUIPMENT ACQUIRED BY NANOTECHNOLOGIES WITH APPLICATIONS IN BUILDINGS

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Abstract*: Latest discoveries in quantum physics and nano-technology development have led to a major revolution in the field of materials and equipments. Substantiation laws that govern the behaviour of matter at the nano scale and their formalization methods of study/simulation allow unprecedented acceleration of discoveries of new materials with exceptional performance in achieving controlled certain functions (thermal, acoustic, seismic protection, energy generators). The paper presents: a) a succinct inventory of scientific achievements in the field of buildings (materials and equipment); b) working principle; c) uses in buildings. The following materials are concerned: phase change materials (embedded in building materials, glass opaque, fluids), meta – materials, used for protection against seismic waves, acoustic, electro–magnetic with major effects on buildings, thermo-insulating materials performance, membrane filtration, nano-fluids, opto-fluidics.*

Key words*: nano-technology buildings, nanomaterials, metamaterials*

1. Nanotechnology. Arguments for their use in buildings

The nanotechnology concept is new[5]. Nanotechnology is science, engineering, and technology conducted at the nanoscale, which is about 1 to 100 nanometers[6]. The concept is very large and refers to the study, design, synthesis, manipulation, and application of materials, devices and functional systems by controlling matter at the nanoscale.

The aim of nanotechnology is to design the new materials with the desired structure and functions, the conception of a new sensor, lab-on-cip & other, the exploitation of properties, the *structura* and the specific behaviour at a nano-scale for other scales.

Our dwellings, buildings where we work, the determining components of human civilization, with the impact on its sustainable development in general and man in particular, are, in the current economic, environmental, energetic and technological context, major users of the products "nanotech". Paradigm shift in physics, biology & other fields and, the

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[5] The ideas and concepts have been discussed by R. Feynman (1959), the term nanotechnology was proposed by N. Taniguchi and the real development in started in 1981, with the development of the scanning tunnelling microscope.
[6] There are many definitions and many points of view on this issue.

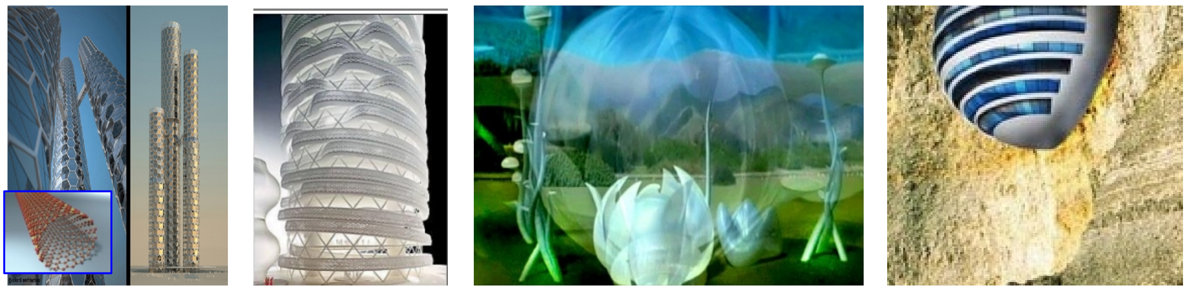
nanoscience discoveries opened, from a certain point of view, a horn in the increase of materials, equipment, models with formula "nano" for all construction, respectively for:

- nanoarchitecture: nano–inspired architectural structure; nonmaterial's with implications for architectural aesthetics.
- buildings envelope: use nanomaterials and metamaterials in structure like these, or composite structure for opaque and transparent buildings elements with different functions: keeping surfaces clean; protection: thermal, acoustic, fire, water, seism; increasing resistance: concrete, glass, etc. ; energy economy: capture/ reflection/ storage/ control, PCM materials;
- indoor air quality: prevents the growth of fungi , sterilized air, controlling humidity;
- potable, gray and waste water treatment: nanomembranes and other;
- for capture/storage and valorisation CO_2;
- for capturing/storage *and valorisation of solar energy and hydrogen….*

So, according to nanowork, the building materials incorporated, nanotechnology is produced, from self-cleaning windows to flexible solar panels to Wi-Fi blocking paint, and "many more are in development, including self-healing concrete, materials to block ultraviolet and infrared radiation, smog-eating coatings and light-emitting walls and ceilings."

Nanoarchitecture

The use of nanotechnology in constructions is strongly linked to sustainability development in area. Viewing the structure of matter at the quantum and studying the behaviour of matter at this level have revealed the mechanisms underlying the different properties exhibited by material structures (strength, flexibility, etc.). These features can be exploited to macro scale and architects and building structure engineers were the first to intuit the possibility of micro-scale expansion behaviour at macro scale. Examples on the use of architectural nanostructuring models are multiples (Fig. 1) and now there was founded a new architectural branch — "nanoarchitecture".



a) b) c)

Fig. 1. Architectural structure inspirited for nanoarchitecture structure of material:
a) Nanoarchitecture inspired on nanotube: Dubai tower [1];
b) Molecular house (for the year 2200) [1] c) Sphere hotel (By Milla Rezanova)

Other drawings on behavioural characteristics of the matter at the nano -scale architectural concepts are exploiting: *self-cleaning functions* for specially treated surfaces; *control functions of the radiation properties of the light spectrum* for the specially treated surfaces; functions and interaction with solar radiation environment of special materials (example: ones obtained by bio-engineering technology) with the role of solar energy production, energy moving masses of air and CO_2 control. The examples will be given at the point for the building envelope.

2. Building envelope and Nanotechnology

2.1.Self-cleaning[7] on

Lotus-Effect. Combine two effects: surface microscopically rough (not smooth) and hydrophobic.

Artificial "lotus surfaces", created with the help of nanotechnology, do not have yet any self-healing capabilities, but they can offer an effective mean of self-cleaning when properly applied. The Lotus-Effect[8] is most well suited for surfaces that are regularly exposed to sufficient quantities of water, e.g. rainwater. Relevant examples: a. materials: self-cleaning coating for wood, self-cleaning paint (*Lotusan*); b. applications: *Ara Pacis Museum, Rome, Italy.*

Photocatalysis-Process - Combines many effects: hydrophobic surfaces; deposited dirt is broken down and lies loose on the surface; a water film washes dirt away; UV light and water are required; reduces maintenance requirements.

Photocatalytic self-cleaning is probably the most widely used nano-function in building construction[9]. The effects and advantages for its use on these materials are multiples: it greatly reduces the extent of dirt adhesion on surfaces; the interval between cleaning cycles may be, however, extended significantly → facility management and personnel costs savings; fewer detergents are required → less environmental pollution and less wear and tear of materials; energy costs for lighting can be reduced accordingly. UV light presented in normal daylight is sufficient to activate the photcatalytic reaction. Organic dirt on the surface of a material is decomposed with the help of a catalyst – usually titanium dioxide which has been used in all kinds of products[10].

Photocatalytic effects can be used with multiple functions: a) self-cleaning function: surface coatings applied on façade panels (made of glass, ceramics, membranes, concrete, tiles with baked-on durable coatings, available for use both indoors and outdoors); b) with noise barriers function; c) to achieve air purifying, water-purifying as well as antimicrobial properties; d) with cooling effect function, by the exploitation of the cooling effect of evaporating water[11]; e) with multiple functions: glass can be combined with other typical functions such as solar-protection glass, and noise insulating properties.

The Photocatalytic coating is only economical for mass produced glass[12].

Easy-to-clean (ETC): Combines the effects of s*mooth surfaces with reduced surface attraction and surface repellence without using the Lotus-Effect.*

Easy-to-clean (ETC) surfaces are water repellent and are: smooth rather than rough; hydrophobic, and often also oleophobic; are a lower force of surface attraction due to a decrease in their surface energy → reduced surface adhesion, water to be repelled, forming droplets and running off effect. This function is used for coating ceramic sanitary installations and shower cubicle glazing, wood, metal, masonry, concrete, leather as well as textiles. Flexible ETC ceramic wall coverings, similar to wallpapers, can withstand

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[7] It was investigated back in the 1970s by the botanist Wilhelm Barthlott.

[8] This is one of the best-known means of designing surfaces with nonmaterials. The "Lotus-Effect" (is evocative, conjuring up associations of beads of water droplets. Barthlott exhibited a microscopically rough water repellent surface, which is covered with tiny knobbles or spikes so that there is little contact surface for water to settle on. Due to this microstructure surfaces that are already hydrophobic are even less wettable. The effect of the rough surface is strengthened still further by a combination of wax (which is also hydrophobic) on the tips of the knobbles on the Lotus leaves and self-healing mechanisms, which result in a perfect, super-hydrophobic self cleaning surface.

[9] The numerous buildings around the world make use of this function.

[10] At a nanoscalar dimension, titanium appears no longer white but transparent, and it's also hydrophilic.

[11] Relevant example: The pavilion Expo 2005, in Japan. Canvas and steel roofing as well as the windows of a trade were equipped with a photocatalytic TiO_2 coating and subjected to a constant stream of water. The water formed a thin film, which evaporates quickly absorbing in the process ambient warmth and thereby reducing the indoor temperature (a potential energy reduction of between 10-20% in relation to conventional air conditioning).

[12] the coating is usually applied in the factory using chemical vapour deposition (CVD), a vacuum coating technique in which an ultra-thin coating is applied in vapour form. Such coatings cannot be retrofitted.

direct exposure to water. The hydrophobic degree of a surface is determined by the angle of contact[13]. Relevant example: *Science to Business Center Nanotronics & Bio, Marl, Germany* (*ccflex, nanoceramic wall covering);* Kaldewei Kompetenz-center (KKC), Ahlen, Germany (*Kaldewei steel-enamel with self-cleaning "Perl-Effekt", easy-to-clean surface).*

2.2. Anti-fogging: realise *clarity for steamed-up surfaces.*

The nano solution is an ultra-thin coating of nanoscalar TiO_2, which exhibits a high surface energy and therefore greater moisture attraction. The film is transparent, creating a fog-free clear appearance[14]. It is used for: bathroom mirrors are obvious candidates for such coating, as they are glass surfaces. Anti-fogging can also be applied to plastics[15].

2.3. Thermal isolation/protection with:

2.3.1. Materials with exceptional insulating properties.

They have in their composition particles with sizes between 400nm÷85nm. They exploit "Thermos" principle[16]. In this category there are:

a) silicon foam or airgel or nanogel. Nanogel material is[17] made up of a special type of silicon foam, foam with an air content of 99.8 %. Nanogel silica quartz foam is obtained by drying the silica gel at high temperature and critical pressure, characterized by a pore size << during free medium through a pipe so as reduced to atmospheric pressure (λ<0.017 W/(m•K) at 1 bar and λ<0.005 W/(m•K) to 0.1 mbar). Nanogel is prepacked and sealed in polycarbonate or fiberglass panels (Kalwall systems and Supersky) transparent[18]. *Aerogels are revolutionizing a new era in residential natural lighting.*

b) Icynene foam for air sealing and insulation is a water based foam insulation (100 %), which provides an excellent air barrier and insulation. No contract, no bend and adhere to most building materials, being applied very simply and fast. It does not change its properties over time. Insulation is recommended for walls, attics, ceilings and floors.

c) Vacuum insulation materials are obtained by venting a fibrous or cellular support packaged in a waterproof sheet, which make the pressure existing in the gaps of the structure to fall very much and that the exchange of heat more rarefied gas; depending on the pressure used to achieve them, the thermal conductivity of the assembly can be reduced up to 10 times of the conductivity of the base material (ex.: Microtherm).

2.3.2. Insulating materials for spacecraft, used to achieve tires

They are obtained by replacing air with rare gases (Ar, Kr, Xe, Fréons, SF6) and change in inner structure of the material. Insulating material is used for opaque (some foam PUR) and glass (insulating glazing, incandescent). There is an optimal relationship between the thermal conductivity of the material density[19] and heat transfer processes established through the various components. Nanostructures used in thermal hyper-isolation represent a concern. The study revealed the nano special behaviour of matter incorporating nanoparticles (example: the decrease of the thermal conductivity of the nanomaterial). Main nanostructures investigated[20].

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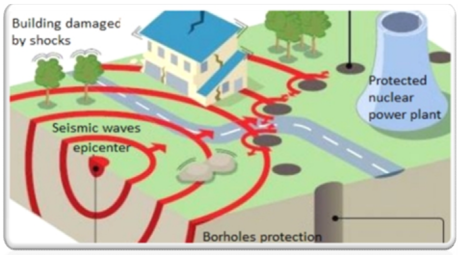
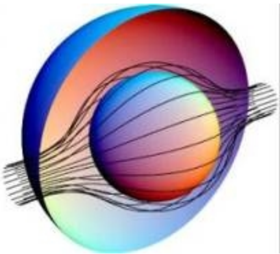
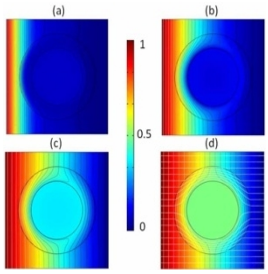
[13] It describes the degree of wetting, and it is a function for the relative surface tensions of the solids, water and air.
[14] On hydrophilic surfaces moisture forms an ultra-thin film instead of water droplets. It still settles on the surface but remains invisible.
[15] For sprays the effect is effective as a temporary.
[16] The void made between the two walls suppresses convection and conduction; metallised walls reduce radiation transfer; remains active only conduction process inside the vessel.
[17] Nano-aerogel is promoted in the laboratory of NASA as "silicon carbon frozen".
[18] For every nano-particle free condition can be extremely toxic to the human body,
[19] and there is an optimal relationship between the thermal conductivity of the material density.
[20] Nanostructured silicon light, fumed or precipitated: a) aerogel, with a range of favourable properties, but low

2.3.3. Metamaterials for thermal-acustical-electro-magnetical and seismical protection

Metamaterials are the focus of a rapidly expanding field, which is driven by a growing demand for revolutionary technologies. Metamaterials[21] refers broadly to any synthetic material, compounds of meta-atoms, with unusual refractive properties and are man-made nanomaterials, comprised of structures whose properties are deliberately engineered to offer a range of response, difficultly or impossibly to achieve in naturally occurring materials or composites. Possible applications of metamaterials include: seismically, thermally, acoustically, anti-wind shield; negative index of refraction; electromagnetic "invisibility" cloaks; smart solar energy systems; optoelectronics; "Perfect" lensing, nanosciences; and other. In order to *design new metamaterials* to meet technological demands, an increased understanding of structural possibilities is necessary. The best way for this is through computer modelling, with a certain degree of mathematical abstraction. Jan S Hesthaven and other researchers from EPFL have developed a computational approach for modelling the metamaterials. An approach called the discontinuous Galerkin method[22] is used, which is a class of numerical methods for solving differential equations that describe how one variable changes in relation to another. The modelling involves a set of differential equations known as Maxwell's equations[23]. These equations translate from continuous functions into discrete or non-continuous ones – a common practice for conventional materials, but more complex for the exotic metamaterials. *Metamaterials making* is a complex process that requires more extensive calculations, precise manufacturing equipment and docking solution components to achieve the desired properties. In any case, these metamaterials having modular parameters are artificially designed for the desired properties (transparency, absorbing or reflecting waves), and can be made by various methods nano-technology, including 3D printing, opening a wide range of possibility. *Relevant exemples,* figure 2: a) Seismic shield model experiment in Grenoble; b) Cloaking heat flux [3].







a) b) c)

Fig. 2. Relevant examples for control waves: a) Seismic shield model experiment in Grenoble (http://maxinevoyance.wordpress.com) [3]; b) Invisibility cloaks (http://www.physics.org); c) Cloaking heat flux[24] [3]

mechanical strength (*hybridization composite:* Aerogel based composite (CABOT)); the composite airgel foam (WO 2007/ Rhine. W so on. (ASPEN); Composite materials – aerogel + silicon (ASPEN)); b) nanostructured organic gels solutions (eg. new proposed polydicyclopentadiene based airgel material); c) xerogels obtained by evaporative drying of loose silicon nanostructure. These nanostructures can be integrated into facades type double-skin or thermal isolation in opaque or translucide materials.

[21] Metamaterials have been invented as a concept very recently, the first experiments were made in 2006 for invisibility to electromagnetic radiation. After that he saw the potential use in other applications.

[22] Researchers have developed also other methods to design metamaterials with well-defined properties. These are buildings based on genetic algorithms, neural networks and graphical representation models in space multi-dimension.

[23] Which describe how (electromagnetic) waves propagate in space and time and detailed models for "how the metamaterials react to (electromagnetic) waves?".

[24] Diffusion of heat from the left on a cloak with $R_1 = 2.10^{-4}$m and $R_2 = 3.10^{-4}$m. The temperature is normalized

2.4. Thermal storage with (PCMs): *for temperature regulation of the construction elements and for the increase of the storage potential*.

Phase change materials (PCMs) valorise the latent heat of vaporization of nanoparticles embedded in building materials/elements, opaque or glazed, or substances, for thermoregulation items, or, increase storage capacity or thermal inertia of the integrative material/substance; it is use for the *passive temperature regulation*[25] *and reduced heating and cooling demand,* in new and existing buildings, for heating as well as cooling.

3. Air-purifying

Pollutants and odours are broken down into their constituent parts → not replace ventilation, but improves air quality. There are two major ways in which nanotechnology is used to reduce air pollution: *catalysts*[26]: can be used to enable a chemical reaction (which changes one type of molecule to another); the reaction is more effective at lower temperatures; catalysts made from nanoparticles have a greater surface area to interact with the reacting chemicals than catalysts made from larger particles→it is possible to interact with more chemicals; by using the nanocatalysts it is possible to chemically decompose odours into their harmless constituent parts (the molecules are cracked, giving off steam and carbon dioxide[27]) and gases and vapours emissions into harmless gases; can improve the performance and cost of catalysts. Using: photocatalytic concrete, building façades, road surfaces and alike, equipped with appropriate coatings (to counteract the effect of industrial and vehicle exhausts), air-purifying paving stones, plasterboard or acoustic panels, road surfaces and paints[28]. Relevant examples: a) the European Hq. of Hyundai Motors Europe in Offenbach, Germany (air-purifying plasterboards); b) paving for Leien Boulevard, Antwerp, Belgium: the paving element is equipped with further functionality: with the help of sunlight and oxidative catalysis, it is able to convert environmental pollutants such as NO into inert nitric acid ions; b) *nano structured membranes*, which are under development to separate carbon dioxide.

4. Water-Purifing

Nanotechnology is used for treatment of: *drinking water*: filtration solution[29]; deionization method using electrodes composed of nano-sized fibers*; b) waste water; c) gray d) groundwater*[30].

throughout time on the left side of the cell. Snapshots of temperature distribution at t = 0.001s (a), t = 0.005s (b), t = 0.02s (c), t = 0.05s (d). Streamlines of thermal flux are also represented with white colour in panel (d). The mesh formed by streamlines and isothermal values illustrates the deformation of the transformed thermal space: the central disc ('invisibility region') is a hole in the metric, which is curved smoothly around it.

[25]To achieve thermoregulatory function envelope, PCM are chosen so that the phase change temperature "T_{SF}" to be close to the temperature of indoor comfort "T_i". For the T_i=25^{0}C it use en general nanoparticles of paraffin encapsuleted.. For an element with PCM located outside, operation is as follows: for Te>T_{SF}: embedded nanoparticles, vaporize and absorb heat of the material which integrates; for Te<T_{SF}: vapours produced in the previous phase condenses and gives off heat which integrates material. Through this mechanism initiates a cycle vaporization/condensation of MSF, and that one cooling/heating elements. The heat being retained in the PCM and used to liquefy the paraffin. Energy is stored latently when the material changes from one physical state to another, whether from solid to liquid or from liquid to gaseous. The latent warmth or cold, which effectively fulfils a buffer function, can be used for temperature regulation.

[26] Which are currently in use and constantly being improved upon.

[27] This approach can also be used to counteract the sick building symptoms (SBS).

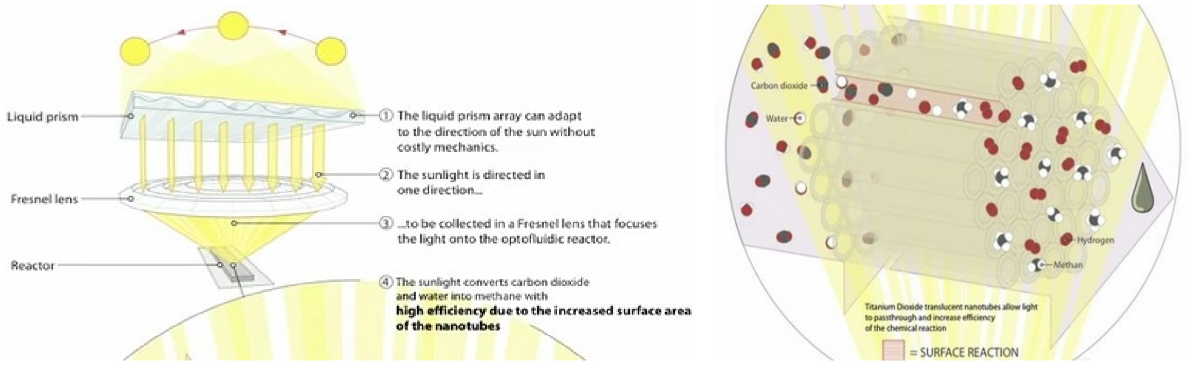
[28] The large surface area of the sails also helps combat pollution by reducing the amount of volatile organic compounds (VOCs) and nitrogen oxide in the air considerably. Indoors, air purification technology is increasingly being used for textiles and paints.

[29] A filter only a few nanometers in diameter is capable of removing virus cells from water.

[30] Nanoparticles can be used to convert the contaminating chemical through a chemical reaction to make it harmless. One challenge is the removal of industrial water pollution, such as a cleaning solvent called TCE.

5. Solar conversion

The systems for solar energy conversion and use know a major technological change by using nanotechnology. In the last 10 years old conversion systems yield increased by 100 % (example: PV Spectrolab patent, in 2006) and recovery efficiency of complex systems by 300% solar energy. Achievements in this field are manifold but we will present only the possibilities of integrating nanotechnology into a high performance domestic utility recently demonstrated by Demetri Psaltis [5]. Using nanotechnology optics with microfluidics may be combined – the microscopic delivery of fluids through extremely small channels or tubes [5].The system proposed by Psaltis using: a) system performance capture solar radiation (direct sunlight using liquid prism, a focusing using Fresnel lenses); b) efficient transport by nanotubes core fluid (Titanium dioxide translucid nanotubes allow light to pass through and increase efficiency of the chemical reaction); c) bioreactor using the CO_2 in the air (purified air) and generate fuel (hydrogen and methane) for domestic use; d) differentiated recovery energy at user, (for integral spectrum): systems light radiation , ultraviolet , infrared; e) performance switching between utilities for functional optimizing.



a) b)

Fig. 3. Optofluidics components for effective systems in conversion and use of solar energy: a) Effective solar capture [5]; b) Nanotubes. [5]

REFERENCES

[1] Johansen j.,The new species of architecture.
[2] Seismic 'shield' stops quake shake, Nature 508, 29, 1(17 April 2014).
[3] Guenneau S. & other, Transformation thermodynamics: cloaking and concentrating heat flux, (C) 2012 OSA, 26 March 2012 / Vol. 20, No. 7 / OPTICS EXPRESS 8218.
[4] Cotorobai V. Paradigm shift with major impact in the development of buildings and installations, ppt presentation , Conference "Buildings Service and Comfortable", Timisoara,2014.
[5] Demetri Psaltis & other, Developing optofluidic technology through the fusion of microfluidics and optics Nature 442, 381-386 (27 July 2006).

HYGROTHERMAL BEHAVIOUR OF UNIDIRECTIONAL FIBRE REINFORCED COMPOSITES

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Abstract: *The hygrothermal behaviour of a unidirectionally reinforced lamina can be characterized by the coefficients of thermal expansion and of hygroscopic expansion. These coefficients can be associated with the physical and mechanical properties of the constituents and with the geometry of the composite. The values of the coefficients of thermal expansion and hygroscopic expansion with respect to the main directions of the material are determined firstly in the paper, and then, the same coefficients expressed with respect to an arbitrary set of axes are determined using the transformation equations used in macromechanics. A case study for a unidirectional reinforced lamina was performed, illustrating the application of the analytical formulas developed in the first part of the paper.*

Key words: *composite lamina, hygrothermal behaviour, thermal expansion, hygroscopic expansion*

1. Introduction

Composite structures are used in environments with different temperature and humidity, and these factors can have a significant effect on the structure performance. The hygrothermal effects on a composite plate are the result of changes in temperature and humidity, depending on the differences between the thermo-physical characteristics of the constituent materials, fibres and matrix.

The hygrothermal behaviour of a unidirectional reinforced composite plate can be characterised by the coefficients of thermal expansion (CTE) and hygroscopic expansion coefficient (due to the humidity, CHE). These coefficients can be related with the physical and mechanical properties of the constituent materials and composite geometry.

2. CTE and CHE coefficients

2.1. CTE and CHE with respect to the main directions of the material

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The CTE with respect to the main axes ($\alpha_1 = \alpha_L$ and $\alpha_2 = \alpha_T$) and the CHE ($\beta_1 = \beta_L$ and $\beta_2 = \beta_T$) with respect to the same directions, can be analyzed in terms of main axes system of a special orthotropic lamina, Fig. 1.

The equation used for determining the CTE for isotropic constituent materials in the longitudinal direction of a special orthotropic lamina ($\alpha_1 = \alpha_L$) is established based on the micromechanics of a unidirectional composite lamina, considering the appropriate assumptions corresponding to the rule of mixtures.

Based on these assumptions Schapery developed the following equation [1]:

$$\text{(2.1)}\quad \alpha_1 = \alpha_L = \frac{E_f \cdot \alpha_f \cdot V_f + E_m \cdot \alpha_m \cdot V_m}{E_f \cdot V_f + E_m \cdot V_m},$$

where

E_f, E_m are the elasticity moduli of the fibres and matrix respectively;

α_f, α_m are the coefficients of thermal expansion of the fibres and matrix respectively;

V_f, V_m are the volume fractions of the fibres and matrix respectively.

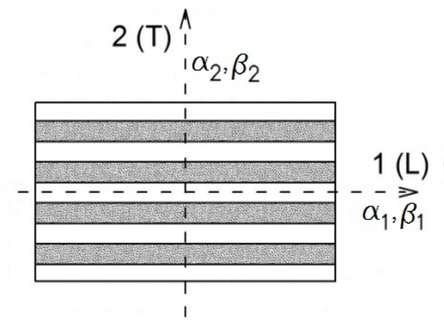


Fig. 1. The coefficients of thermal expansion and hygrothermal expansion of an orthotropic special lamina

Equation (2.1), which has been established for determining the coefficient of thermal expansion in longitudinal direction, is similar to the rule of mixtures used for computing the longitudinal elastic modulus.

The equation for CTE in transverse direction is:

$$\text{(2.2)}\quad \alpha_2 = \alpha_T = \alpha_f \cdot V_f (1 + \nu_f) + \alpha_m \cdot V_m (1 + \nu_m) - \nu_{12} \cdot \alpha_1,$$

where

ν_f, ν_m are Poisson's ratios for fibres and matrix respectively;

ν_{12} is major Poisson's ratio, obtained using the rule of mixtures with the following equation $\nu_{12} = \nu_f V_f + \nu_m V_m$;

α_1 is the coefficient of thermal expansion in longitudinal direction, computed with equation (2.1)

The equations used in micromechanics for determining the hygroscopic expansion coefficients are similar. Since in most cases of expansion due to moisture the fibres do not absorb water (i.e. $\beta_f = \beta_{1f} = \beta_{2f} = 0$), the expressions for the coefficients of hygroscopic expansion in a unidirectional reinforced lamina with isotropic component materials [2] are:

in longitudinal direction

$$\text{(2.3)}\quad \beta_1 = \beta_L = \frac{E_m \cdot \beta_m \cdot V_m}{E_f \cdot V_f + E_m \cdot V_m} = \beta_m \frac{E_m \cdot V_m}{E_1},$$

in transverse direction

$$\beta_2 = \beta_T = \beta_m \frac{V_m}{E_1} \cdot \left[E_1 + V_f (\nu_m E_f - \nu_f E_m) \right], \tag{2.4}$$

where β_m is the coefficient of expansion of the matrix due to moisture.

2.2. CTE and CHE with respect to a general system of coordinate axes

The computing formulas used for the evaluation of the coefficients α_x, α_y, α_{xy} and β_x, β_y, β_{xy} respectively, corresponding to the general system of axes (x,y), (Fig. 2), using the appropriate transformation relations are:

$$\begin{Bmatrix} \alpha_x \\ \alpha_y \\ \alpha_{xy} \end{Bmatrix} = \begin{bmatrix} \cos^2\theta & \sin^2\theta & -2\cdot\sin\theta\cdot\cos\theta \\ \sin^2\theta & \cos^2\theta & 2\cdot\sin\theta\cdot\cos\theta \\ \sin\theta\cdot\cos\theta & -\sin\theta\cdot\cos\theta & \cos^2\theta - \sin^2\theta \end{bmatrix} \cdot \begin{Bmatrix} \alpha_1 \\ \alpha_2 \\ 0 \end{Bmatrix}, \tag{2.5}$$

or

$$\begin{aligned} \alpha_x &= \alpha_1 \cdot \cos^2\theta + \alpha_2 \cdot \sin^2\theta \\ \alpha_y &= \alpha_1 \cdot \sin^2\theta + \alpha_2 \cdot \cos^2\theta \quad , \\ \alpha_{xy} &= 2(\alpha_1 - \alpha_2) \cdot \cos\theta \cdot \sin\theta \end{aligned} \tag{2.6}$$

and

$$\begin{aligned} \beta_x &= \beta_1 \cdot \cos^2\theta + \beta_2 \cdot \sin^2\theta \\ \beta_y &= \beta_1 \cdot \sin^2\theta + \beta_2 \cdot \cos^2\theta \quad , \\ \beta_{xy} &= 2(\beta_1 - \beta_2) \cdot \cos\theta \cdot \sin\theta \end{aligned} \tag{2.7}$$

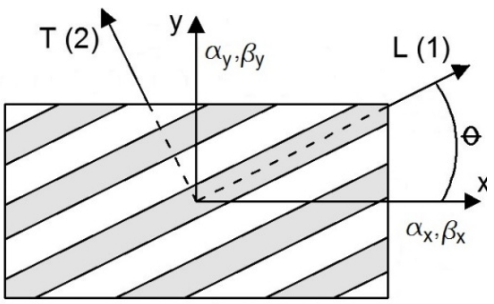


Fig. 2. The coefficients of thermal expansion (α_x, α_y) and expansion due to moisture of a general orthotropic lamina

3. Hygrothermal strains in a unidirectional reinforced lamina

Knowing the values of the coefficients α_1, α_2 and β_1, β_2, respectively, with respect to the main directions of the lamina, the strains induced in the lamina with respect to the material axes can be established due to the temperature differences ΔT.

$$\begin{Bmatrix} \varepsilon_1^T \\ \varepsilon_2^T \\ 0 \end{Bmatrix} = \Delta T \cdot \begin{Bmatrix} \alpha_1 \\ \alpha_2 \\ 0 \end{Bmatrix}, \tag{3.1}$$

and the strains induced in the lamina with respect to the material axes due to moisture variation ΔU:

$$\begin{Bmatrix} \varepsilon_1^U \\ \varepsilon_2^U \\ 0 \end{Bmatrix} = \Delta U \cdot \begin{Bmatrix} \beta_1 \\ \beta_2 \\ 0 \end{Bmatrix}, \tag{3.2}$$

In case of special orthotropic lamina, the strains due to temperature and moisture variation do not include terms corresponding to the specific angular deformations with respect to the material axes [3].

Combining equation (2.6) with (3.1) and (2.7) with (3.2), the equations for the strains in the general system of axes (x, y) can be determined, depending on the coefficients of thermal expansion, and hygroscopic expansion respectively with respect to the principal axes of the material and the angle of rotation of the general axes to the principal ones.

$$\begin{Bmatrix} \varepsilon_x^T \\ \varepsilon_y^T \\ \gamma_{xy}^T \end{Bmatrix} = \begin{Bmatrix} \alpha_x \\ \alpha_y \\ \alpha_{xy} \end{Bmatrix} \cdot \Delta T, \tag{3.3}$$

and

$$\begin{Bmatrix} \varepsilon_x^U \\ \varepsilon_y^U \\ \gamma_{xy}^U \end{Bmatrix} = \begin{Bmatrix} \beta_x \\ \beta_y \\ \beta_{xy} \end{Bmatrix} \cdot \Delta U, \tag{3.4}$$

4. Case study

In this section the coefficients of thermal expansion and the strains induced in the lamina by temperature gradient for a composite lamina made of unidirectional S glass fibres and epoxy matrix were analysed. The properties of the constituent materials used in this matter are, [4]: for the fibres $\alpha_f = 2.9$ (10^{-6} / °C), $E_f = 85.5$ GPa, $\upsilon_f = 0.22$, and for the matrix $\alpha_m = 60$ (10^{-6} / °C), $E_m = 3.5$ GPa, $\upsilon_m = 0.38$.

Using equations (2.1) and (2.2) the values of thermal expansion coefficients with respect to the principal directions have been determined, and the variation curves in terms of the fibre volume fraction were represented for both coefficients α_1 and α_2, (Fig. 3).

In order to determine the values of the thermal expansion coefficients with respect to the general directions (x, y), equations (2.6) were used and thus the corresponding variation curves were plotted within the angular range θ = 0 ... 90° (Fig. 4).

Knowing the values of the coefficients α_1, α_2 with respect to the main directions of the lamina and considering a range from 0° to 45° for the temperature differences ΔT, the strains induced in the lamina with respect to the material axes were represented in Figure 5, while the variation with ΔT of the strains with respect to a general system of axes (x, y) are shown in Figure 6 and Figure 7.

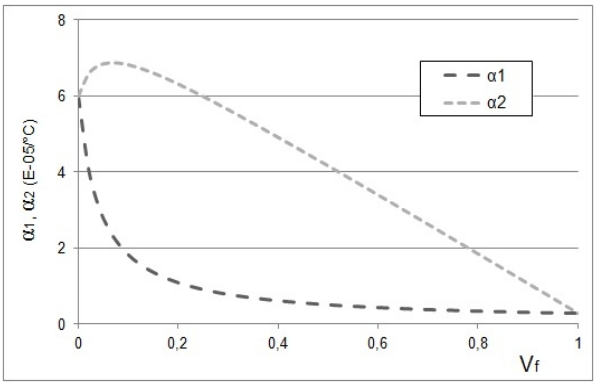


Fig. 3. The coefficients of thermal expansion (α_1, α_2) with respect to the fibre volume fraction for a special orthotropic lamina

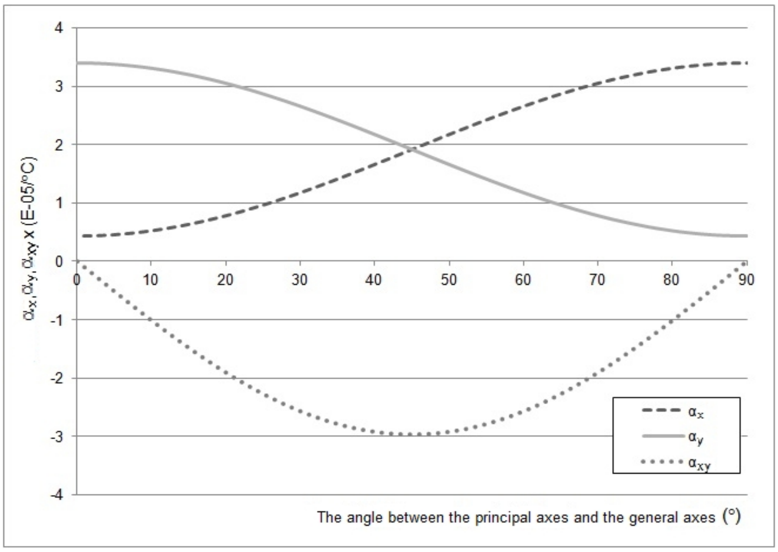


Fig. 4. The coefficients of thermal expansion (α_x, α_y, α_{xy}) with respect to the angle between axes for a general orthotropic lamina

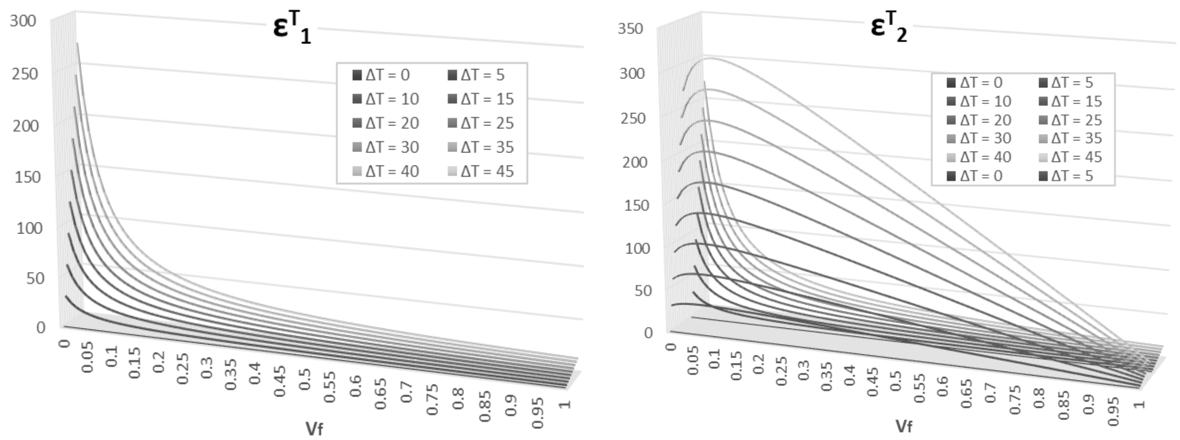
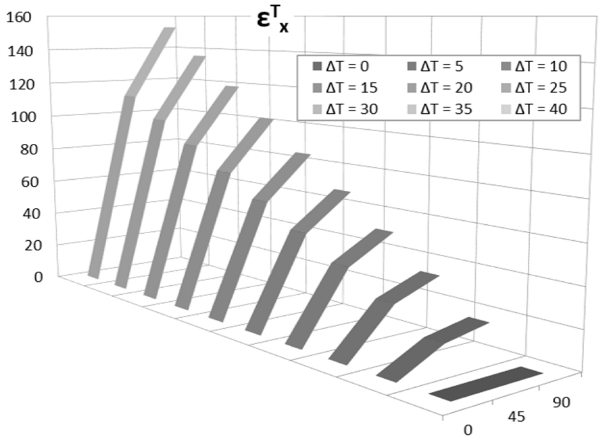


Fig. 5. Strains on longitudinal and transverse directions due to temperature differences ΔT (ε^T_1, ε^T_2) with respect to the material axes



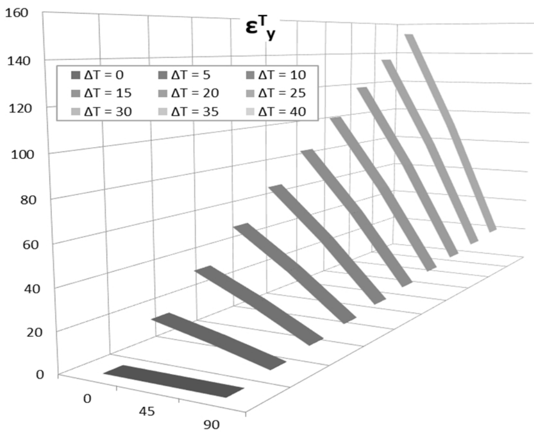


Fig. 7. Strains on longitudinal and transverse directions due to temperature differences ΔT (ε^T_x, ε^T_y) with respect to the general axes

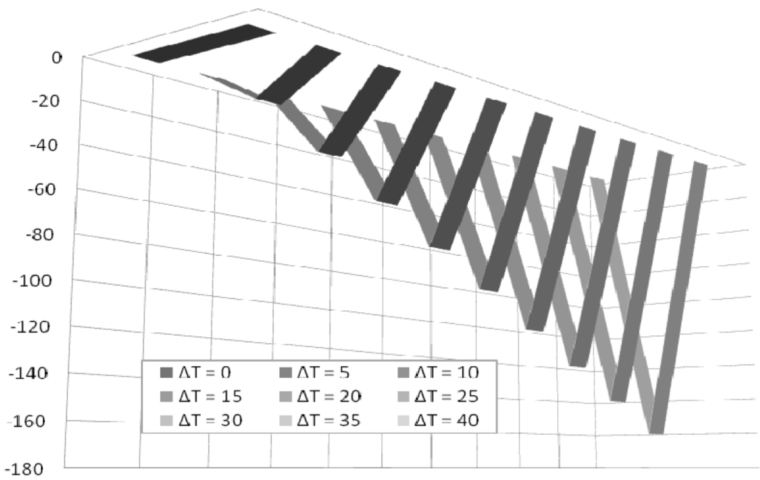


Fig. 7. Strains on transverse direction due to temperature differences ΔT (γ^T_{xy}) with respect to the general axes

Conclusion

The equations used in micromechanics are successfully applied in the analysis of hygrothermal behaviour by means of thermal and hygroscopic expansion coefficients.

The longitudinal fibres prevent the free expansion of the matrix in the direction of the reinforcement, thus this component is forced to expand more in transversal direction than the unreinforced matrix.

REFERENCES

[1] Schapery R. A. Thermal expansion coefficients of composite materials based on energy principles, J. Composite Materials, Vol. 2, 1968, 380-404.

[2] Daniel I., Ishai O. Engineering mechanics of composite materials. Second edition, Oxford University Press, Oxford, 2006.

[3] Kaw A.K. Mechanics of composite materials. Second edition, CRC Press, Taylor & Francis, Boca Raton, 2006.

[4] Taranu N., Bejan L., Cozmanciuc R., Hohan R. Materiale și elemente compozite I. Ed. Politehnium, Iasi, 2013.

THE SHEAR MODULUS OF ELASTOMERS USED IN BASE ISOLATION

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***Abstract**: The base isolation consists in decoupling the structure from the horizontal motion components of an earthquake by mounting bearings between a building and its foundation. A bearing must ensure the horizontal displacement of the structure relative to the foundation and it must simultaneously have a high vertical stiffness in order to prevent the possible swing phenomena of the building. The paper presents the experimental results on the behaviour under shear of four types of elastomers used in base isolation bearings. The following elastomeric specimens were tested: natural rubber/butadiene rubber (NR/BR) with 63 Shore A hardness, chloroprene/neoprene rubber (CR) with 64 Shore A hardness, natural rubber (NR) with 65 Shore A hardness and natural rubber/butadiene rubber/styrene butadiene rubber with polyamide/polyethylene fibres (NR/BR/SBR + PA/PE fibres) with 65 Shore A hardness. The shear moduli of elastomeric specimens were determined according to ASTM-D 4014:2003, Annex A.*

***Key words**: elastomers, shear modulus, elastomeric bearings, base isolation.*

1. Introduction

The base isolation is an effective way of isolating the movement of the entire structure of the ground movement using a flexible interface between the structure and its foundation. The greatest advantage of this method is to avoid the degradation of a structure, its functionality being possible immediately after an earthquake.

Seismic base isolation can be achieved on different bearings. The failure of an elastomeric bearing is caused by the fatigue phenomenon of the elastomer, the breakage or failure of the reinforcement plates, the detachment or buckling of the bearing. Therefore the design codes specify the allowable stress in compression and shear, the deformations limit, the minimum thickness of metal plates and the evaluation criteria of the bearing stability [1]. In most standards, the limit imposed for the angular deflection is 70 % of the total height of the elastomeric bearing.

The shear modulus of elastomers is an important property in the anti-seismic bearings design. Most manufacturers of elastomeric bearings use the hardness as an indicator of stiffness [2].

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2. Experimental determination of shear modulus

2.1. Test specimens

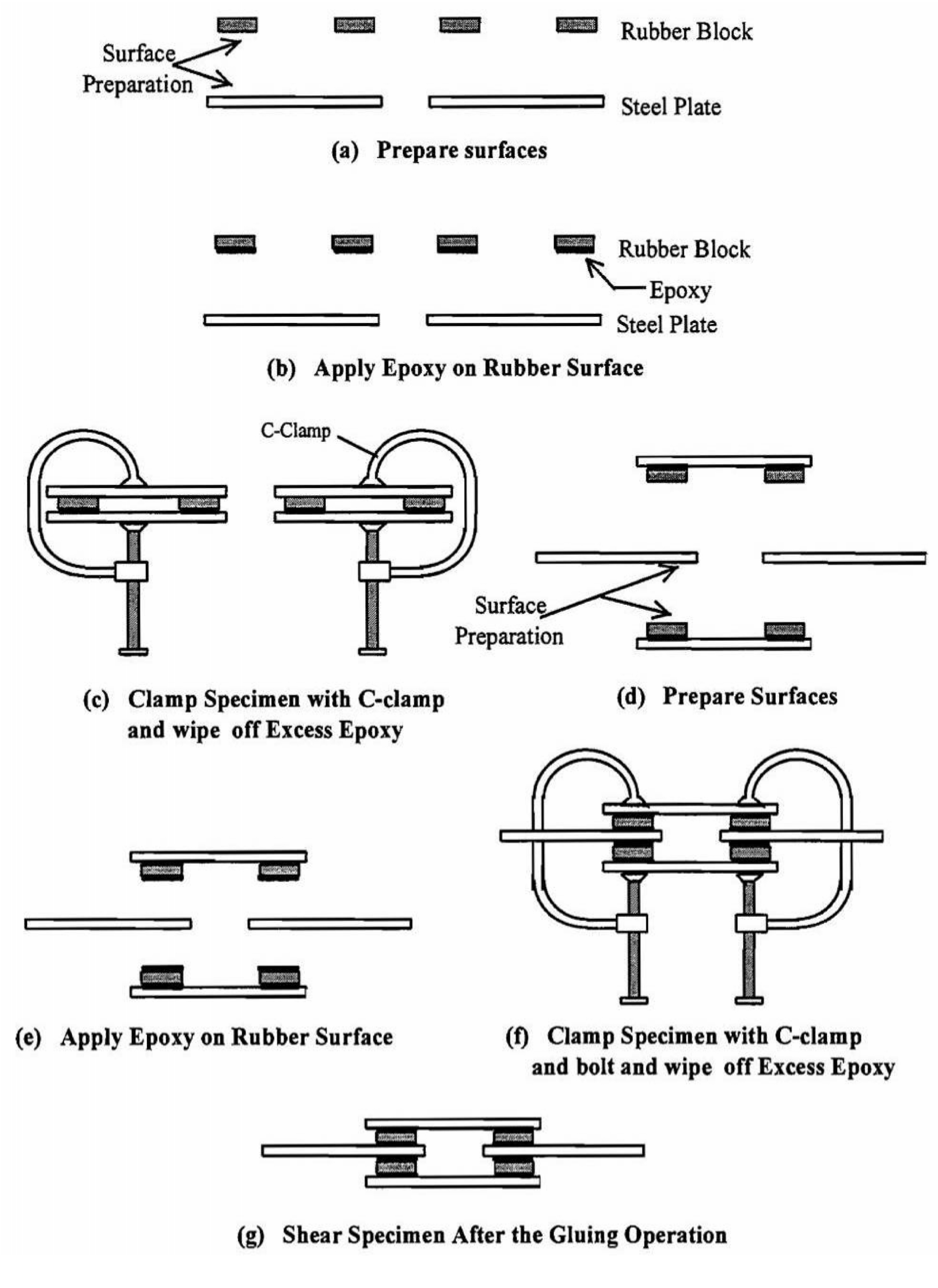

Fig. 1. Bonding of the shear specimen [2]

According to ASTM D 4014-2003 Annex A1, the shear test specimens consist of four identical samples of elastomer bonded to four metal plates. The thickness of an elastomer specimen must be greater than 6 mm and the length and width (diameter) should be not less than four times the thickness [3]. The Loctite 480 adhesive was applied after filling and degreasing the elastomer and plate surfaces (Fig. 1).

The laboratory tests were carried out on elastomer specimens with different compositions and hardness:

- natural rubber/butadiene rubber (NR/BR) with 63 Shore A hardness;
- chloroprene/neoprene rubber (CR) with 64 Shore A hardness;
- natural rubber (NR) with 65 Shore A hardness;
- natural rubber/butadiene rubber/styrene butadiene rubber with polyamide/ polyethylene fibres (NR/BR/SBR + PA/PE fibres) with 65 Shore A hardness.

The materials were provided by S.C. FREYROM S.A. which is the manufacturer of bearings for seismic base isolation and bearings for bridges.

The shear test specimen have the diameter of 28 mm, the thickness of 6.5 mm and are bonded to metal plates with a thickness of 4 mm (Fig. 2).

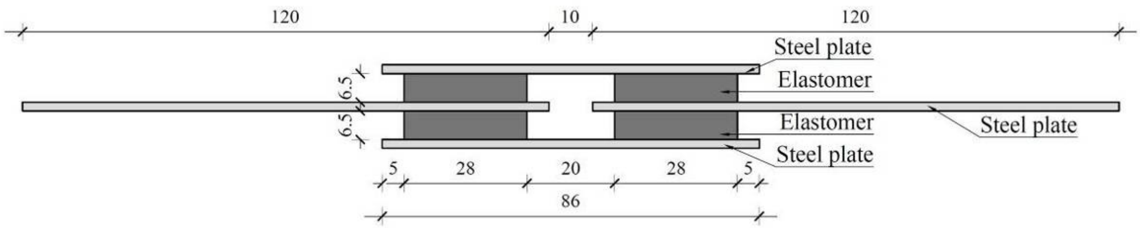

Fig. 2. Shear test specimen

2.2. Equipment and test procedure

The shear test of elastomer specimens was achieved with a Controlled Electro Mechanism Universal Testing Machine WDW (Fig. 3). The Controlled Electro Mechanism Universal Testing Machine allows automatic recording of the force and displacement using the program WinWdw. According to ASTM D 4014-2003 Annex A1, six cycles of loading – unloading were carried out to a deformation equal to the elastomer thickness (Fig. 4).

a) b) c)

Fig. 3. Shear test: a) the testing machine; b) the specimen; c) the deformed shape

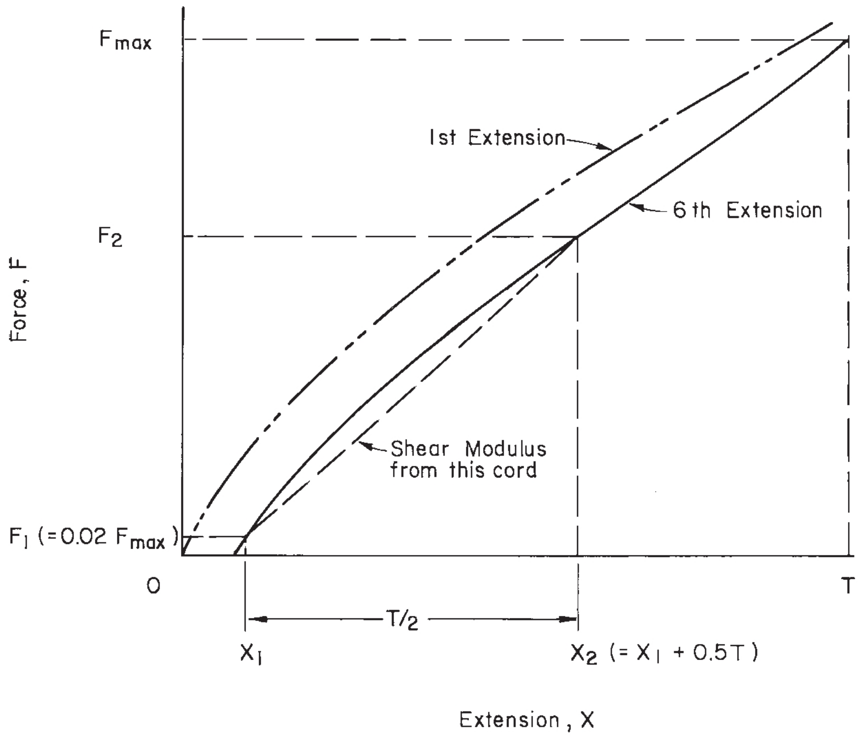

Fig. 4. Shear test force - extension curves [3]

According to ASTM D 4014-2003 Annex A1, the shear modulus is determined by the relationship:

$$G = \frac{2 \cdot (F_2 - F_1)}{A}, \quad (2.1)$$

where: F_1 is 2 % of the maximum force which corresponds to an extension x_1;

F_2 – the corresponding force for the displacement $x_2 = x_1 + 0.5h$; h is the thickness of the elastomer sample;

A – the cross-sectional area of the elastomer specimen.

3. Experimental results

The force - strain curves of elastomer specimens are plotted (Fig. 5,..,8):

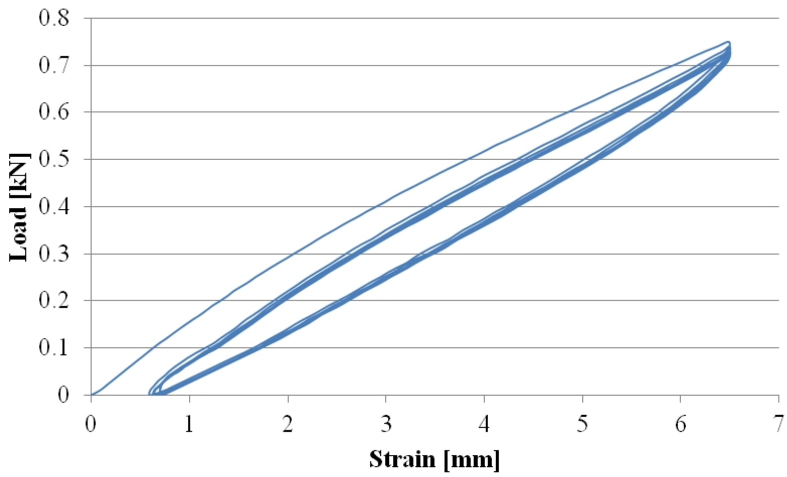

Fig. 5. Load - strain curves of NR/BR specimen

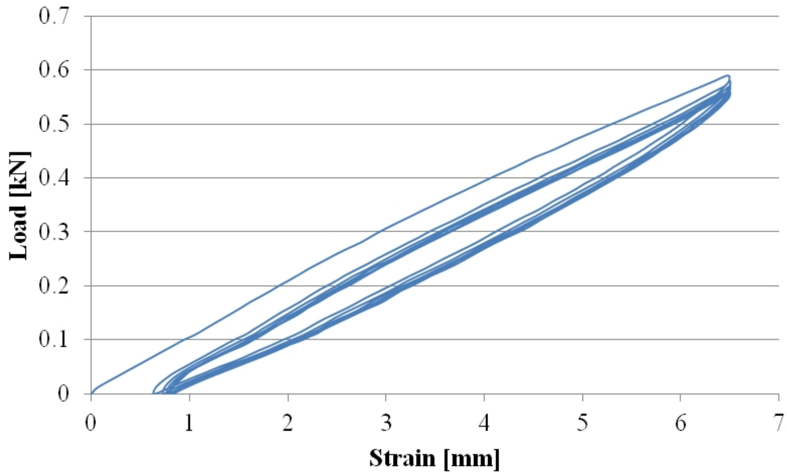

Fig. 6. Load - strain curves of CR specimen

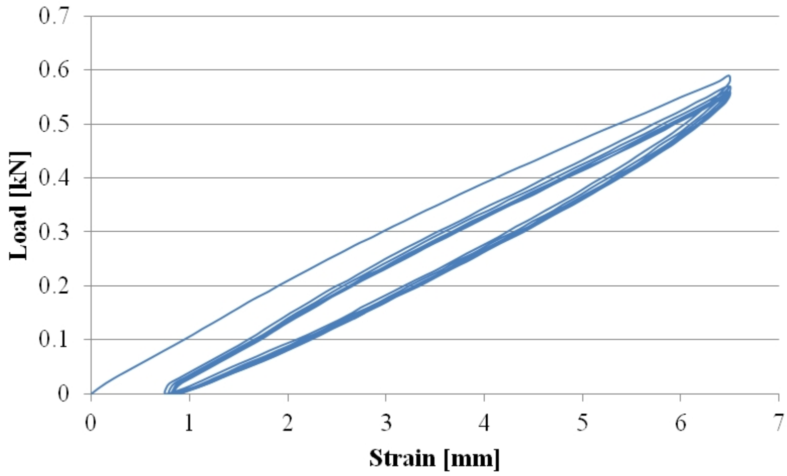

Fig. 7. Load - strain curves of NR specimen

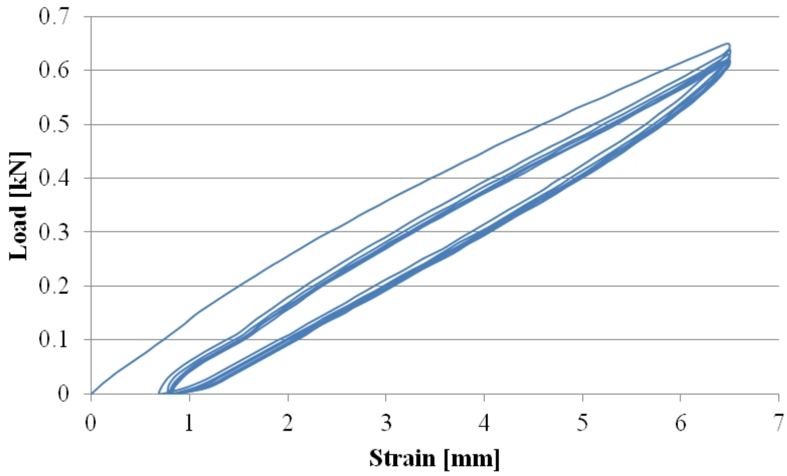

Fig. 8. Load - strain curves of NR/BR/SBR+ PA/PE fibres specimen

The shear modulus values are shown in the Tabl. 1:

Table 1. Shear Modulus Values [MPa]

NR/BR	CR	NR	NR/BR/SBR+ PA/PE fibres
1.1	0.9	0.87	0.96

Conclusion

The shear modulus depends on the elastomer composition and the amount of filler materials. In the case of elastomers with the same hardness, NR and NR/BR/SBR+ PA/PE fibres, the shear moduli have different values due to the different chemical composition.

The highest value of the shear modulus was obtained for NR/BR specimen, being higher by 26 % compared to the shear modulus of NR specimen.

In conclusion, the hardness is not a sufficient indicator of quality or performances of elastomers, although it is easy to measure. In the speciality literature, the values of elastomer moduli in compression and shear are given in terms of hardness only as information.

REFERENCES

[1] Yoon H., I.J. Kwahk, Y.J.Kim. A study on the ultimate performances of elastomeric bearings in Korea, Journal of Civil Engineering, Vol. 17, No. 2, 2013, 438- 449.

[2] Arditzoglou Y.J., J.A. Yura, A.H. Haines. Test methods for elastomeric bearings on bridges, Texas, U.S., 1995, 94 p.

[3] ASTM D 4014-2003. Standard Specification for Plain and Steel-Laminated Elastomeric Bearings for Bridges. Annex A1: Determination of shear modulus, U.S., 2003.

LAMINA FAILURE THEORIES OF THE UNIDIRECTIONAL REINFORCED FRP COMPOSITES

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***Abstract**: One of the most important challenges met during the design process of an FRP lamina, especially when the loading orientation does not coincide with the natural axes of the material, consists in determining the strength properties. The latter can be predicted by the macromechanical failure theories which take into account the stress and strain variation with orientation expressing them with respect to the basic strength parameters referred to the principal material axes. The objectives of this paper are to briefly present the most important macromechanical failure criteria for composites, their availability domains and the degrees of reliability. Also, a case study is presented, in order to apply the failure theories for a given FRP lamina.*

***Key words**: FRP composites, strength parameters, failure theories, macromechanics, failure mechanism.*

1. Introduction

The ability to anticipate failure is considered to be a fundamental condition for the successful design of a civil engineering structure. The first step in creating a set of principles for the design of structural elements is to understand and establish parameters to describe failure. In case of steel structures, failure is almost certainly related to the initiation and propagation of yield or rupture [1]. Steel, which is an isotropic material, generally has two strength parameters: normal strength and shear strength. Thus, a basic failure theory for an isotropic material consists in identifying the principal normal stresses

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and the maximum shear stresses and comparing them to the corresponding ultimate values. If any of the latter are exceeded, failure of the material occurs [2].

On the other hand, in case of the orthotropic FRP composite lamina, the failure theories must be related to the strengths along the material axes. Unidirectional FRP laminas have two material axes: one parallel and one perpendicular with respect to the fibres direction. Consequently, there are four normal strength parameters, one couple for tension (f_{Lt}, f_{Tt} are the longitudinal and transverse tensile strengths, respectively) and another for compression (f_{Lc} and f_{Tc} are the longitudinal and transverse compression strengths, respectively). The fifth one is the in plane shear strength (f_{LTs}).

The generally orthotropic lamina subjected to normal stresses σ_x, σ_y and shear stress τ_{xy} is presented in Fig. 1. Since the loading direction is different to the material axes and all strength parameters are related to the latter, the stresses must be transformed with respect to the angle Θ (Eq. 1.1).

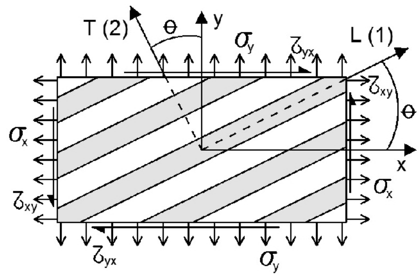


Fig. 1. General orthotropic lamina

$$\begin{Bmatrix} \sigma_1 \\ \sigma_2 \\ \tau_{12} \end{Bmatrix} = \begin{pmatrix} \cos^2\theta & \sin^2\theta & 2\sin\theta\cos\theta \\ \sin^2\theta & \cos^2\theta & -2\sin\theta\cos\theta \\ -\sin\theta\cos\theta & \sin\theta\cos\theta & \cos^2\theta - \sin^2\theta \end{pmatrix} \begin{Bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{Bmatrix} \quad (1.1)$$

2. Lamina failure theories

Macromechanical failure criteria for the homogeneous FRP unidirectional lamina, such as maximum stress, maximum strain, Tsai-Hill and Tsai-Wu theories, have been proposed by extending and adapting isotropic failure theories to account for the anisotropy of the composite materials.

2.1. Maximum stress theory

Based on the maximum normal stress and maximum shear stress theories for isotropic materials developed by Rankine and Tresca respectively, Kelly [3] adapted these theories to orthotropic composites under plane stress conditions. Thus, the off-axis stresses can be reduced to the strengths of the unidirectional lamina in the material axes.

The maximum stress theory for the unidirectional lamina assumes that failure occurs whenever any of the stress component attains its limiting value, independent of all other components of stress [4]. According to this theory, in order to avoid failure, the following set of inequalities must be satisfied.

$$\begin{aligned} &-f_{Lc} < \sigma_1 < f_{Lt} \\ &-f_{Tc} < \sigma_2 < f_{Tt} \quad , \\ &-f_{LTs} < \tau_{12} < f_{LTs} \end{aligned} \quad (2.1)$$

where σ_1, σ_2 are the maximum normal stresses in the material directions and τ_{12} is the maximum shear stress in the (1,2) plane.

In the general case, when the loading direction is different to the material axes and the lamina is subjected only in x direction (Fig. 2a), the stresses are transformed with respect to the angle (Θ) between the two systems of axes.

$$\text{(2.2)} \quad \begin{aligned} \sigma_1 &= \sigma_x \cos^2\theta \\ \sigma_2 &= \sigma_x \sin^2\theta \\ \tau_{12} &= -\sigma_x \sin\theta\cos\theta \end{aligned}$$

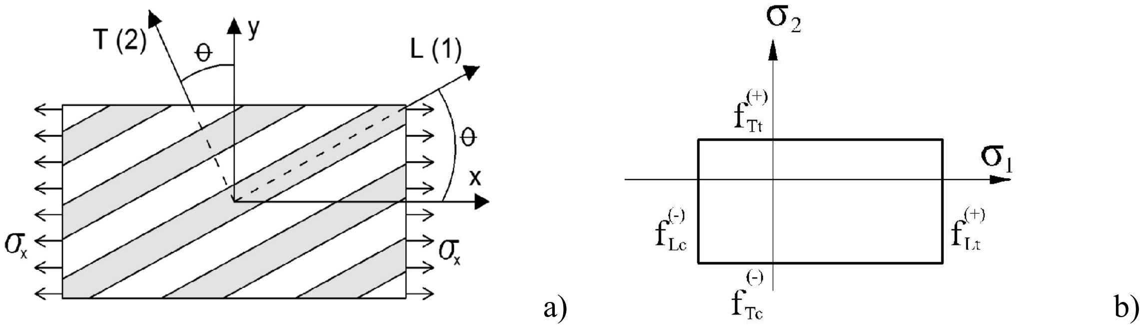


Fig. 2. a) General orthotropic lamina loaded by σ_x
b) Failure envelope for maximum stress theory

For the two dimensional state of stress, the failure envelope takes the form of a rectangle, presented in Fig. 2b.

2.2. Maximum strain theory

The maximum strain theory states that failure occurs when at least one of the strain components along the principal material axes exceeds the corresponding ultimate strain in that direction [5]. The following set of inequalities must be satisfied, in order to avoid failure.

$$\text{(2.3)} \quad \begin{aligned} &-\varepsilon_{Lc} < \varepsilon_1 < \varepsilon_{Lt} \\ &-\varepsilon_{Tc} < \varepsilon_2 < \varepsilon_{Tt} \quad , \\ &-\gamma_{LTs} < \gamma_{12} < \gamma_{LTs} \end{aligned}$$

where ε_1, ε_2 and γ_{12} are the strain components referred to the principal material axes and ε_{Lt}, ε_{Lc}, ε_{Tt}, ε_{Tc} are γ_{LTs} are the ultimate tensile, compressive and shear strain along the longitudinal and transverse direction, respectively.

If the unidirectional lamina is subjected to stresses only in x direction and the loading direction is different to the principal material axes, the strains are transformed taking into account the angle (Θ) between the two system of axes.

$$\text{(2.4)} \quad \begin{aligned} \varepsilon_1 &= \frac{\sigma_x}{E_1}(\cos^2\theta - \upsilon_{12}\sin^2\theta) \\ \varepsilon_2 &= \frac{\sigma_x}{E_2}(\sin^2\theta - \upsilon_{21}\cos^2\theta), \\ \gamma_{12} &= \frac{\sigma_x}{G_{12}}\sin\theta\cos\theta \end{aligned}$$

where E_1, E_2 and G_{12} are the elastic and shear moduli with respect to the principal material axes and ν_{12}, ν_{21} are the Poisson's coefficients.

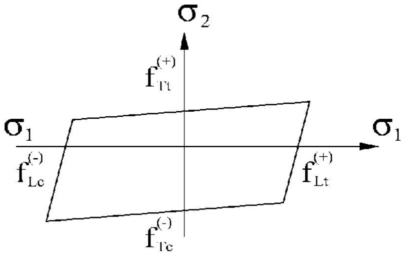


Fig. 3. Failure envelope for maximum strain theory

For the two dimensional state of stress, the failure envelope takes the form of a parallelogram, presented in Fig. 3, its centre being on the origin of σ_1- σ_2 coordinate system in case of equal strengths or off the origin for unequal strengths.

2.3. Tsai-Hill theory

This theory is based on the deviatory or distortional energy proposed by Von Mises for isotropic materials. Firstly, Hill [6] adapted the maximum distortional energy failure criterion to anisotropic materials followed by Tsai [7] who proposed the criterion for the orthotropic unidirectional lamina [8]. For the plane state of stress, the equation which describes the boundary of the failure envelope (Fig. 4) is:

$$(2.5)\quad \frac{\sigma_1^{\,2}}{f_{Lt}^{\,2}} - \frac{\sigma_1\sigma_2}{f_{Lt}^{\,2}} + \frac{\sigma_2^{\,2}}{f_{Tt}^{\,2}} + \frac{\tau_{12}^{\,2}}{f_{LTs}^{\,2}} = 1$$

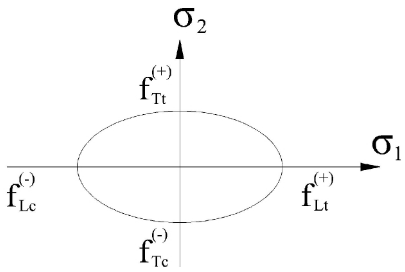


Fig. 4. Failure envelope for unidirectional lamina under biaxial strength for equal strengths

2.4. Tsai-Wu theory

Tsai and Wu [9] were the first to apply the strain energy failure theory of Beltrami to the unidirectional lamina under plane stress. This failure theory is more general than Tsai-Hill theory because it takes into account the different strengths in tension and compression. A lamina is considered to be failed if the left side of Eq. (2.6) equals or exceeds 1.

$$(2.6)\quad F_1\sigma_1 + F_2\sigma_2 + F_6\tau_{12} + F_{11}\sigma_1^2 + F_{22}\sigma_2^2 + F_{66}\tau_{12}^2 + 2F_{12}\sigma_1\sigma_2 = 1,$$

$$(2.7)\quad \begin{aligned} F_1 &= \frac{1}{f_{Lt}} - \frac{1}{f_{Lc}}; \quad & F_{11} &= \frac{1}{f_{Lt}f_{Lc}} \\ F_2 &= \frac{1}{f_{Tt}} - \frac{1}{f_{Tc}}; \quad & F_{22} &= \frac{1}{f_{Tt}f_{Tc}} \\ F_6 &= 0; & F_{66} &= \frac{1}{f_{LTs}^{\,2}} \end{aligned}$$

The values F_{12} are usually determined under a biaxial stress test but its values can be approximated using the following condition [10].

(2.8) $$-\frac{1}{2}(F_{11}F_{22})^{1/2} \le F_{12} \le 0$$

For a given value of τ_{12} the failure envelope has the shape of an inclined ellipse, and it is presented in Fig. 5 for the particular case of E Glass – Epoxy unidirectional lamina.

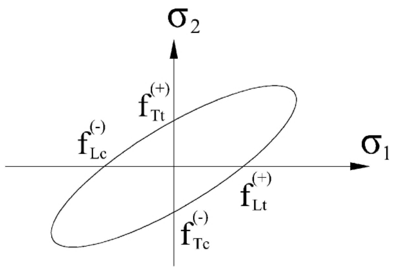
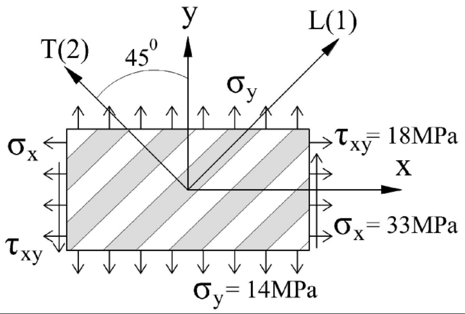


Fig. 5. Failure envelope for E Glass-Epoxy unidirectional lamina for Tsai-Wu criterion [9]

3. Case study

Check the following 45^0 angle unidirectional E glass / epoxy lamina under maximum stress, maximum strain, Tsai-Hill and Tsai-Wu criterions. The mechanical and elastic properties of the lamina are: f_{Lt} = 910 MPa, f_{Tt} = 19.3 MPa, f_{Lc} = 81.2 MPa, f_{Tc} = 40.1 MPa, f_{LTs} = 25.3 MPa, E_1 = 45.33 GPa, E_2 = 7.89 GPa, G_{12} = 3.05 GPa, ν_{12} = 0.278 and ν_{21} = 0.053.

Table 1. Checking the lamina failure theories

45^0 Angle unidirectional lamina under σ_x, σ_y and τ_{xy}

Maximum stress theory
Transforming the stress components with respect to the material axes: $\begin{Bmatrix}\sigma_1\\ \sigma_2\\ \tau_{12}\end{Bmatrix} = \begin{pmatrix}\cos^2 45 & \sin^2 45 & 2(\sin 45)(\cos 45)\\ \sin^2 45 & \cos^2 45 & -2(\sin 45)(\cos 45)\\ (-\sin 45)\cos 45 & (\sin 45)(\cos 45) & (\cos^2 45)(-\sin^2 45)\end{pmatrix}\begin{Bmatrix}33\\ 14\\ 18\end{Bmatrix} = \begin{Bmatrix}41.5\\ 5.5\\ -9.5\end{Bmatrix} MPa$ Eq. (2.1) is satisfied because all stress components are lower than the corresponding lamina strengths. Thus, no failure occurs.
Maximum strain theory
Transforming the strain components with respect to the material axes using Eq. (2.4): $\varepsilon_1 = 0.878\cdot 10^{-3}$ $\varepsilon_2 = 0.442\cdot 10^{-3}$ $\gamma_{12} = 3.113\cdot 10^{-3}$ Calculating the ultimate strains with respect to the material axes: $\varepsilon_{Lt} = f_{Lt}/E_1 = 20\cdot 10^{-3}$ $\varepsilon_{Lc} = f_{Lc}/E_1 = 1.79\cdot 10^{-3}$ $\varepsilon_{Tt} = f_{Tt}/E_2 = 2.44\cdot 10^{-3}$ $\varepsilon_{Tc} = f_{Tc}/E_2 = 5.08\cdot 10^{-3}$ $\varepsilon_{LTs} = f_{LTs}/G_{12} = 8.29\cdot 10^{-3}$ All strain components satisfy the inequalities presented in Eq. 2.3. Thus, no failure occurs.

Tsai-Hill theory
Appling Eq. (2.5): $\frac{\sigma_1^2}{f_{Lt}^2}-\frac{\sigma_1\sigma_2}{f_{Lt}^2}+\frac{\sigma_2^2}{f_{Tt}^2}+\frac{\tau_{12}^2}{f_{LTs}^2}=0.224<1$ Since the inequality is satisfied, no failure is expected.
Tsai-Wu theory
Calculating the coefficients using Eqs. (2.9) and (2.10): $F_1=-11.21\cdot10^{-3}$ $F_2=26.87\cdot10^{-3}$ $F_{11}=1.35\cdot10^{-5}$ $F_{22}=1.29\cdot10^{-3}$ $F_6=0$ $F_{12}=0$ $F_{66}=-1.56\cdot10^{-3}$ And using them in Eq. (2.8): $F_1\sigma_1+F_2\sigma_2+F_6\tau_{12}+F_{11}\sigma_1^2+F_{22}\sigma_2^2+F_{66}\tau_{12}^2+2F_{12}\sigma_1\sigma_2=0.7<1$ Since the inequality is satisfied, no failure is expected.

Conclusion

The usability of the failure criterions is correlated with the characteristics of the materials and with the state of stress to which the latter are subjected. Thus, the maximum stress and maximum strain theories are more appropriate for materials with a fragile behaviour, subjected to positive σ_1 and σ_2 stresses. Moreover, maximum strain criterion takes into account the interaction between the stress components by the Poisson's coefficients [4].

On the other hand, Tsai-Hill and Tsai-Wu theories are suitable for materials with ductile behaviour, subjected to compression and shear, giving the closest predictions with respect to the experimental results. They are much easier to apply because of the single condition that has to be satisfied in order to avoid failure in comparison to the maximum stress and strain criterions that have to fulfil six different conditions. Although Tsai-Wu criterion has good failure predictions, it implies experimental determination of the F_{12} coefficient which might be, in some cases, time and cost consuming.

REFERENCES

[1] Gotsis P.K., Chamis C.C., Minnetyan L. Prediction of composite laminate fracture: Micromechanics and progressive fracture, Failure criteria in fibre reinforced polymer composites: The world-wide Failure Exercise, Elsevier Ltd, Oxford, 2004, 98-121.
[2] Kaw A.K. Mechanics of composite materials, 2nd Edition, Boca Raton 2006.
[3] Kelly A., Strong Solids, Clarendon Press, Oxford, 1966.
[4] Taranu N., Bejan L., Cozmanciuc R., Hohan R. Materiale si elemente composite I, Politehnium, Iasi, Romania, 2013.
[5] Daniel I., Ishai O. Engineering mechanics of composite materials, 2nd Edition, Oxford University Press, Oxford, UK, 2006.
[6] Hill R. A theory of the yielding and plastic flow of anisotropic materials, Proceedings of the Royal Society, Series A, Vol. 193, 1948.
[7] Azzi V.D., Tsai S.W. Anisotropic strength of composites, Experimental Mechanics, Vol. 5, No. 9, 1965, 283-288.
[8] Gibson R.F., Principles of composite material mechanics, 3rd Edition, CRC Press, London, UK, 2012.
[9] Tsai S.W., Wu E.M. A general theory of strength for anisotropic materials, J. composite materials, Vol. 5, 1973, 448-446.
[10] Mallick P.K. Fiber-reinforced composites. Materials, manufacturing and design, 3rd Edition, CRC Press, Boca Raton, 2008.

PARTICULARITIES OF LAMINATED COMPOSITES OPTIMIZATION

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***Abstract**: Advanced composite materials have properties which are quite different from conventional materials. In many engineering applications it is more convenient to use composite materials rather than conventional ones. In particular, advanced composite materials are widely used in applications where a high strength-to-weight ratio is the most important criterion in the choice of material. However, the large number of design variables and the complex mechanical behavior associated with such materials make the structural design much more difficult and more labour intensive than those involving conventional materials. These characteristics are a good reason to make use of optimization methods in the sense of transforming the composite material structural design in a more systematic task, hence becoming less dependent to the designer sensitivity and achieving the maximum material performance. This paper points out the components of laminated composites structural optimization by specifying general techniques of optimization for these structures.*

***Key words**: optimization design, composite materials, optimization algorithm*

1. Introduction

Composite materials have received a substantial attention as manufacturing materials. This is due to their high stiffness-to-weight and strength-to-weight ratios and their ability to be custom designed to suit the particular environment in which they are used. A composite structure usually consists of one or more laminates. A laminate combines multiple stacks of thin layers of material, called laminas or plies, where each ply is based on small diameter fibres of a particular orientation and material type. These plies are held together by a matrix material such as epoxy, which serves to support the fibres and distribute the load amongst them.

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An important issue in designing laminated fiber composite structures is the optimal selection of number of plies, fiber angle, material or thickness of each ply and, consequently, the laminate thickness. By appropriate selection of stacking sequence and material for each lamina, it is possible to find the best composite structure for a particular case, allowing the designer to achieve a reduced cost and weight of the component while ensuring the required safety.

Analysis of composite laminate design can be computationally expensive and much of the research effort in this area is concerned about improving the efficiency of the various optimization methods.

2. The optimization techniques

Optimization is a method to determine the best possible solutions, using a set of mathematical equations that represent a physical system. The optimization techniques play an important role in structural design, the very purpose of which is to find the best way so that a designer or a decision maker can derive a maximum benefit from the available resources. The main characteristic of optimal design is that it consists of only logical decisions.

Each approach to automated structural optimization features three components [1], Fig. 1:

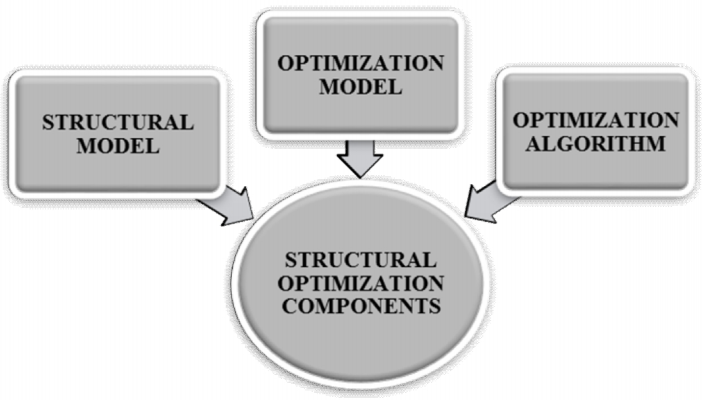

Fig. 1. Structural optimization components

The structural model reflects the physical behavior, relevant to predict the product qualities, driving the optimization objectives and constraint values. The optimization model is based on a definition of the optimization problem and a parameterized representation scheme. The optimization problem describes targeted product qualities, usually in the form of one or more objectives and a set of constraints. The representation schema consists of a choice of decision variables (y) in a search space (X) of attributes to be optimized. The basic requirements for an efficient structural design are that the response of the structure should be acceptable as per various specifications. The best design could be in terms of minimum cost, minimum weight, maximum performance or a combination of these. Many of the methods lead to a local minimum/maximum, most of them converging to local minimum. This, however, depends on the mathematical nature of the objective function and constraints.

Generally, the optimization problem has an objective function that measures the reliability or efficiency of the design. The maximization of the reliability is normally performed within some limits that narrow down the design choice, which are called constraints. As a final point, an optimization problem has design variables, which are the parameters that are changed during the design process. The design variables may be continuous or discrete, depending on whether they can take values from a continuum space, or are limited to a number of discrete values. Integer variables are special case of discrete variables. The basic schemas are: design variables, constraints, objective functions, problem domains and the environment for the design.

Optimization algorithms can be divided into two classes, Fig. 2:

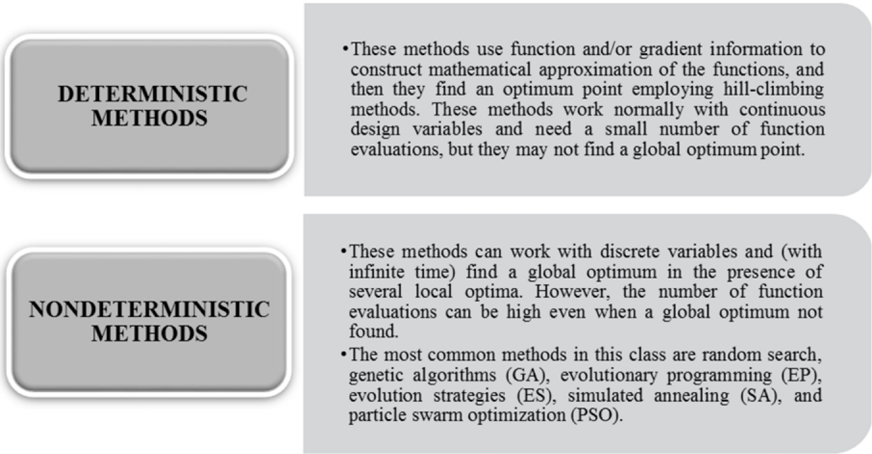

Fig. 2. The methods used in optimization algorithms

The structural optimization problem can be stated as:

Minimize or maximize:

(2.1) $F = F(x_1, x_2, x_3 ... x_n)$

Subject to:

$$(2.2) \quad \begin{cases} C_1 = C_1(x_1, x_2, x_3 ... x_n) = 0 \\ C_2 = C_2(x_1, x_2, x_3 ... x_n) = 0 \\ \qquad ... \\ C_n = C_n(x_1, x_2, x_3 ... x_n) = 0 \end{cases}$$

and:

$$(2.3) \quad \begin{cases} \Phi_1 = \Phi_1(x_1, x_2, x_3 ... x_n) \geq 0 \\ \Phi_2 = \Phi_2(x_1, x_2, x_3 ... x_n) \geq 0 \\ \qquad ... \\ \Phi_n = \Phi_n(x_1, x_2, x_3 ... x_n) \geq 0 \end{cases}$$

where $x_1, x_2, x_3 ... x_n$ are the design variables, $C_1, C_2, C_3 ... C_n$ are equality constraints and $\Phi_1, \Phi_2, \Phi_3 ... \Phi_n$ are the inequality constraints.

The nature of the mathematical programming problem depends on the functional type of F, C and Φ. If these are linear functions of design variables, then the problem is treated as a linear programming problem. On the other hand, if any one of them is a nonlinear function of the design variable, then it is classified as a nonlinear programming problem.

The search and optimization techniques are broadly classified into three main categories: calculus based, enumerative and stochastic search techniques [2], Fig. 3:

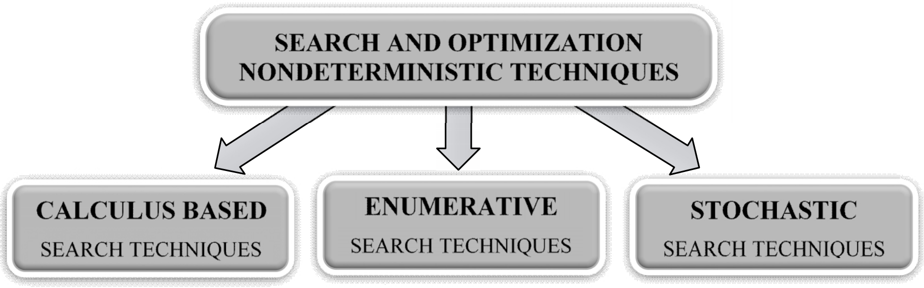

Fig. 3. Classification of available search techniques

Calculus based search technique consists of two different approaches: direct and indirect. Direct approach uses the concept of the function's gradient value in the search space to estimate nearby optimum solutions. Indirect approach identifies the points with extremes, where the gradient value of the function is zero and converges on such points for optimum solutions. One major drawback associated with this methodology is that most of the practical functions in engineering have multiple local optima, as shown in Fig. 4, which may cause this technique to converge early on a local optimum solution, instead of the global one.

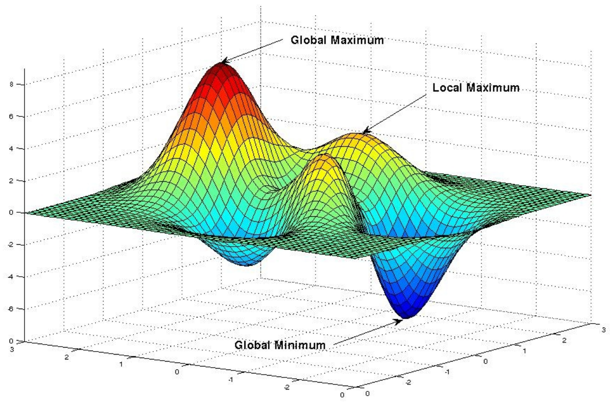

Fig. 4. Large search space with global and multiple local optimum solutions

Due to this reason, this type of approach usually gives a solution which is not fully optimized to its possible extent, decreasing the efficiency of the technique [2]. In order to avoid early convergence on a local optima, repeated parallel searches, with different starting point in the search space for each run, are required.

Enumerative search techniques are based on detailed search of every possible point in the entire search space, which makes this technique very expensive. The approach of enumerative techniques requires the search process to advance from point to point while, at the same time, updating the current solutions with other optimum results, when these are encountered during the process. The process continues until the whole search space is explored.

Stochastic search techniques are random, yet guided, search techniques, where the selection of points in the search space is suggested by the search already done so far. The process then replaces the current solution with a more optimized one, when encountered. This makes stochastic technique quite similar to enumerative technique, but instead of searching every possible point, it uses operators such as selection, combination and mutation, to guide the path of the search inside the search space. Stochastic or probabilistic programming deals with situations where some or all of the parameters of the optimization problem are described by some random variables. The basic idea used in stochastic programming is to convert the stochastic problem into an equivalent deterministic problem. The resulting deterministic problem is then solved by using familiar techniques such as linear, geometric, dynamic, and nonlinear programming.

Performing engineering design optimization often requires knowledge about the stage of the design, design variables and their minimum and maximum limits (independent variables), constraints, measurement of the design performance (dependent variables), design parameters and relationships between the independent and dependent variables (i.e. a design evaluation model). The use of algorithms for design optimization is gaining popularity. This helps to partially automate the optimization process and allows a better search for the best design. Large-scale optimization requires significant computing power and efficient algorithms such as swarm intelligence.

3. The optimization of laminated composites

Optimal design of laminated composite structures is challenging, due to the possibility to locally adapt the material system to the mechanical situation. In general, optimization methods, based on the lamination parameters, are restricted to global structural responses, such as stiffness, and do not include local strength constraints at the ply level.

The parameters usually fine-tuned in the optimization process are: the type of constituent materials and the volume fractions for each constituent, the fibres orientation, the fabrication procedure, the thickness and the orientation of each ply, the number of plies and their stacking sequence, (Fig.5).

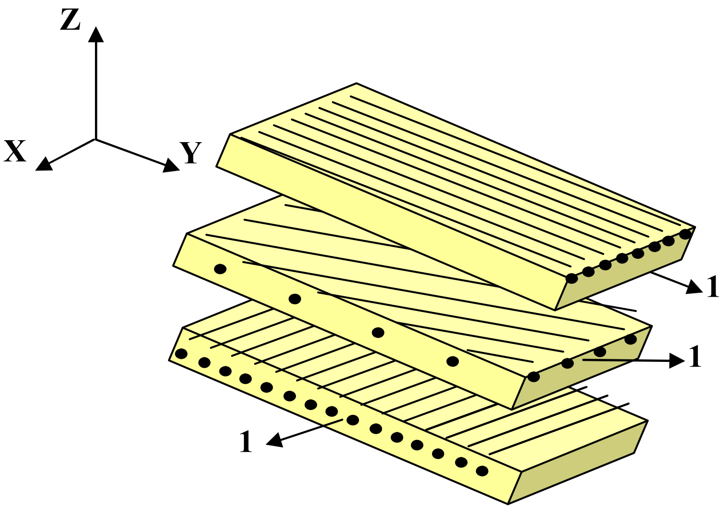

Fig. 5. A laminated composite made of plies with different fibre orientation

The current problem of optimization has been defined as a multi-objective optimization problem of minimizing both the weight of the component as well as the total cost for a composite, for a required strength, so that it satisfies a specific failure criterion. The goal is to find the values of the variables within the feasible space that optimizes the objective function, while satisfying the constraints.

Nowadays, the methods for global laminate optimization are often limited to analytical geometries [3], leading to optimized designs that need interpretation by an expert [4], or are restricted to few design objectives, such as minimum compliance [5]. Composite laminated structures provide improved design flexibility, with the possibility of tailoring their stiffness and strength by selecting fiber orientations. Therefore dedicated design methods, taking into account composite materials specifics, are required. In this case, the models employed are governed by mechanical laws. The specific challenge in composite design and optimization is that the design problem is discrete in its nature: a laminated composite consists of a discrete number of layers, and for ease of manufacturing the fiber orientation angles of the plies in the laminate are restricted to a discrete set, commonly {−45°, 0°, +45°, 90°}. An excellent overview of the optimization tools that can be used for the optimization of laminated composites is provided in Ghiasi et al. [6].

Designing laminated composites has become a challenging problem for the designer because of a wide range of parameters that can be varied, and because the complex behavior and multiple failure modes of these structures require sophisticated analysis techniques. The possibility of achieving an efficient design that is safe against multiple failure mechanisms, coupled with the difficulty in selecting the values of a large set of design variables, makes structural optimization an efficient tool for the design of laminated composite structures [7].

With the arrival of evolutionary optimization algorithms, one can optimize a composite laminate without treating it as a continuous problem. Genetic algorithms (GA) were quickly identified as good candidates for the optimization of composite laminates, as they are well suited to searching a discrete design space. Discrete optimization problems may be handled in two main ways. The first is to discretize the solutions from a continuous optimization method. Although this allows the use of continuous methods, gradient-based search methods are more difficult to apply, as the discrete design space will not easily give gradients, either by analytical or numerical differentiation. The alternative to discretization of a continuous solution is to use a search algorithm that is inherently discrete. These methods are heuristic, and include ant colony optimization (ACO) and the GA. They find solutions within a discrete design space, as a digital representation of its variables, without any other knowledge than the fitness of each design.

Nature inspired techniques such as Genetic Algorithm (GA), Artificial Immune System (AIS), Particle Swarm Optimization (PSO) etc., provide a robust and efficient approach in solving real world, complex problems of optimal structural design. The Genetic Algorithm (GA) and Simulated Annealing (SA) algorithm are two of the most popular stochastic optimization techniques.

Conclusions

In recent years, the world agenda has really been set on care for climate and environment, as well as on efficient use of raw materials. In terms of efficient use of materials, composite structures are a key player. The idea behind building structures from composite materials is focused around efficient use of materials.

Composite materials have been successfully replacing the conventional materials in many structural applications. Major virtues of composite materials include higher specific strength and stiffness, better corrosion and wear resistance, among many other things. In contemporary composite design, researchers are trying to find the arrangement of material constituents that best satisfies a posted set of requirements, with respect to strength, stiffness, cost and/or weight. Optimal design of laminated composite structures is challenging due to the possibility to locally adapt the material system to the mechanical situation. Trying to find solution to optimization problems, many researchers have been looking for inspiration in the world of insects or in the evolution of human being.

Stochastic methods are the most appropriate for composite lay-up design, because of their capabilities of handling a mixture of continuous and discrete variables, finding the global optimum of a multi-modal objective function. During the last two decades, there has been a growing interest in using GA techniques for the optimum design of structures made of laminated composites. The main trend in this area has been set to optimizing the stacking sequence of laminates.

REFERENCES

[1] Eschenauer, H., Olhoff, N. and Schnell, W., (1997), Applied Structural Mechanics. Springer
[2] Gürdal, Z., Haftka, R.T., and Hajela, P., 1999, Design and Optimization of Laminated Composite Materials, John Wiley & Sons, Inc., New York, pp. 169-310, Chap. 5,8
[3] Messager, T., Pyrz, M., Gineste, B., Chauchot, P., (2002), Optimal laminations of thin underwater composite cylindrical vessels. Compos Struct, 58(4):529–37
[4] Hansel, W., Treptow, A., Becker, W., Freisleben, B., (2002), A heuristic and genetic topology optimization algorithm for weight-minimal laminate structures. Compos Struct., 58:287–94
[5] Kocvara, M., (2000), Modern optimization algorithms in topology design. Computer aided topology optimization seminar, Bayreuth, Germany
[6] Ghiasi, H., Pasini, D., Lessard, L. (2009), Optimum stacking sequence design of composite materials part I: Constant stiffness design, Composite Structures 90(1): 2009, 1–1
[7] Haftka, R.T., Gürdal, Z., (1992), Elements of Structural Optimization. 3rd ed. Netherlands, Kluwer Academic Publishers

NON-DESTRUCTIVE TECHNIQUES IN MECHANICAL CHARACTERIZATION OF MASONRY HISTORICAL BUILDINGS

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Abstract: *Geophysical prospecting surveys are being increasingly used in the non-destructive evaluation of masonry historical structures taking into considerations that the diagnostic analysis of ancient buildings supposes important challenges from the point of view of its evaluation under field conditions. Therefore this paper describes the application of three non-destructive testing techniques: ground penetrating radar, flat-jacks and infrared thermography method. The aim of the study is to define the preliminary mechanical characteristics and structural elements inner geometries of the analyzed masonry historical structures. The results of the study reveals that non-destructive techniques can be used for providing valuable information regarding the evaluation of the current state of the cultural heritage buildings and the efficiency of the intervention solutions. Moreover, this knowledge of great significance in the intervention process resulted with a minimal effect on the structural component analyzed.*

Key words: *non-destructive, masonry, results interpretation*

1. Introduction

Non-destructive and minor-destructive testing may be useful in identifying defects in the interior of the masonry and in the characterization of structural elements sections. However, these procedures can only provide qualitative results. Although non-destructive evaluation techniques on cult monuments are relatively advanced, they can be difficult to apply due to several factors: different types of masonry materials, high heterogeneity of the constituent materials, interpretation and harmonize the results from different techniques. Moreover, most non-destructive techniques from different or adjacent research fields require application in a complementary nature and specific calibration. The expert must be able to interpret the results of all applied techniques and use them at least in comparison between different parts of the structural elements of the monument.

2. Flat jack testing

This in situ testing method is described in the standards: ASTM Standard C 1196-91 [1] the method with one flat jack and ASTM Standard C 1197-91 [2] the method with two jacks. Flat-jacks testing method is a minor-destructive test that can be performed in situ to

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determine the following characteristics of the existing masonry: the state of stress in a wall of the analysed building; axial compression strength of masonry; masonry deformability properties which define the constitutive law σ-ε and modulus of elasticity.

The single flat-jack test is used to determine the state of stress in a wall of the analyzed structure, and is based on the stress relaxation caused by a cut perpendicular to the wall surface. A thin Flat-Jack is placed inside the slot and the pressure is gradually increased in order to restore the distance measured before the cut. When two jacks are used simultaneously, they delimit a masonry sample of appreciable size, to which a uniaxial compression stress can be applied. In this way, a compression test can be carried out on an undisturbed sample of considerable size. Several loading-unloading cycles can be performed at increasing stress levels, in order to determine the deformability modulus of the masonry during the loading and unloading stages [3].

Both methods were used on “Vasile Lupu” School in Iasi (Fig. 1). Flat presses were semi-circular with a radius of 35 cm and the distance between the measured points (either side of the gap) were evaluated with an extensometer reading up to 0.001 m. The following measurements were recorded during the test with a single jack:

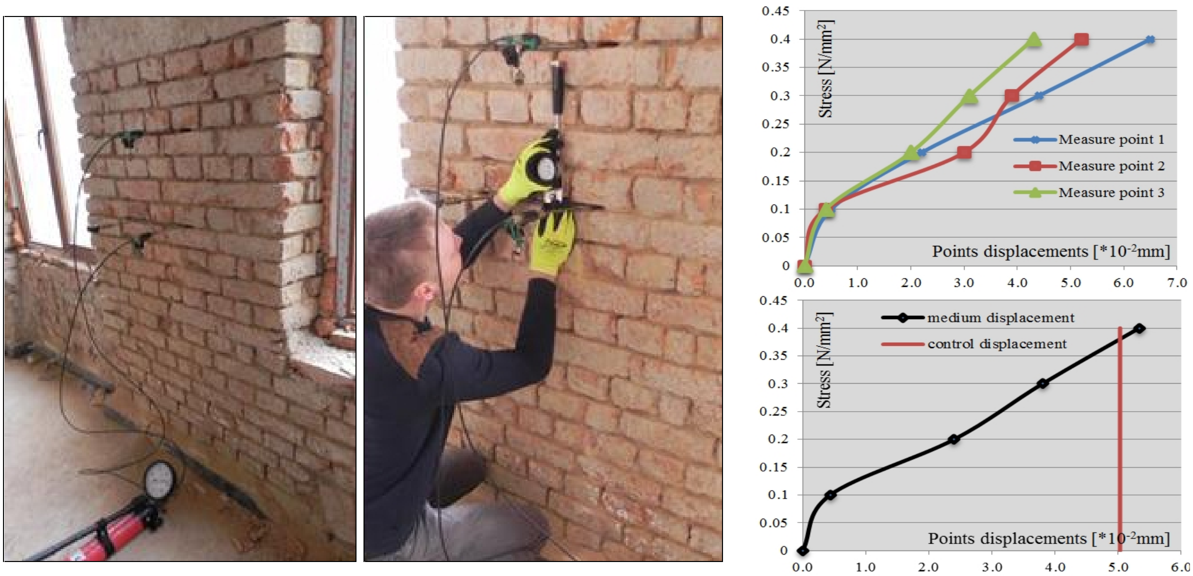

Fig. 1. Flat-jacks tests preparation and the measurements recorded during the test with a single jack

Target displacements initially measured were intercepted at a pressure of 0.380 N/mm^2 and the final value of 0.266 N/mm^2 resulted after applying the calibration factors. The state of stress in the analysed wall was used in the calibration of the computational finite element model.

In order to determine the axial compression strength of masonry and the masonry deformability properties which define the constitutive law σ-ε and the modulus of elasticity two flat-jacks method was used. The pressure in the jacks was controlled so that three loading-unloading cycles resulted. Based on the values read during the test load-deformation graphics for each measurements points where drawn and a final chart with average values between the three sets of curves plotted. Masonry compressive strength resulted with the value of f_k = 1.925 N/mm^2 (after the correction with jacks calibration coefficients). The specific deformation corresponding to masonry failure was mediated at ε_m=6.43 ‰. The elasticity modulus of masonry resulted E_z = 1454 N/mm^2 (Fig. 2).

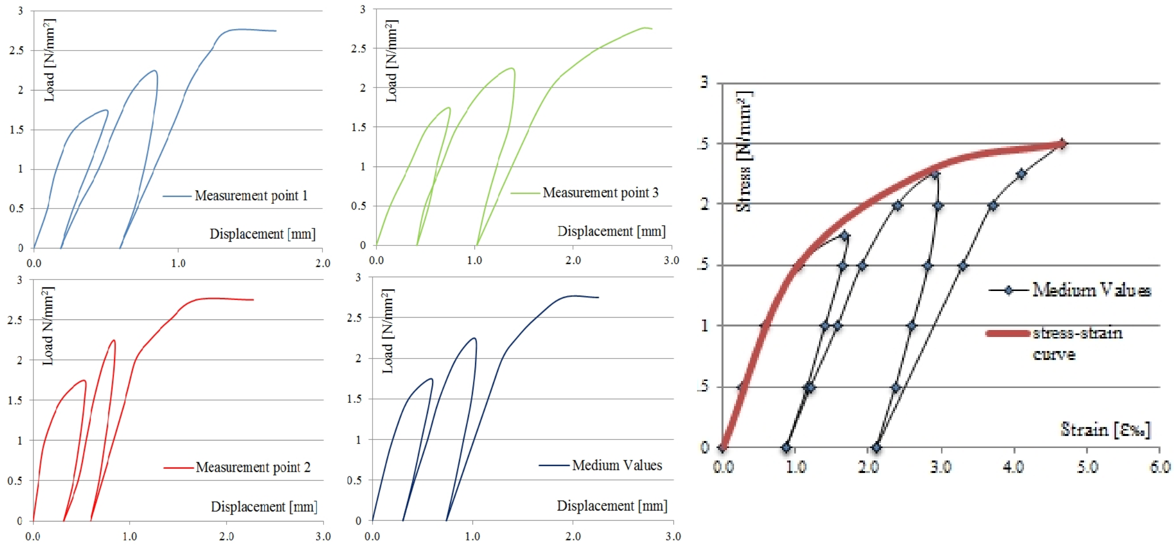

Fig. 2. Results from two flat-jacks test

The use of this tests in historic masonry buildings is facilitated by the fact that it can be done in any area of the building (wall, pillar, arc), allowing a comprehensive picture of the stress state and mechanical characterization of masonry with a high degree of accuracy and speed of execution. If masonry with apparently different characteristics is found during the intervention works in uncovered areas the test could be repeated immediately.

3. Ground penetration radar

The principle of the method consists in the transmittance of short electromagnetic pulses of 1-60 ns (in VHF / UHF bands between 100MHz and 2.6GHz for historic masonry buildings) to the studied materials, their reflection occurring at the interface areas with different electromagnetic properties because of the interior defects of masonry, moisture or different materials. These properties are related to the electrical conductivity and the dielectric constant of the material. Radar method is used in the structural evaluation of historic monuments in locating the position of internal flaws or inclusions of different materials, to analyse the moisture inside the masonry and to control the rehabilitation interventions [4-5]. This test method is described in ASTM D6432 [6] and in ASTM D4748 [7].

Prior testing is necessary to calibrate the radar, and to choose the measurement and sensitivity field. Resolution and depth of penetration of the signal is dependent on the frequency of the electromagnetic impulses. Low frequency antennas are used in investigating massive masonry sections, where penetration depths reached up to 4m, but big wave radar reduces the ability to locate faults. High frequency antennas are used where higher resolution is needed for the analysis of the area near the surface of masonry [8].

Radar testing was performed on a stone monument made in 1717 in Iasi (Fig. 3). The cross was cut from a single block of limestone, with a height of 3.40 m over which it was placed a stone termination of the same height of 60 cm. The arms of the cross are relatively short compared with the overall height (30 cm) and are connected to the vertical component elements in the form of quarters of a circle. Foundation on which rests the cross is made from a block of stone. Taking into consideration that the base of the column has a horizontal fracture, the issue of a connecting metal tie existence was made. Also, radar testing aimed to identify degradation within the limestone. Measurements were performed with a type Mala CX11 radar with an antenna provided with wheels.

Horizontal and vertical readings at the fracture level have been considered. At the time of testing, the stone exposed to the weather condition was wet, therefore the measurements were performed with the speed of the electromagnetic pulses of 80m/μs and 115m/μs. A 40cm penetration depth and two antenna frequencies of 1.6GHz and 2.3GHz were used. Radargrams resolution depends largely on the characteristics of the material and the frequency of the pulses. As the frequency increases, the resolution increases but the depth of the measurements decreases. No metal tie connection was found at the junction between the two parts of the structure, the only signal interferences described with small hyperbolas on the radargrams are probably due to insignificant changes of the stone mechanical characteristics in its depth.

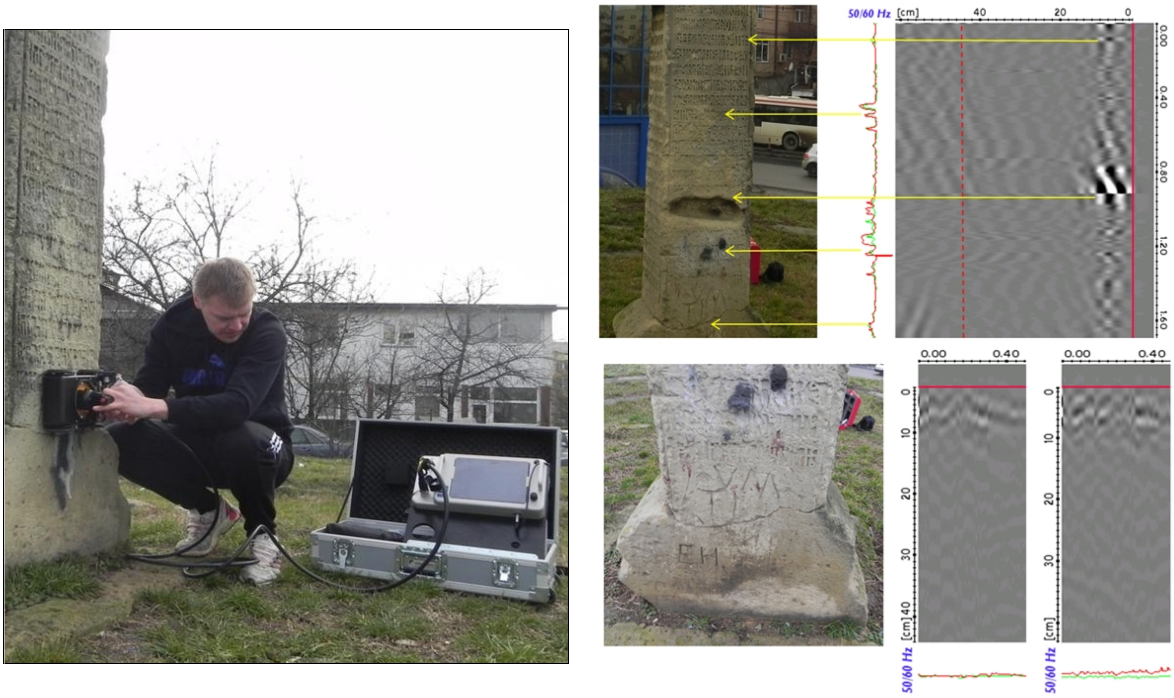

Fig. 3. Radar testing on a stone monument

To identify the degradation within the limestone cross vertical radar tests profiles were made with the 2.3 GHz antenna, 60cm measurement depth and speed of 115m/μs. The horizontal axis represents the measure depth and the vertical axis the measurement distance on the cross. On the radargrams resulted the column width of 45cm is determined by the accentuation of the hyperbolas. The degradation in the form of a cavern, intercepted at the distance measuring 0.9m, is distinguished by the color changes more pronounced than others from the same depth due to the stone engravings. Signal interference appear at the bottom crack level, at the gray-black seepage and at the distance of 0.5m perhaps at the level of less pronounced seepage.

4. Infrared thermography

Infrared thermography is a non-destructive method for diagnosing the state of the constructions based on masonry property to emit differentiated the heat accumulated according to the presence of structural defects in the mass of the material. The energy captured at the surface of the brickwork depends on the spectral properties (emissivity, reflectivity), thermal properties (conductivity, specific heat, thermal diffusion) and other physical properties of the material (porosity, density, water content) [9-10].

Radiation captured in infrared thermography testing by an infrared sensor test depend on the emission coefficient of the surface and of the environment, given that a fraction can be reflected or absorbed by the atmosphere surrounding the object and the camera. They can be defined as a function of surface temperature of the element, making it possible to calculate and reproduce the temperature map using Stefan-Boltzmann's law [11]:

$$\frac{q}{A}=\varepsilon\sigma T^4$$

where: q – energy release rate (W);

A – aria of the surface which releases energy (m^2);

T- the absolute temperature of the surface (K);

σ- Boltzmann constant (=$5.676x10^8$ $Wm^{-2}K^{-4}$).

The accuracy of measurement depends on ambient parameters such as temperature, wind speed, distance to the element analysed. Weather conditions can have a significant influence due to, for example, a temperature increases for a structural element exposed to solar radiation and a temperature descrease because of wind action. The method is particularly useful in rapid assessment of large areas and in localization of particular zones that requires further investigation [12].

The tests were carried out on a heritage old building in Bucharest (Fig. 4) with the FLIR B250 infrared camera with thermal sensitivity 70 mK for 30°C, with the spectral range 7.5-13μm and image frequency between 9 and 30 Hz. The accuracy of measurement is ± 2°C for a measurement field between -20°C and +120°C.

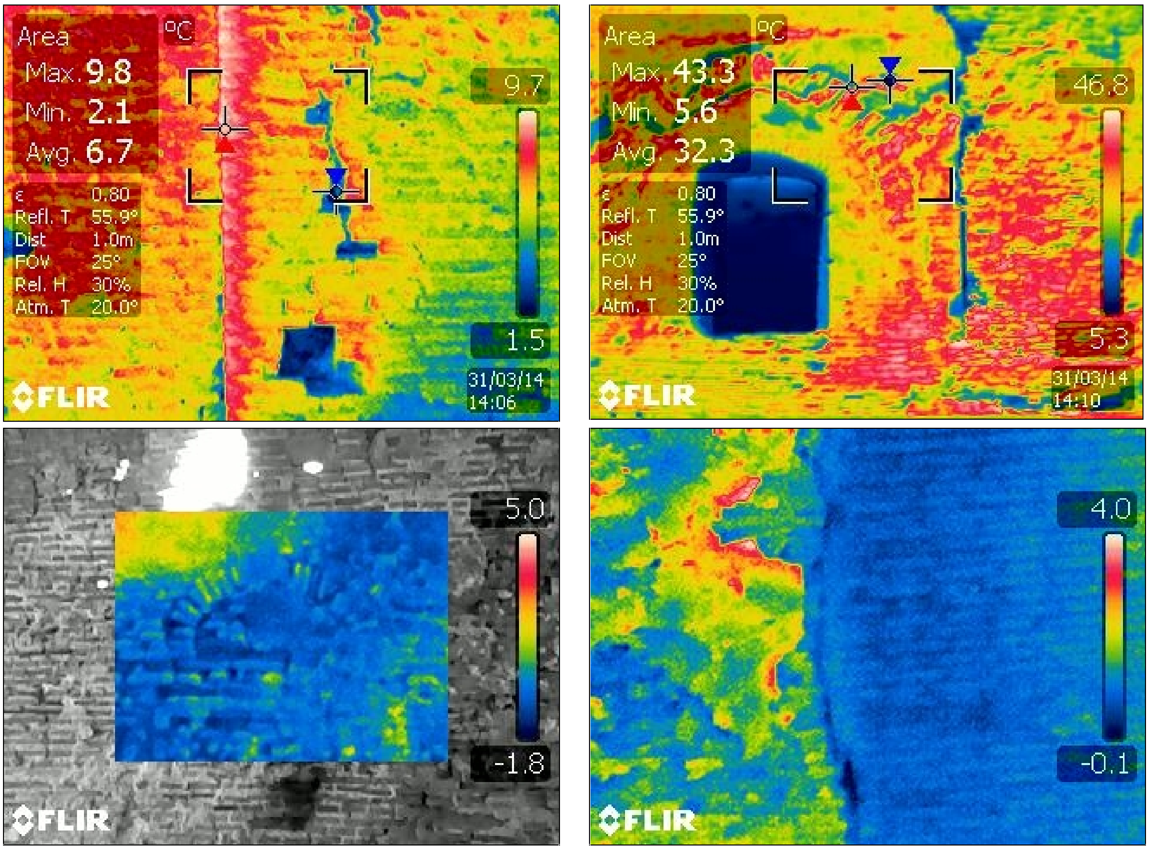

Fig. 4. Infrared thermography testing on a masonry heritage building

In investigation of these types of structures, where the restoration and conservation solutions can cause irreversible degradation to the building integrity, infrared thermography is a useful tool. Masonry, and especially historic masonry, has a very inhomogeneous structure, containing several different materials (brick, stone, mortar, plaster, wood, metal, etc.) with different thermal properties. Thus, thermography is, in general, well-suited for the detection of plaster and tile delaminations, for the investigation of cracks, for the location of detached parts behind the plaster, for the characterization of the masonry structure behind plaster, for the location of empty joints, and for the detection of excessive moisture [3].

Conclusion

Flat-jacks testing method is a minor-destructive test that can be performed in situ to determine the following characteristics of the existing masonry: the state of stress in a wall of the analysed building, axial compression strength of masonry, masonry deformability properties which define the constitutive law σ-ε and modulus of elasticity. The use of this tests in historic masonry buildings is facilitated by the fact that it can be done in any area of the building (wall, pillar, arc), allowing a comprehensive picture of the stress state and mechanical characterization of masonry with a high degree of accuracy and speed of execution. Radar method is used in the structural evaluation of historic monuments in locating the position of internal flaws or inclusions of different materials, to analyse the moisture inside the masonry and to control the rehabilitation interventions. In the diagnosis of historic masonry buildings infrared thermography is generally recognized as a rapid testing method for identification of masonry texture, hidden elements (gaps, closed spaces, windows, niches), the crack patterns, masonry heterogeneity and distribution of moisture in its interior.

REFERENCES

[1] ASTM Standard C 1196-91, In-situ compressive stress within solid unit masonry estimated using flat-jack Measurements.
[2] ASTM Standard C 1197-91, In-situ measurement of masonry deformability properties using flat-jack method.
[3] Vlatko B.,Mojmir U.,Roko Z., Bokan B., An integrated diagnostic approach for the assessment of historic masonry, Journal of Cultural Heritage 11, 2010.
[4] Binda L., Zanzi L., Lualdi M., Condoleo P., The use of georadar to assess damage to a masonry Bell Tower in Cremona, Italy, NDT&E Int;38(3):171–9, 2005.
[5] Binda L., Saisi A., Tiraboschi C., Investigation procedures for the diagnosis of historic masonries, Constr Build Mater, 14(4):199–233, 2000.
[6] ASTM D6432-11, Standard guide for using the surface ground penetrating radar method for subsurface investigation.
[7] ASTM D4748-10, Standard test method for determining the thickness of bound pavement layers using short-pulse radar.
[8] Faella G., Frunzio G., Guadagnuolo M., Donadio A., Ferri L., The Church of the nativity in Bethlehem: Non Destructive tests for the structural knowledge, Journal of Cultural Heritage 12, e27-e41, 2012.
[9] Pleşu R., Teodoriu G., Tăranu G., Infrared Thermography applications for building investigation, Buletinul Institutului Politehnic din Iaşi, Tomul LVIII (LXII), Fasc. 1, 2012.
[10] Binda L., Cantini L., Cucchi M., Thermovision: Applications in Conservation Field to Detect Hidden Characteristics of Building Structures. 11th North Amer. Masonry Conf., Minneapolis, USA, 1-12, 2011.
[11] Bagavathiappan S., Lahiri B., Infrared Thermography for condition monitoring – A review, Infrared Physics & Technology 60, 35-55, 2013.
[12] Suprenant B., Schuller M., Nondestructive Evaluation & Testing of Masonry Structures, Published by The Aberdeen Goup 426 S. Westgate St. Addison, II.60101, 1995.

ТЕХНОЛОГИЧНИ ВЪЗМОЖНОСТИ ЗА УКРЕПВАНЕ НА ФУНДАМЕНТИ НА СГРАДИТЕ

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TECHNOLOGICAL FEATURES OF STRENGTHENING OF FOUNDATIONS OF BUILDING

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Abstract: *This study shares the experience in the work of strengthening the foundations for reconstruction in selected sites. Results from studies of organizational and technological characteristics of the works are presented. It is proven that to ensure both the sustainability and stability of the reconstructed building structures affect the consistency and technological dimensions in the field of work. Several recommendations for technology of strengthen of the foundations of buildings are presented.*

Key words*: reconstruction, foundations, reinforcement of structures*

Введение

Процесс эксплуатации и реконструкции зданий сопровождается комплексом работ по обеспечению их функциональной пригодности, надежности и долговечности. В этот комплекс работ входят мероприятия ремонтно-восстановительного характера. Достаточно часто приходится прибегать к работам по усилению фундаментов зданий. Причины усиления фундаментов можно классифицировать по нескольким группам:

- трещины и деформации несущих строительных конструкций зданий, вызванные физическим износом самих конструкций или изменением гидрогеологических условий грунтов оснований;
- увеличение нагрузок на фундаменты вследствие надстроек, пристроек или иных работ, повлекших за собой изменение схемы работы конструкций и их геометрических параметров.

В практике применяется целый ряд способов усиления фундаментов. Несмотря на существенное разнообразие конструктивных решений зданий, многие способы

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усиления стали типовыми [1]. К числу наиболее распространенных способов следует отнести:

- увеличение опорной площади фундаментов за счет устройства бетонных и железобетонных обойм;
- передача нагрузок на нижележащие слои грунтов через буронабивные и вдавливаемые сваи;
- подведение под существующие конструкции дополнительных элементов;
- изменение статической схемы работы путем преобразования типов фундаментов (например, столбчатых в ленточные);
- инъецирование в тело фундаментов различных растворов и другие.

Анализ частоты применения указанных способов методом экспертных оценок показал, что наибольшее распространение получил способ устройства различных обойм (увеличение опорной площади фундаментов).

Выполнение работ по усилению фундаментов сопряжено с целым рядом технологических особенностей, которые оказывают влияние на общую устойчивость существующих строительных конструкций зданий. Особенно актуальны указанные особенности при выполнении работ по подведению под подошвой существующих фундаментов новых элементов. Эти работы могут приводить к существенным так называемым «технологическим» осадкам фундаментов и соответственно могут вызывать деформации вышележащих строительных конструкций. Поэтому на стадии подготовки к выполнению работ необходимо провести детальное обследование технического состояния существующих строительных конструкций, анализ гидрогеологических свойств грунтов оснований, оценку проектируемых архитектурно-конструктивных и организационно-технологических решений усиления фундаментов [2]. Следует также иметь в виду, что на эффективность строительных процессов существенное влияние оказывают такие факторы, как стесненность объектов, ветхость отдельных строительных конструкций, условия эксплуатации реконструируемого здания, невозможность предварительного детального обследования строительных конструкций фундаментов и другое [1].

В этой связи исследование практического опыта усиления фундаментов имеет важное значение для выработки рациональных организационно-технологических решений выполнения строительных работ с учетом указанных особенностей.

При реконструкции одного из зданий в городе Харькове проектной документацией предусмотрено усиление фундаментов и увеличение высоты подвальных помещений. Это могло быть достигнуто за счет подведения под фундаменты дополнительных железобетонных элементов [3]. Здание 4-х этажное, сложной планировочной конфигурации, 1914 года постройки. Фундаменты, выполнены из глиняного обыкновенного кирпича на известково-песчаном растворе, толщиной 710,0 мм. Во 2-м - 4-м этажах расположены жилые помещения. Реконструкция выполнялась без временного выселения жильцов жилых этажей.

В результате обследования здания было установлено, что на поверхности строительных конструкций имеется ряд повреждений и деформаций в виде наклонных и вертикальных трещины стен. Установлено, что в процессе почти 100-летней эксплуатации здание многократно перестраивалось, устраивались различные каналы, отверстия, проемы в стенах подвала. Неоднократно происходили аварии водопроводных сетей, в результате чего увлажнялись грунты оснований фундаментов. Все это существенно ослабило несущую способность фундаментов и стен здания.

Фактическая высота подвала составляла 2200,0 мм, что не обеспечивало бы нормальной эксплуатации после реконструкции. С учетом указанных факторов было принято решение об усилении фундаментов всех наружных и внутренних стен части здания с одновременным его заглублением для последующего увеличения высоты подвального этажа до высоты 2700,0 мм.

Конструкция подводимых элементов была определена расчетным путем. Принцип расчета основывался на обеспечении минимального изменения напряжений под подошвой фундаментов и вероятных осадок, не превышающих предельно допустимых значений из-за частичного увеличения нагрузок от устройства дополнительных железобетонных элементов и вследствие разработки (участками) грунтов под подошвой фундаментов. Расчеты выполнялись с помощью компьютерной программы. Установлено, что после увеличения нагрузки из-за подведения элементов напряжение под подошвой увеличивается всего на 2%. Это могло бы привести к появлению дополнительных осадок, равным 1,38 мм, что не превышает предельно допустимых значений [4]. С целью максимального исключения возможных осадок было принято решение об увеличении ширины подошвы фундамента на 200,0 мм. С учетом данного решения расчетная осадка составила около 0,12 мм. Фактический мониторинг осадок в процессе выполнения работ также не выявил существенных осадок.

При разработке проекта производства работ (ППР) была разработана схема выполнения работ по усилению фундаментов с целью исключения «технологических» осадок. Принцип расчета базировался на выборе количества одновременно разрабатываемых участков грунтов под подошвой фундаментов. Указанное количество участков соответствует уменьшению площади подошвы фундаментов. Установлено, что уменьшение площади подошвы фундаментов до 20% практически не влияет на деформативность грунтов оснований. С учетом этого было предусмотрено условное членение по длине существующего ленточного фундамента здания на захватки, длиной около 1000,0 мм. При этом число захваток не менее 6, рис.1. Принятая разбивка позволила выполнять работы по подведению новых элементов фундаментов без риска существенных осадок, как существующих участков фундаментов, так и стен здания.

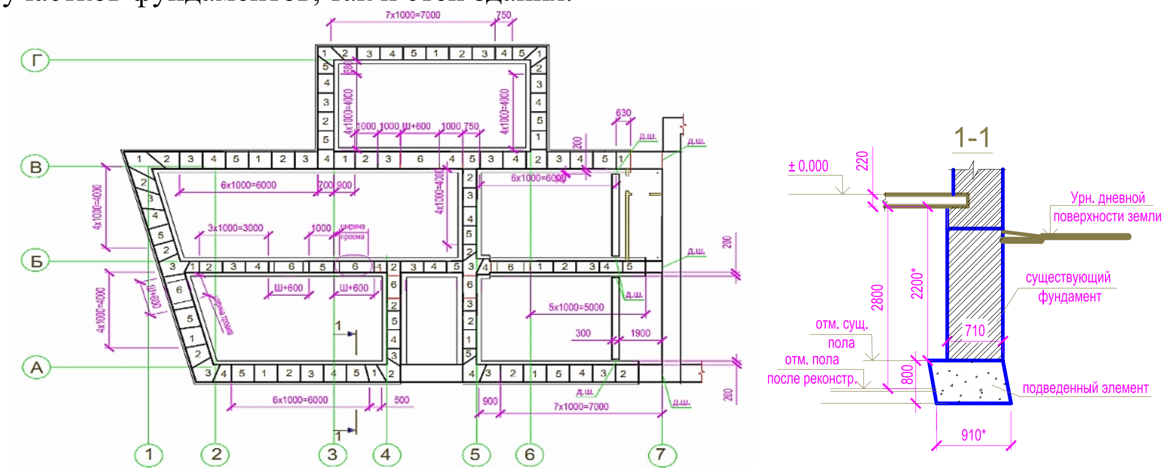

Рис. 1. Схема разбивки фундаментов на захватки: 1…6 – номера захваток.

До начала строительных работ был выполнен комплекс подготовительных мероприятий по обеспечению объекта средствами безопасности производства работ и безопасности жителей дома. Последующая технологическая очередность работ приведена в таблице 1. Производство строительных работ осуществлялось с постоянным мониторингом технического состояния существующих и примыкающих строительных конструкций. С учетом условий эксплуатации здания и особой стесненности строительные работы выполнялись в основном вручную. Бетонная смесь нижних слоев транспортировалась через оконные проемы подвала по лоткам непосредственно в разработанные выемки. Верхний слой бетона укладывался вручную.

Анализ организационно-технологических решений выполнения работ по усилению фундаментов на данном объекте показал, что интенсификация строительных работ весьма ограничена. Трудоемкость усиления фундаментов составила около 54,8 чел.-час./ м. п. ленточного фундамента.

Реконструкция другого здания предполагала усиление фундаментов существующего здания из-за намерений надстройки еще 2-х этажей. На этом объекте было принято решение по устройству под подошвой существующих фундаментов вдавливаемых свай, которые передавали бы нагрузки на нижележащие слои грунтов [5]. Конструктивная схема усиления приведена на рис. 2.

Таблица 1. Технологическая последовательность усиления фундаментов путем устройства дополнительных элементов под подошвой

Выполняемые работы	Фотофиксация
Устранение выявленных на поверхности стен подвала повреждений и деформаций (закладка всех устроенных ранее проемов, заделка трещин, бетонирование ниш и борозд). После выполнения указанных мероприятий было разрешено приступить к работам по усилению фундаментов.	
На одноименных захватках (№№ 1) были выполнены работы по разработке грунта на глубину около 800,0 мм на длину захватки около 1000,0 мм и на всю ширину подошвы фундамента. Земляные работы выполнялись вручную с пакетированием грунта и выносом для вывоза в отвал.	
В устроенных выемках были установлены арматурные сетки, установлена опалубка (со стороны разработки грунта), выполнена укладка и уплотнение бетонной смеси нижнего слоя на высоту около 600,0 мм. После технологического перерыва (2 дня), была выполнена укладка верхнего слоя бетонной смеси толщиной около 200,0 мм. Использовалась жесткая бетонная смесь, которая укладывалась методом виброзачеканки. Этот технологический прием был принят для уменьшения усадочных процессов бетона и соответственно для исключения возможных осадок существующих фундаментов здания.	 
После достижения бетоном проектной прочности, были выполнены работы по распалубке конструкций и приступили к разработке грунта на последующих захватках (№№ 2, №№ 3…).	
В результате последовательного выполнения работ на всех последующих захватках была устроена дополнительная железобетонная лента высотой около 800,0 мм. После был разработан грунт пола подвала на глубину около 500, 0 мм, что обеспечило требуемую проектную высоту помещений, составляющую около 2700,0 мм.	

Аналогично приведенному выше примеру был проведен комплекс работ по расчетному определению вероятных деформаций грунтов оснований и существующих конструкций здания из-за проведения работ по усилению.

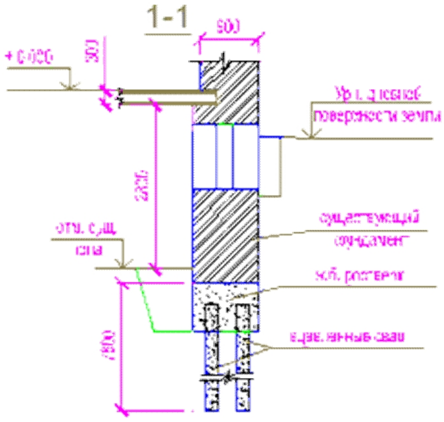

Рис. 2. Конструктивная схема усиления фундаментов путем устройства вдавливаемых свай

Это позволило установить схему производства строительных работ и соответственно по установлению количества и размеров захваток. После проведения тщательной инженерной подготовки приступили к строительным работам, согласно приведенной технологической последовательности, таблица 2.

Для вдавливания свай применялись малогабаритные гидравлические установки с вдавливающим усилием 50 тс. Бетонная смесь подавалась через оконные проемы непосредственно из автобетоносмесителей по лоткам. Разработанный грунт пакетировался и выносился за пределы помещений для вывоза.

Удельная трудоемкость усиления ленточного фундамента данным способом составила около 136 чел.-час/м.п.

Осуществляемый постоянно в процессе работ мониторинг технического состояния существующих строительных конструкций показал, что существенных деформаций конструкций не было выявлено.

Таблица 2. Технологическая последовательность усиления фундаментов путем устройства вдавливаемых свай

Выполняемые работы	Фотофиксация
По длине ленточные фундаменты здания условно разделили на захватки, длиной около 1000,0 мм (не менее 5-ти). Выполнили разработку грунта на одноименных захватках (№№1). Выемка грунта выполнялась на ширину захватки, глубиной около 1800,0 мм.	
Для обеспечения удобства вдавливания свай были устроены при помощи переносных буровых установок - лидерные скважины, глубиной 1,5 – 2,5 м. Установлено звено сваи. В зазор между верхом звена сваи и низом фундамента устанавливался домкрат и осуществлялось вдавливание сваи.	
Наращиванием звеньев свай осуществляется по мере их вдавливания. Отдельные сваи куста, вдавливаются последовательно (в соответствии с проектом) на проектную глубину (около 6-8 м). Качество устройства свай выполнялось периодическими испытаниями.	

Устанавливалась опалубка, осуществлялось армирование, укладка и уплотнение бетонной смеси ростверка. Бетонирование осуществлялось в два этапа. Вначале выполнялась укладка бетонной смеси на высоту захватки не доходя до низа подошвы фундамента на 50 – 100 мм. После твердения бетона и стабилизации усадочных явлений – выполнялась укладка жесткой бетонной смеси в оставшийся зазор между подошвой фундамента и поверхностью ростверка методом виброзачеканки. После достижения бетоном проектной прочности, была выполнена обратная засыпка грунта выемок захваток.	 

Выводы

Практический опыт усиления фундаментов позволяет сделать следующие выводы:

- повышение эффективности строительных работ может быть достигнуто только за счет тщательного анализа технического состояния строительных конструкций существующего здания и условий производства работ;
- работам по усилению фундаментов должен предшествовать детальный комплекс инженерной подготовки;
- безопасность производства работ, устойчивость и надежность эксплуатации существующих конструкций зданий может быть обеспечена путем разработки рациональных организационно-технологических решений. Эти решения базируются на проведении поверочных расчетов принимаемых вариантов схем разбивки на захватки (расчеты предельно допустимых технологических осадок);
- надежность и безопасность эксплуатации реконструируемого здания и непосредственного выполнения строительных работ должна быть обеспечена постоянным мониторингом технического состояния существующих и устраиваемых строительных конструкций здания;
- снижение трудоемкости может быть достигнуто за счет частичной механизации работ и совмещения простых однородных строительных процессов, выполняемых на различных захватках;
- приведенный опыт позволит оптимизировать организационно-технологические решения выполнения аналогичных работ по усилению фундаментов путем подведения под подошву дополнительных элементов.

ЛИТЕРАТУРА

[1] Савйовский В.В. Технология реконструкции –Харьков.: Основа, 1997.- 256 с.
[2] ДБН В.3.1-1-2002 Ремонт и усиление несущих и ограждающих строительных конструкций и оснований промышленных зданий и сооружений.-К.: Госстрой Украины, 2003, 82.
[3] Савйовский В., Савйовский А. Усиление фундаментов при реконструкции здания. MOTROL. — Commission of motorization and energetics in agriculture: Polish Academy of sciences. — Lublin, 2013. — Vol. 15, № 6. — P. 59-66.
[4] ДБН В.2.1-10-2009 Основи та фундаменти споруд. Мінрегіонбуд України, 2009, 161.
[5] Савйовский В.В., Харнам М.В., Шмигер П.М. Усиление фундаментов реконструируемого здания устройством вдавливаемых свай. Науковий вісник будівництва. - Вип. 39. – Харків: ХДТУБА, ХОТВ АБУ, 2006. – С. 204 – 212.

ON-SITE MEASUREMENT OF INDIRECT STRENGTH IN TENSION OF HISTORICAL BUILDING MATERIALS

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***Abstract**: This article deals with determination of mechanical properties of brittle building materials like stones of existing structures using portable device. Due to the fact, that the material samples may change their properties (for example, due to changes in humidity) during transportation, it is preferred to test samples on site. For these reasons portable testing device was developed. The testing machine operates on the split test principles. In split test a disc specimen is compressed with diametrically opposite and symmetric line loads. The first goal of this paper is to document improvement of the device's design to provide reproducible measurement, which will be consistent with theoretical assumptions. This paper mainly concentrates on the boundary condition of the split test. For this reason, different types of contacts were studied. Set of experiments was performed in order to fulfill the condition of crack initiating in the middle of the specimen. Secondly a practical use of portable devices is demonstrated by studies of sandstone from quarries from East Bohemia. This sandstone is often used for historical buildings.*

***Key words**: Split test, Brazilian disc, Tensile Strength, Sandstone, Portable testing machine, Digital Image Correlation*

1. Introduction

The presence of numerous randomly and irregularly spaced defects in brittle materials (stones, bricks, etc.) results in high dispersion of measured parameters, especially in tensile strength. This problem is usually overcome by large set of experiments and statistical evaluation, but this is not a case for precious materials from historical objects, because the samples are rare, ussualy gathered by core drilling. Therefore a method requiring less, ideally only one specimen is preferable. Direct assessment of elastic modulus E, tensile strength σ_{UT} and fracture toughness K_{IC} of brittle materials such a rocks and building materials represents a difficult problem for experimental instrumentation. Therefore alternative solutions have been proposed like for example intact specimens with jaw-type, or sophisticated zero-eccentricity devices, or the use of pre-notched cylindrical specimens etc. [1, 2]. One of these alternative solutions, called the Brazilian test has been popular for determining tensile strength for brittle building materials mainly due its simplicity. The Brazilian test is performed by compression with diametrically opposite concentrated loads on a disc specimen, see Fig. 1. The Brazilian test differs from Split test

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by the specimen thickness. The specimen used in Brazilian test has a thickness several times lower than specimen diameter. Contrary, in the case of Split test is height of cylindrical specimen higher than diameter. The theoretical basis for the split test is analytical solution developed by Hondros for the determination of elastic modulus and Poisson's ratio [3]. Complete stress solution linear contact between grips and specimen is expressed by

$$(1.1)\qquad \sigma_x = \frac{2P}{\pi L}\left(\frac{\cos\theta_1 \sin^2\theta_1}{r_1} + \frac{\cos\theta_2 \sin^2\theta_2}{r_2}\right) - \frac{2P}{\pi DL},$$

$$(1.2)\qquad \sigma_y = \frac{2P}{\pi L}\left(\frac{\cos^3\theta_1}{r_1} + \frac{\cos^3\theta_2}{r_2}\right) - \frac{2P}{\pi DL},$$

$$(1.2)\qquad \tau_{xy} = \frac{2P}{\pi L}\left(\frac{\cos^2\theta_1 \sin\theta_1}{r_1} + \frac{\cos^2\theta_2 \sin\theta_2}{r_2}\right),$$

where P is the line load [N/m], L is the thickness of the disc and D is the diameter of specimen. Meaning of Θ_1, Θ_2, r_1 and r_2 is obvious from the Fig. 1.

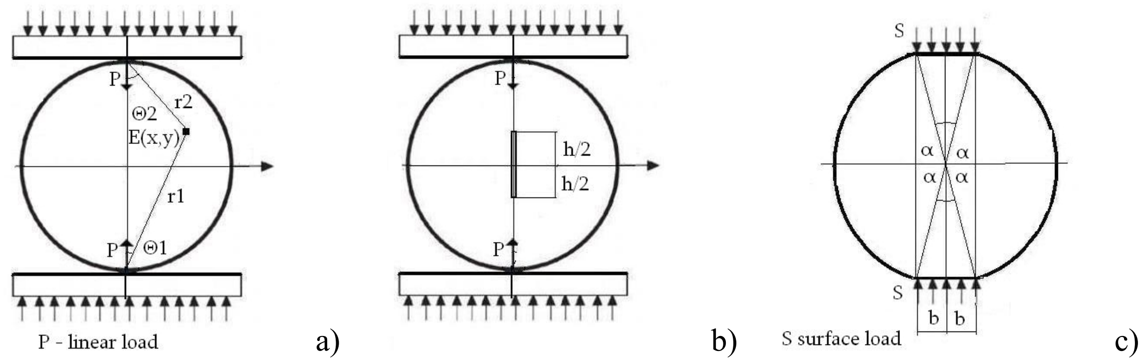


Fig. 1. Figure caption: a) Brazilian test; b) Brazilian test with notched specimen (*h* length of the notch); c) Brazilian test with flatted specimen (2*b* is width of the contact area)

Fairhurst [4]. concluded that failure is expected to initiate at the center of disc, and in this case the tensile strength R_T is calculated by equation:

$$(1.4)\qquad R_T = \frac{2P_{\max}}{\pi LD},$$

but actually the failure often initiates at the loading points. This conclusion was verified with experiments by Hudson [5]. However, when the crack initiates at loading point, Eq.1.4 gives erroneous results. Contrary to the theory, both specimen and jaws/grips are partly deformed and the contact problem is in reality "plane-to-plane", not "curve-to-curve" [1,2]. This problem can be solved, for example, so that the sample will be notched on the end face (see Fig. 1 b). However, the presence of the notch on the face of specimen fundamentally affects displacement field and applicability of Eq.1.4 is questionable. Another way of solving the problem is to use a flatted Brazilian disc [3] (see Fig. 1 c) or in used disc under parabolically distributed load [1, 2], i.e. contact of two cylindrical surfaces (see Fig. 2 a). The scope of this article does not allows a deeper analysis of each case of specimen, therefore, we briefly describe only the most recent case, which gives the best results.

2. The load distribution and the contact length

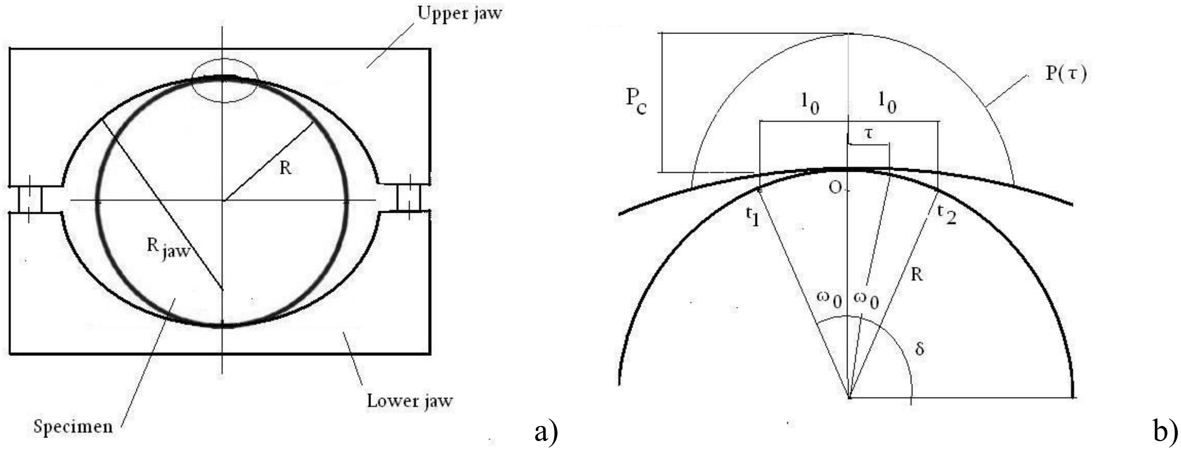


Fig. 2. a) Jaws geometry; b) The contact problem:definition of symbols and distribution of radial pressure imposed by jaw on the disc.

The displacement field can be described effectively if the grips have cylindrical shape with radius $R_{jaw}> R$, where the R_{jaw} is radius on jaw and R is radius of specimen, see Fig. 2 a. The experimental machine is composed of two linearly elastic bodies, jaw and the specimen. We assume that the contact between disc and jaw corresponds to a plane mixed fundamental problem of classic linear elasicity [2]. Under these assumptions, and using Muskhelishvili's complex potentials method for Hertz's problem, we obtain the radial pressure distribution [2]:

(2.1) $$P(\tau) = \frac{1}{3RK}\sqrt{l^2 - \tau^2} ,$$

(2.2) $$K = \frac{\kappa_1 + 1}{4\mu_1} + \frac{\kappa_2 + 1}{4\mu_2} ,$$

where κ_1, κ_2 and μ_1, μ_2 are the Muskhelishvili's constants and shear moduli of the disc's and jaw's materials. Eq. 2.1 shows, that the interaction between jaw and disc represents a radial distribution corresponding to circular arc. The actual contact angle ω_0 and actual contact length l_0 are given by:

(2.4) $$\omega_0 = \sqrt{\frac{6KP_0}{\pi R}} ,$$

(2.4) $$2l = 2\sqrt{\frac{6RKP_0}{\pi}} ,$$

where P_0 is the pressure force. However, from the Eq.2.1 it is clear that the solution cannot be obtained in closed form. Therefore an alternative distribution is used [2]:

(2.5) $$P(\tau) = \frac{\pi d}{8RK}\left[1 - \left(\frac{\tau}{l}\right)^2\right] .$$

The Eq.2.5 is statically equivalent to the Eq.2.1, see

(2.6) $$P_0 = \int_{-l}^{l} \frac{\pi l}{8RK}\left[1-\left(\frac{\tau}{l}\right)^2\right] d\tau = \int_{-l}^{l} \frac{1}{RK}\sqrt{l^2+\tau^2}\, d\tau \ .$$

In the Cartesian reference system (see. Fig. 2b) and following geometrical simplifications for small values of ω_0 can be written:

(2.7) $$P(\delta) = P_C\left(1-\frac{\cos^2\delta}{\sin^2\delta}\right),$$

(2.8) $$P_C = \sqrt{\frac{3\pi P_0}{32KR}} \ .$$

3. Experimental device

The testing device is primarily intended for split tests of core samples. The weight of testing device is approximately 25 kg, and its outside dimensions are 350x350x170 mm. Core sample should have diameter 50 mm (In fact, when using a drill with a diameter of 50 mm, the diameter of the cylindrical sample is between 47-50 mm) or 35 mm when removable jaw is used. Maximal length of specimen is 100 mm. The loading is performed by moving the lower grips upward. The lower grip is lifted by wedge mechanism. Linear movement of the wedge is implemented by screw rotation. Screw rotation is realized manually or alternatively by stepper engine. Epicyclical gear-box with transmission coefficient of 64 is inserted between stepper engine and loading screw in this case. Maximal loading force is limited by 100 kN. Loading force is registered by logger from measuring bolt. Force data are imaged by data-logger display and can be recorded by a computer in digital form. Loading displacement data are obtained directly by measuring instruments based on optoelectronics sensors and by non-directly by counting of the loading screw revolutions, both types of data can be recorded by a computer in digital form. Interchangeable jaws with different ratios $R_{jaw}/R_{specimen}$. are installed in the testing machine. The custom written software is used to control the test equipment. This software allows direct calculation of tensile strength R_T, compressive strength R_C and flexural strength R_F using data obtained from the test device, without further operator intervention.

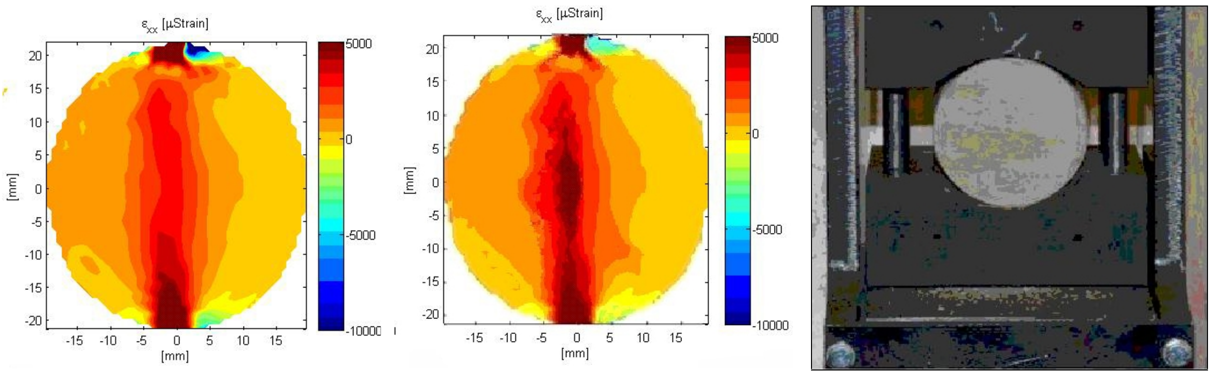
4. Experimental procedure

4.1. Digital Image Correlation

During preliminary laboratory tests, location of crack initiation was determined by the Digital Image Correlation. The Digital Image Correlation (DIC) is an optical method to measure displacements and deformations on an object surface [6]. DIC tracks the position of the same physical points shown in a reference image and a deformed image. This pairing of corresponding points is carried out automatically on the object surface marked with random distribution of point. Spacial resolution of DIC method depends on fine structure of the random pattern on the surface. This natural structure can be of natural origin o rit can be prepared artifically, for example by aerosol paint made with airbrush. The most important step in any code implementing DIC is a pairing procedure, where a square subset of pixels around around point of interest on a reference image and their corresponding location is determined on the deformed image. Once the location of the same point is determined in both images, the displacement of the point caused by loading can be calculated even up to sub-pixel. High precision calculations can be achieved using advanced computational methods [6].

3.1. Stone Testing in Laboratory

Specimens were prepared from sandstone by core drilling. The specimens were obtained in dry condition. Diameter of the specimens was 47-50 mm and length was about 70 mm. Specimens were loaded to final rupture by the portable loading device developed. Four different cases were studied: 1) flat jaw (Fig.1a) made from steel was directly in contact with the specimen; 2) notched disc (Fig.1b); 3) flatted disc (Fig.1c); 4) radial jaws (Fig.2a) with ratio R_{jaw}/R = (1.2; 1.5; 2; 3). Experiments conducted in the laboratory were supplemented with control measurements of deformation of the experimental machine frame and test specimen using laser triangulation.



a) b) c)

Fig. 3.Strain fields ε_{xx} before rupture specimen, deformation is given in micro-strain
a) ratio R_{jaw}/R= 3; b) R_{jaw}/R= 1.5; c) technical data

In the case of jaws with radius, the crack initiate in the (most probably) centre of disc. For calculation of specimens strength was used parabolic distribution of load at the contact between specimen and jaw. The best results were obtained when the ratio R_{jaw}/R= 1.5 was used, see Fig. 3.

3.2. Stone Testing On-Site

The aim of these measurements was to compare the results obtained by the portable device in the basic version, with the results obtained in the laboratory using additional measurement and control of the condition of cracks inside the body using DIC. Mechanical properties of specimen measured by portable device and control batch measured by additional equipment are compared in Tabl.1. The measured mechanical properties were compressive strength R_C , flexural strength R_F, tensile strength R_T. Tabl. 1 shows that laboratory results differs only a little from the results obtained by portable version of the test device. The difference is unimportant especially when one considers that this is a material with high dispersion of measured parameters.

Table 1. Mechanical properties of dry specimen. The indexes L- measurement in laboratory, ON – on site, measurement with transportable version of experimental device.

Stone	R_c ON [MPa]	R_c L [MPa]	R_FON [MPa]	R_FL [MPa]	R_TON [MPa]	R_FL [MPa]
Sandstone (Hořice , ČR)	15	12	1.9	1.7	1.9	1.7
Sandstone (Božanov,ČR)	23	24	4.1	3.9	3.1	3.0
Sandstone (Mšeno,ČR)	19	20	3.0	3.0	2.8	2.9

Conclusion

Experimental set-up was tested for different implementation of boundary condition by different shape of jaw. In the case of jaws with radius (ratio R_{jaw}/R = 1.5), the crack initiate in the (most probably) center of disc. It ca be concluded for the optimalization of design of jaws that the smaller, technically yet feasible ratio between the two radii yields to situation when crack initiates from the location near center of the specimen.

Acknowledgements

This work has been supported by Project NAKI DF11PØ1OVVØØ1.

REFERENCES

[1] Major Š., Jandejsek I., Valach J.,Vavřík D. Portable Device for Indirect Assessment of Strength in Tension of Building Materials and Problem of Boundary Condition, Applied Mechanics and Materials, Vol.486, 2014, 307-312

[2] Kourkoulis S.K., Markides Ch.F., Chatzistergos P.E., The Brazilian Disc under parabolically varying load: Theoretical and experimental study of the displacement field, International Journal of Solids and Structures , Vol. 49, 2012, 959–972

[3] Wang Q.Z., Jia X.M., Kou S.Q., Zhang Z.X., Lindqvist P.A. The flattened Brayilian disc specimen used for testing elastic modulus, tensile strength and fracture toughness of brittle rocks: analytical and numerical results, International Journal of Rock Mechanics & Mining Science, a1, 2004, 245-253.

[4] Fairhurst C. International Journal of Rock Mechanics and Mining Sciences and Geomechanics, Volume 1, Issue 4, October 1964, 535–540

[5] Yang, Y., Smith, L., Gothekar, A., Chen, X., 2010. Measure Strain Distribution Using Digital Image Correlation (DIC) for Tensile Tests. Technical Report, Oakland University.

[6] Hudson J.A., Brown E.T., Rummel F., International Journal of Rock Mechanics and Mining Sciences, 9, 1972, 2241–2248

PHOTOVOLTAIC WATER MANAGEMENT

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Abstracts: *There is a need to address the supply, use and disposal of water at manufacturing fascilities and it is very complex. Since solar power generations is well suited for non-petroleum industries PV manufacturing fascilities are being targeted. A primary tool for developing the water management plan is the water management diagram, where initial planning permits require estimates of water consumption and wastewater discharge. It should include offsite effluence and residuals from treatments.*

Key words: *water, disposal, water management plan, water consumption, discharge.*

1. PREPARATIONS FOR THE WATER MANAGEMENT DIAGRAM

PV manufacturers must use multiple criteria for selecting new manufacturing sites and approaches. Until recently, water supply, discharge and costs of water have not been considered much. Sites are often selected with unique water management constraints.
Many Middle Eastern nations, where water has become a critical resource, are looking to establish non-petroleum industries for the future generations, so the PV facilities are being targeted. If you want to manage the cost of water operations, as well as environmental permitting and set up benchmarks, you are going to need comprehensive water management plan for the facility or site. A primary tool for developing water management plan is the water management diagram. It should be developed early in the facility design, with understandable adjustments later on.

In the beginning planning requires estimates of water consumption and the discharge of wastewater, and measures used to reduce consumptions and recycle water internally. A water management diagram should include 1) water users with supply water criteria and characterization; 2) water sources, flows and quality; 3) onsite water treatment systems, with input chemicals, output residuals, output water and quality; 4) also, offsite effluents and residuals from treatment. The general types of information should be prepared in order to create WMD and consider some of the caveats.

2. PROCESSES REQUIRING WATER

The processes which require water include various cleaning and cooling steps. Those steps are associated with wafer sawing, wafer removal, bricking cropping and cleaning. There are also chemical make-up and rinsing which are associated with silicon reclaim, texture etching, feedstock etching and isolation etching. We should also mention processes such as glass cleaning.

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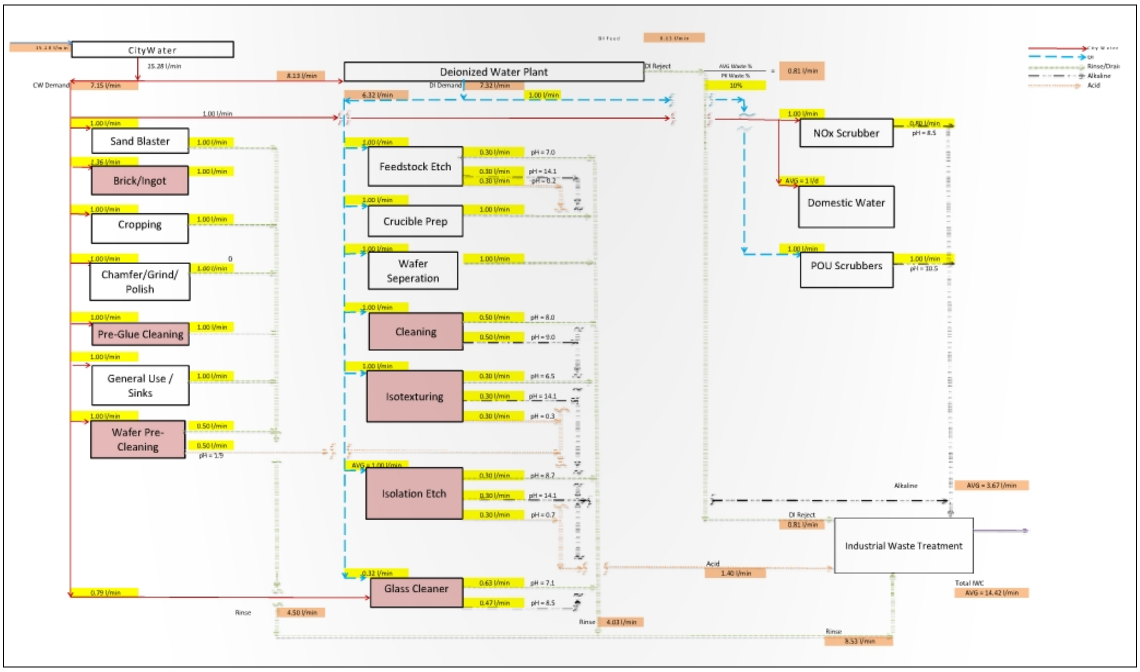

Fig. 1. WMD for a silicon PV factory

Larger plants are pursuing cost reduction practices with kerf reclaim and carbid slurry reclaim. With these included, the set of process water requirements are increasing. Each PV type process should have its rates of water quality established, and in line with the manufacturing process technology.

Water treatment system design should obtain the specific level of water quality which is required for each process in emerging PV technologies. There is a complicated resolution of the number of different water qualities required for the various processes. In other words, a project may have a combination of different manufacturing processes. The processes may come from the process equipment supplier, from internal development of the manufacturer or from the third-party process technology supplier.

The systems developed in previous manufacturing facilities are called 'city water', 'RO water' and 'DI water'. None of these three system has quality parameters which can be accepted in industry. Also, equipment suppliers do not realize that deionized water that might range from 5 to 15MΩ, for which they give resistivity specification, is not available for conventional deionization technology. Mixed bed ion exchange, when operated effectively, generally delivers more than 17MΩcm.

From a practical standpoint, the three categories of water quality which are mentioned, find their place in the PV facility design. City water is used to supply dirty processes- saw coolant, brick rinsing and front end rinsing. The steps which require a consistent supply of clean water for critical cleaning and chemical processing, can use deionized water with nominal resistivity greater than 17MΩcm. RO water is used for a few manufacturing steps. It is specified for facility support systems, because it is of intermediate quality that is hard to define in terms of specified quality parameters.

The specific criteria for water supplies should be established early in the project in order to prepare a good WMD.

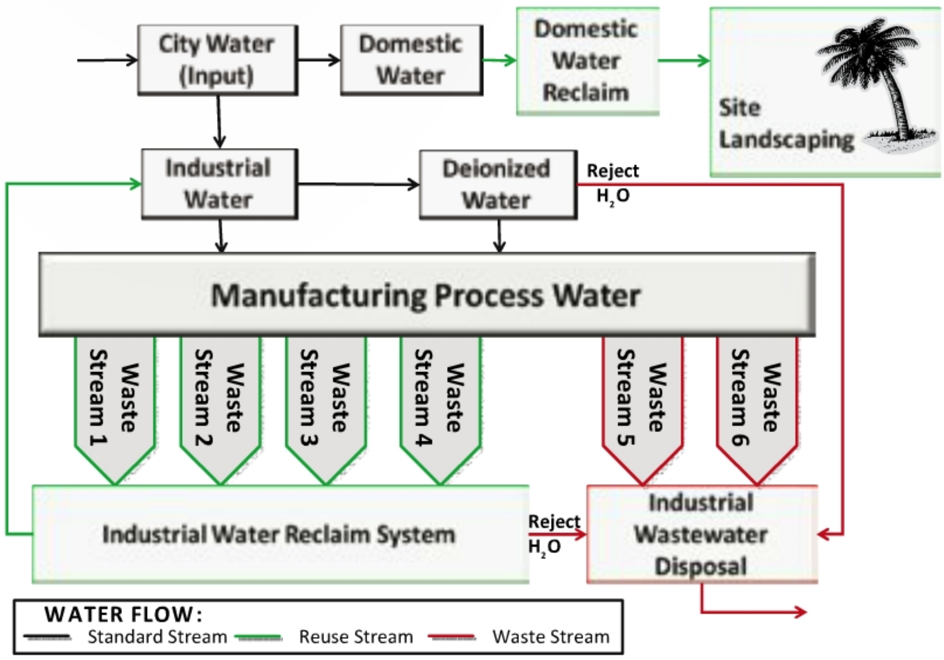

Fig. 2. Water reuse scenario for a >120MW PV manufacturing facility

3. FACILITY PROCESS SYSTEMS

A number of systems, designed to support the manufacturing process, are one step away from the direct processing of the product. These may be provided by a centralized system in the facility or supplied along with the process equipment.

One or more process exausted streams are likle to be abated by any PV manufacturing facility that utilizes vapour deposition, plating or etching processes. Air abatement may include a plant wide system with a network of collection ducts, which are distributed to multiple tools with similar exhausted contaminants, or a point-of-use system connected to dedicated tools.

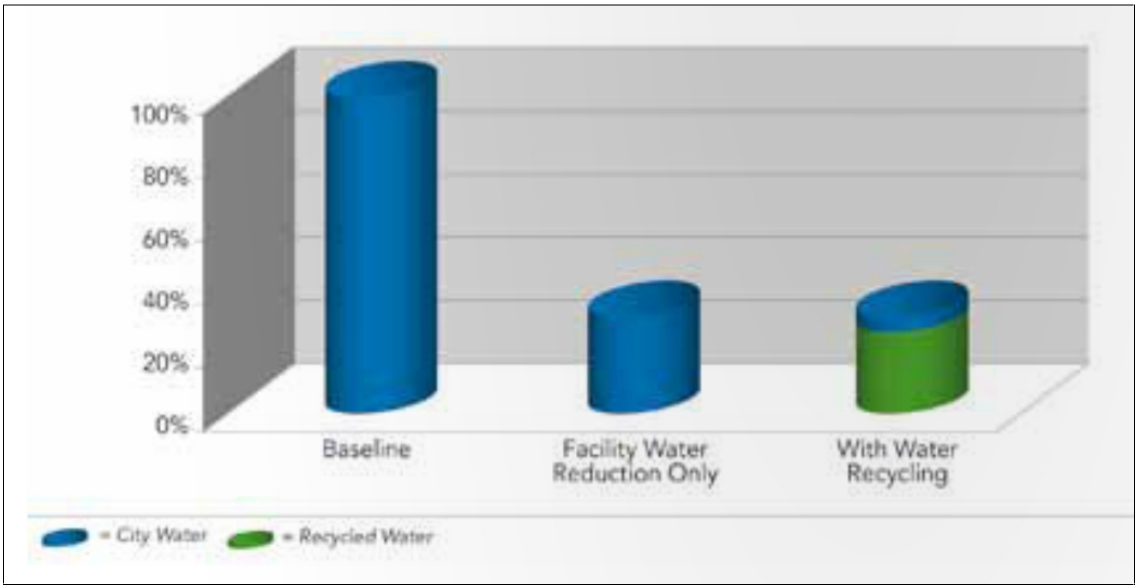

Fig. 3. Potential reduction forecast of incoming water- reduction and recycling impacts

When you use a packed-bed towers using water for scrubbing of acid and ammonia, vaporous is well understood. It provides adequate protection for most aqueous cleaning processes. The amount and quality of water which is going to be used depend on the scrubber capacity and make-up water quality. The chemicals to control pH in these scrubbers can be used and it is a common practice. However, it has its pros and cons when compared with water use, wastewater disposal and chemical consumption.

When silicon acid is done with acid mixtures (including nitric and hydrofluoric), it liberates a significant amount of nitrogen oxides-NO_χ. This requires more aggressive chemical management in the scrubber. This scrubber will have a more complex wastewater blow-down and its own make up water demand. Etching process may also produce silicon tetrafluoride. When the levels of silicon and fluoride in the NO_χ scrubber are significant, chemical consumption can be increased. So, it must be planned appropriately.

Typical deposition tools require abatement of a mixture of corrosive and flammable gases. The abatement can be a combustion chamber of a POU unit followed by a wet quench chamber. Hard water will tend to form calcium fluoride and other calcium salts because of the high level of fluoride and high temperature of this liquor. The salts deposite in the workings of the scrubber, and they reduce and clog capacity.

In order to create a proper WMD, it must be noted that wet scrubbers evaporate a continuous quantity of pure water into the atmosphere, which increases concentration of chemicals in the wastewater.

REFERENCES

[1] "Building Integrated Photovoltaics (BIPV)". wbdg.org. Retrieved 2011-07-26.

[2] buildingsolar.com: Building-Integrated Photovoltaics, Wisconsin Public Service Corporation, accessed: 2007-03-23.

[3] Desingning with solar power – a source book for building integrated photovoltaics (BIPV), editors : Deoprasad & Mark Snow

[4] Eiffert, Patrina; Kiss, Gregory J. (2000). Building-Integrated Photovoltaic Designs for Commercial and Institutional Structures: A Source Book for Architect. 59. ISBN9781428918047. 60–61.

[5] Solar Architecture – strategies visions concepts, Christian Schittich (Ed.)

[6] Henemann, Andreas (2008-11-29). "BIPV: Built- in Solar Energy". Renewable Energy Focus (Science Direct) 9 (6): 14, 16–19. doi:10.1016/S1471-0846(08)70179-3.

REHABILITATION AND STRENGTHENING OF MASONRY STRUCTURES WITH FIBER-REINFORCED COMPOSITE SYSTEM - THE ORGANIZATIONALLY- TECHNOLOGICAL AND CONSTRUCTIVE SOLUTIONS IN ACCORDANCE OF EROCUDES

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***Abstract**: The masonry structures and masonry constructive elements for centuries are one of the most widely applied in the construction of various types of structures, as in Bulgaria as well around the world. Meet masonry in housing, construction of public, administrative and industrial buildings, as well as in real architectural and historical heritage. Loadbearing masonry structures are commonly used in low-rise and medium height buildings, forming a substantial percentage of the housing fund in Bulgaria.*
Experience from numerous conducted surveys of the constructive condition of the existing buildings demonstrates the need of measures for strengthening and rehabilitation, dictated by the requirement to meet current standards for structural resistance or the desire for reconstruction and modernization of the existing masonry buildings.
This project aims to conduct experimental and theoretical study of structural, organizational and technological solutions for rehabilitation and strengthening of the elements of bearing masonry by vertical and horizontal static loading.

***Key words**: masonry structures and elements, constructive investigation, bearing capacity, strengthening and rehabilitation, FRP composite systems, Eurocodes*

1. Introduction

Masonry structures are the oldest structures ever made. The masonry structures and masonry constructive elements for centuries are one of the most widely applied in the construction of various types of structures, as in Bulgaria as well around the world. Meet masonry in housing, construction of public, administrative and industrial buildings, as well as in real architectural and historical heritage.

Masonry structures are susceptible to extensive damage followed by failure and collapse when subjected to loads resulting from man-made events and natural forces or

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disasters, as wind, earthquakes and accidents. Recent natural disasters, as earthquakes, and the terrorist acts have clearly demonstrated that the development of effective and affordable strategies for the strengthening of masonry structures and elements is urgently needed.

Entering on the design and construction practice of the regulations from the system "Eurocodes" is associated with an increase in the requirements for new build and existing masonry structures. This requires the necessity of search of advanced systems and technologies to improve the bearing capacity of the masonry, respectively masonry structural elements and masonry structures as a whole, as a response to these challenges.

On the other hand, the need for preservation, conservation and restoration of the architectural and historical heritage is are addressing to solving specific issues in repair and strengthening of masonry structures.

Rehabilitation can be defined as an action to bring a structure (or structural elements) that is deficient in design demand to the desired specific performance standard. Depending on the state of the structure and the desired post intervention performance standard, rehabilitation can be divided into two categories: strengthening and repair. Strengthening is the process of increasing of the existing capacity of a non-damaged structure (or a structural component) to a specified standard. Repair, on the other hand, is the rehabilitation of a damaged structure or structural component with the aim of recuperation the original bearing capacity of the damaged structure.

One of the entering in the global building practice advanced method for strengthening and rehabilitation, which is and an element of the recent study, is the application of the Fiber – Reinforced Polymer (FRP) composite systems.

The use of FRP materials for civil engineering applications is relatively new. However, they have been in application for a long time in other industries such as aircraft, marine and naval industries, automobile's construction and manufacturing the chemical apparatus. FRP composites have superior technical characteristics. Among these is the high strength-to-weight ratio. FRP composites are neutral electro-magnetically and electrically, non-corrosive materials and systems. In addition, some types of FRP composites are very flexible such that they can be formed almost to any desired shape, light enough to be handled on the job site with no need for heavy equipment, and they occupy negligible space as compared to the existing structural members.

The purpose of this study is to synthesize and investigate effective advanced constructive, organizationally - technological and economically viable solutions, applicable as for repair and strengthening of existing masonry, as well and in preservation, conservation and restoration of real architecture - historical heritage in accordance of current legislation in Bulgaria. It is essential to consider the principles of minimum intervention, reversibility, noninvasiveness, durability and compatibility with the original materials and structure. Diversity of applied loadbearing masonry structural elements and structures in general, suggest and finding of adequate solutions for the specific constructive and organizationally - technological problems. Generally considering these principles and criteria the best solution could be found out among a set of alternative possibilities or a combination of different techniques.

2. Eurocodes and masonry structures

The objectives of the Eurocodes are the harmonization of technical rules for the design of building and civil engineering works. Main advantages of the Eurocodes are: the harmonization of building standards in Europe; the standardization of the basic requirements and of the design concept for the different types of construction; the more flexibility in the design practice; the equalization of the safety levels in respect of the different combinations of actions, the different types of buildings and building elements; and higher allowable stresses in some cases.

On the other hand the full use of new possibilities demands: a higher level of knowledge and engineering education; an increasing amount of personal work and the availability of adequate software products.

Eurocode 6 "Design of Masonry structures": examines the design of building and civil engineering works in unreinforced, reinforced, prestressed, confined masonry; is concerned only with the requirements for resistance, serviceability, durability of structures; is not concerned with other requirements, so for thermal or sound insulation, and does not cover the special requirements of seismic design (given in Eurocode 8).

Eurocode 8 "Design of structures for earthquake resistance". Its purpose is to ensure, that in the event of earthquakes human lives are protected, damage is limited, and structures important for civil protection remain operational.

This is achieved through satisfying the following two fundamental requirements: No-collapse requirement: The structure should withstand the design seismic action without local or global collapse; Damage limitation requirement: The structure should withstand a seismic action with larger probability of occurrence than that of the design seismic action, without the occurrence of excessive damage.

As recognized in the EN 1998 document, the random nature of the seismic events and the limited resources available to counter their effects are such as to make the attainment of the above goals only partially possible and best measurable in probabilistic terms. Thus the competent authorities, the structure owner and the designer, professionally responsible for the seismic design of a project, make a fundamental trade-off between costly higher resistances and higher risks of economic loss. The extent of the seismic protection that can be provided to different categories of buildings is a matter of optimal allocation of resources and is therefore expected to vary from country to country, depending on the relative importance of the seismic risk with respect to risks of other origin and on the global economic resources.

Section 9 examines the specific rules for masonry structures. Masonry is generally considered to present specific problems for construction in seismic areas due to its poor strength in tension, weight and brittle response in tension and compression.

Table 1. Typical values of unit mass and strength for various structural materials and corresponding ratios

Structural material		Unit mass ρ (kg/m^3)	Strenght f Range of values (MPa)	Ratio f/ρ (10^{-3}MPa/kg /m^3)
Wood	Compression and tension	550	20-30	35 - 55
Structural steel	Compression and tension	7800	275 - 355	35 - 45
Concrete	Compression	2400	25 - 80	10 - 30
	Tension	2400	2 - 3,5	0,8 - 1,5
Reinforced concrete	Bending	2500	10 - 25	4 - 10
Masonry	Compression	2100	4 - 8	1,9 - 3,8
	Tension	2100	0,3 - 0,5	0,1 - 2,0

The specific problems of the seismic performance of masonry are reflecting by the low of values of ratio f/ρ, both in compression and tension. However the masonry structures may present densely distributed walls; dissipation of energy in a distributed fashion by widespread cracking (which has to be controlled either by tying or by distributed reinforcement); good robustness (if all elements are appropriately tied together).

Regarding to the Eurocodes (EN1996) the use of unreinforced masonry is recommended only for Low seismicity cases (recommended NDP). Unreinforced masonry (EN1998-1) may not be used if a_g S > 0,20 g (recommended NDP that should depend on the requirements for materials properties).

Large number of NDPs reflect and is intended to accommodate the large variety of materials and construction practices for masonry across Europe.

Table 2. Upper limits of behaviour factors (recommended NDPs):

Type of construction	Q
Unreinforced masonry in accordance of EN 1996 alone	1,5
Unreinforced masonry in accordance of EN 1998	1,5–2,5
Confined masonry	2,0–3,0
Reinforced masonry	2,5–3,0

Regarding to the Eurocode 8, the structural analysis considerate: Uncracked or cracked (recommended) stiffness (the cracked stiffness approx. 50%); Redistribution of base shear among walls; If appropriate (existence of coupling beams/spandrels) may be used a frame analysis.

Construction rules and geometric conditions, regarding Eurocode 8 required: in General: Floor continuity and effective diaphragm effect; Connections between floors and walls; Shear walls in two orthogonal directions. For the Shear walls is recommended: Minimum effective thickness - $t_{ef,min}$; Maximum height to thickness ratio - $(h_{ef} / t_{ef})_{max}$ and Minimum length to height ratio $(l/h)_{min}$.

Table 3. Geometric requirements for shear walls:

Masonry type	$t_{ef,min}$ (mm)	$(h_{ef} / t_{ef})_{max}$	$(l/h)_{min}$
Unreinforced, with natural stone units	350	9	0,5
Unreinforced, with any other type of units	240	12	0,4
Unreinforced, with any other type of units, in cases of low seismicity	170	15	0,35
Confined masonry	240	15	0,3
Reinforced masonry	240	15	No restriction
t_{ef} - thickness of the wall (EN 1996 - 1); h_{ef} - effective height of the wall (EN 1996 - 1-1); h - greater clear height of the openings adjacent to the wall; l - length of the wall			

3. Scope of the experimental study

This experimental study aim is to conduct experimental and theoretical investigation of structural, organizational and technological solutions for rehabilitation and strengthening of the elements of bearing masonry by vertical and horizontal static loading.

The aim is with the obtained results to assess the effectiveness and applicability of the advanced FRP composite materials and systems for strengthening and rehabilitation of existing masonry structural elements.

The dimensions of the specimens will be designed, regarding the specifics of the behavior of the masonry elements in existing structures.

4. Aims and objectives

The main objective of the research is to: investigate the failure mechanism of un-strengthened and FRP strengthened masonry walls and columns; investigate the possible ways of application of near surface mounted and externally bonded reinforcement FRP materials and systems; investigate the behaviour of epoxy resin; to analyze the both flexure and shear strengthening phenomenon; analyze the better application geometry and configuration and possible outcome received from the past and recent experiments. The effectiveness of different FRP layouts subjected to different kind of impacts (vertical and horizontal static loading) will be critically analysed. The field where further research is necessary will be localised.

5. Methodology

To carry on this experimental research a lot of investigations of the old masonry building fund in Bulgaria had been studied, as well and worldwide scientific experience in strengthening and rehabilitation techniques. Their principal outcome has been extracted and the general problems have been identified. Also some of their experimental results have been more elaborately analyzed and good practices are reviewed. In some cases, it is seen that different researchers did their study in a particular field and got same type of result. Those outcomes are highly marked.

6. Description of the proposed experimental study and the possibilities for its application

It is envisaged the preparation of a group of samples representing different masonry structural elements (walls and columns) made from unreinforced masonry with clay bricks. Masonry elements will be loaded to the level of the computational loads, which aims replication of the existing masonry structure. After their strengthening, the experimental samples will be tested until destruction, with wich will be followed their constructive efficiency.

With this experimental study will be examined and organizational and technological aspects of the different variants of strengthening and rehabilitation of masonry structures and elements. This study will be assessed the cost effectiveness of the solution adopted for the strengthening and rehabilitation based on adduced specific costs.

Conclusions

The general condition of the buildings fund in Bulgaria, entering the higher requirements of the Eurocodes impose the need for searching advanced and effective in constructive, technological, organizational and economic aspects methods for strengthening and rehabilitation and require an intensive scientific - applied research in this field of civil engineering practice.

REFERENCES

[1] Ordinance № RD -02 -20- 19 of 29 December 2011 for structural design of buildings through the application of the European system for the design of building structures;
[2] Ordinance amending and supplementing Ordinance № RD -02 -20- 19 of 2011 for structural design of buildings through the implementation of the European system for the design of building structures;
[3] BS EN 1991-1-1:2002 - Eurocode 1: Actions on structures. Part 1-1: General actions. Densities, self weight, imposed loads for buildings;
[4] BS EN 1996-1-1:2006: Design of masonry structures. Part 1-1: General rules for reinforced and unreinforced masonry structures;
[5] BS EN 1996-1-1:2005 - Eurocode 6: Design of masonry structures. Part 1-1: General rules. General rules and rules for buildings;
[6] BS EN 1996 - Eurocode 6: Design of masonry structures. Part 2: Design considerations, selection of materials and execution of masonry;
[7] BS EN 1996-3:2006 - Eurocode 6: Design of masonry structures. Part 3: Simplified calculation methods for unreinforced masonry structures;
[8] BS EN 1998-1:2004 - Eurocode 8: Design of structures for earthquake resistance. Part 1: General rules, seismic actions and rules for buildings;
[9] BS EN 1998-1:2004 - Eurocode 8: Design of structures for earthquake resistance. Part 1: General rules, seismic actions and rules for buildings;
[10] EN 1998-3:2005 Eurocode 8: Design of structures for earthquake resistance – Part 3: Assessment and retrofitting of buildings;
[11] EC Carvalho, Chairman TC250/SC8, EUROCODES, Background and Applications Eurocode 8, Timber and Masonry structures, Brussels, 18-20 February 2008 – Dissemination of information workshop 1;
[12] G. Solomos, A. Pinto, S. Dimova, A review of the seismic hazard zonation in national building codes in the context of Eurocode 8, JRC Scientific and technical reports, European Communities, EUR 23563 EN – 2008;
[13] Petar Sotirov, Nicola Ignatiev, Daria Mihaleva, Ivan Pavlov, A Practical Guide to solved examples of the application of Eurocode 8-1 - Design of structures for earthquake resistance;
[14] Elena Vaseva, Nicola Ignatiev, Daria Mihaleva, Ivan Pavlov, A Practical Guide to the solved examples of the application of Eurocode 8 - Part 3;
[15] Nisimov D. Haskia, Masonry structures: Bearing masonry structures (manual) , Technika, Sofia 1986;
[16] Nisimov D. Haskia, "Masonry and masonry structures", Technika, Sofia - 1961;
[17] Regulation 2 for the design of buildings and structures in seismic areas.

V. SUSTAINABLE CONSTRUCTION. ENERGY EFFICIENCY. NET-ZERO ENERGY BUILDING. ENVIRONMENTAL ENGINEERING AND ENVIRONMENTAL SECURITY

PARADIGM SHIFT IN THE DEVELOPMENT STRATEGIES OF FUTURE CITIES

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***Abstract**: We are currently witnessing the multiple paradigm shifts in all areas including the urban development. Models, strategies, concepts adopted to present have discovered their imperfections/flaws. Models, strategies, concepts adopted to present their imperfections and researchers in the field trying to refine/ improve/change. The concept of urban resilience is a recent concept introduced into the conception/management/exploitation/control policies of the urban utilities systems but especially into the risk management policies in the case of possible disturbances. This is structurally different form the concept of urban sustainable development, which can be completed with aspects regarding risk management associated to different possible disturbances. Within the paper, the two main concepts of urban development are mainly presented; the way in which these may be implemented in order to contribute to the sustainable and flexible development of the urban systems is analyzed. Also, there are proposed, at conceptual level, new concepts, more suitable for modeling urban development.*

***Key words**: new urban development paradigms, urban durable development, urban resilience*

1. Urban systems

„The city", complex form of human establishment, with variable dimensions and multiple functions (political-administrative, industrial, commercial, cultural, etc.), with a functional-constructive-organizational-political structure extremely complex and in a continuous dynamics, dependable on the *situs* where it is located and with major influences on it, will become, according to some forecasting specialists, the major administrative form in the future (ONU)[5].

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[5] *The process of urbanization has exceeded the level of 50% and the urbanization rate is still increasing (70% in 2050).*

The process of urbanization is practically a dynamic, complex process which takes place at different spatial and temporal levels (Alberti et al 2003). This is equally a social phenomenon and a physical transformation of the area/landscape[6] afferent to the city determining the relation of the humanity with the Biosphere (IHDP 2005). The urbanization processes and their outcome on the environment and human development are not fully known/studied (McGranahan et al, 2005). For this reason, studies and programmes for a deep analysis of the urban systems have been initiated, as desirable directions of evolution, mechanisms, appropriate strategies and possible politics to be applied on this field.

The science of the study, approach and development of the urban systems has become pluri-disciplinary, cross-cut and integrated approaching, based on the system theory all the determining aspects, internal connections of the systems (from its multiple and different components, horizontally and vertically) as well as between it and the environment.

The city/ *the urban system* may be composed through an open complex dynamic system model, formed by a diversity of sub-systems (utility, social, political, administrative).

Concepts of urban development have been underlain and laid down, but none of the proposed concepts has the global concept feature, integrative and generally valid.

However, from these, the concepts of sustainable development have drawn the attention of specialists, and very recently, the concept of urban resilience, concepts which through an appropriate use and together with their implementation may be a solution for the directing of the urban development.

2. Major directions for urban development. Concepts. Characterization

2.1. The concept of "sustainable development"

It has as general objective *„do not compromise the development of the future generations", simultaneously observing the correction of the consequences of an unequal development within the regions.* The sustainable development consists on the implementation of the objective principle of *interdependence* and a normative principle of *spatial and temporal equity* [2][7]. Searching the sustainable development and respectively promoting the concept valuable, moral judgments on the desired objectives, targeted territories, chosen time scales are imposed. Consequently, within the dialectical analysis process of the concepts of sustainability and disturbance it cannot be concretely emphasized what must be done and the way it must be done, as pursuant to the considerate reference time scales (long or short term) and the values which are implemented. The appearance of the sustainability concept coincided with the appearance of "risk society" but "risk management" is not an major objective for sustainable development [3]. The application of sustainable development concept within the urban development does not have answers to several dynamic aspects regarding the systems evolutions and their media. The concept does not have principles to overpass the problems regarding the breakdown and instability and includes problems regarding uncertainty referring to future necessities and evolutions of environment background.

Therefore, *the development may be sustainable during crisis time, if human and goods protection is a priority, without observing the economic or environmental consequences.*
$\Rightarrow$ *In uncertain and emergency cases, the sustainable development does not have an object.*

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[6]Within the process of urbanization it has been accomplished until now the most complex mosaic for the land covering the most different solutions for their use have been experimented, with major consequences on the environment and more and more accessible to the global climatic changes.
[7] The concept is the emanation of anthropocentric[7.1] philosophical thinking and consequently it is characterized by a certain level of subjectivism.
[7.1] Idealist philosophical conceptions, according to which "the man is the centre and the objective of the universe".

If the sustainable urban development is considered, the complex approaching of all interest aspects is imposed: physical, economical, functional, social, and political: ⇒ *the city cannot be sustainable within the actual administrative limits*. If within the sustainable development principles the physical environment is considered as being the base of a human development, within urban development, the accent is on the society development, therefore, this bases entirely, and sometimes very much, on its environment (closer or further) in order to answer the served population needs: water, energy, lands, primary materials, etc. In this case the urban sustainable development is a purely theoretic concept or a technical utopia [4], through which an ideal may be defined, a target to which an iterated way may aspire. ⇒ „*The sustainable city*" may be considered at most a *prospective referential* [5], in relation with the cities which try to develop / evolve through social continuous transactions between actors and dedicated projects [5]. The results of negotiations become in this way targeted objectives (normative and moral). These may be defined by a set of indicators referring to life quality, environment, economic competitiveness, social justice, territories activity, externalities, and the materialization of those objectives long - term designed, cannot be accomplished unless the conditions and the management methods of different possible disturbances are provided which have as result: interactions between uses, some of them being in contradiction; fluctuations of resources necessary for their functioning; fluctuations of the environment.

2.2. The Concept of *"urban resilience"*

2.2.1. The concept of "resilience"

The resilience[8] is a theoretical concept which has its roots in material physics[9], but which has been developed and enriched[10] to the level of *meta*-concept → Resilience.

It is differently defined, according to the observed problems, or as:

- an "umbrella-concept" [6]
- a "limit object-field" [7]: state and process which lead to this.

It may be expressed through different *specific indicators* or with *global* nature [1].

2.2.2. The increasing of resilience

A feature of many existing systems is that their resilience may be generally increased in specific situations from their existential *curriculum*-ul: beginning/s; prevention, initiation installment accumulation of some stresses; „*histerezis*-es"; expected & unexpected events, exterior from the system: natural disasters, accidental shocks, etc.

The increasing of the resilience (stability, return; function: sustainable) different *tehné-bio-socio*-ensembles is favored by some aspects, behaviors/generated structures, observations, special factors/particulars. The increasing of the resilience of the considered system: is expressed by: *a. parameters; b. functional relation; c. appropriate modeling* of the system.

2.2.3. Urban resilience

Within the concept of *urban resilience* a multiple ensemble of urban environment specific problems is observed (urban planning, architecture, engineering, economics, geography, sociology) as well as the necessary methodology for their approaching. In the case of a high level of uncertainty, the science does not have the ability to offer the

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[8] Ethimologically speaking, the word "resilience" has its roots in the latin verb "salio, -ire" meaning "to jump". The verb received the prefix "re-", also with latin origin, meaning "back". According to the ethimilogical dictionary (Harper, 2010), the term dates back in 1620 and heas the emaninig of "to jump back".

[9] *Mechanical resilience*: caracteristic measure for material behaviour for shock impacts.

[10] *Metamorphosis (*definition; application) its *paradigma is interesting*: *in theoria, in praxis' in qualitas, in quantitas.*

deciders the practical and scientific input factors in order to apply their policies. In this case, the permanent exchanges and the co-construction of knowledge and decisions are post-normal science fundamental elements, which should benefit from a cross-cut and creative concept [8]. However, the notion of resilience *favors the exchange and innovation*, when it may favor different vague aspects, leading to a certain lack of strictness which may reduce its use.

In this case, *the urban resilience is* defined as being:

- *the ability of urban system to absorb a certain major disturbance and to recover its functions after its manifestation,* respectively
- *a feature (native/achieved), which points out a variety of characteristics sometimes in contradiction[6]: redundancy, diversity, adaptability, interdependence or connectivity, flexibility, so on*.[11]

If, generally speaking, the final objective of any system is that to maintain its functions, the accomplishment of this objective is made several times within the disadvantage of other systems which they interact with, case in which we may state that the development has not been accomplished in a sustainable way. The development may be sustainable if the systems have self-adjustment mechanisms, but their intervention may lead to the decrease of individual resilience.

Therefore, at a spatial level, the concept of sustainability is wider than the resilience which, may be considered as a native and/or achieved feature of any system, respectively as a descriptive measure.

On the other hand, the application of the concept of resilience at a micro level, respectively at lower time scales leads to the definition of some specific resilience, while the application of this concept at a macro level, respectively at higher time scales leads to the definition of global resilience.

For improvement the resilient potential of urban systems it is necessary and possible:

- the accurate definition of the urban system: including its components as many as possible[12];
- the identification of different components of meta-concept of resilience, with applicability within the urban structure field;
- prospective approaching, respectively operational;
- the proposal of a more operative definition for the notion of resilience as[13].

The increasing/improvement objectives of the urban resilience may be achieved:

- *on short-term*, using a strategy:
  - Limiting the level of disturbance of technical systems based on a very good ability to resist and absorb;
  - Organizational, which may observe the return to normality as rapid as possible[14];
  - Maintaining the functioning in fault condition[15]: the three increasing mechanisms of the resilience form a so-called resilience triangle.

    $\Rightarrow\mathcal{R}$= ability of subsystems (service, activity, population, etc.) to answer to a disturbance.

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[11] This definition is sometimes connected to the maintaining processes of functionality, being associated with the sustainable development but, delimitating by these when the maintaining is accomplished without considering the external systems.
[12] Inhabitants, activities, infrastructure, population, administration, neighbors, resources.
[13] A feature of urban system, based on its characteristics and its translation in appropriate indicators, which may allow the development of some instruments and methods for intervention – control and decision (activated by the actors of the city) appropriate for the implementation of the process of resilience improvement.
[14] Through an optimal management of the methods and resources and a good accessibility.
[15] The function is partially achieved or at a lower performance level.

- *on long-term,* through a continuous improvement process[16] which has as objective the increase of the specific resilience using the systems own ability to learn and adapt using at least one of the three indicators mentioned above.

  ⇒ $\mathcal{R}$ = *ability of urban system in ensemble as to maintain its main functions.*

A possibility to logically implementation of the two concepts is that the durability is seen as a utopic ideal and the resilience as a feature of the systems. This approach allows the study of the possibilities to change the ideal course in comparison with possible social – economic changes, especially for the urban systems in transition.

Practically, "the improvement of the urban resilience increases the change of a sustainable development in a changing environment where the future is unpredictable" (*Annex 1*). The differences between the resilience and sustainable development are: *a. the resilience concept* is: universal; objective and descriptive; on long and short term; a method; *b. the durability concept* is: anthropocentric; subjective and normative; on long term; finality.

3. A possible global and complex concept of urban development

City/urban system, is a "living organism" with its own organs, functional networks and its metabolism. Its structure is complex. It interacts with its environment by multi-channel (resources, natural events, etc.) and in multiples ways. It is in a continuous change/budding but at the same time, it must keep developing. Development concepts discussed so far are not sufficient to define the model of urban development.

A holistic approach, integrating the new paradigms (Tabl. 1) at a functional level and the human evolution principle would allow capturing as many aspects, essential for urban development.

And as, human evolution is performed in multiple ways, horizontally and vertically through the accumulation and jumps (fig.1), aiming to prioritize spiritual evolution [4], gradually increasing levels of spirituality more efficient, so, the city must be associated with a development model with dynamic jumps, horizontal and vertical specific quantified by the interconnections between man spiritualized available. The spiritual evolution of Man, governed by spiritual intelligence, the need for deeper meanings, core values, goals higher and at the same time, they are the gateway to the objectives pursued, but the concept can be extended to the community and the city as an organism alive.

Annex 1

May be admitted that (Strunz, 2012), the durability is a normative target/objective concept and the resilience is a descriptive concept which allows the understanding of the system evolution processes, which can or cannot reach the initially established objectives. Therefore, the resilience may be conceived as an operational step which offers answers to a part of the sustainable urban development problems and especially to the integral management of the complex urban system, as a consequence of the adopted systemic approach.

The approaching of urban development based on the concept of urban resilience above defined, allows the reconstruction after a disaster but also the sustainable extension and recovery, providing the best resilience of the urban system to possible disturbances predictable or inevitable. In this way the rupture phenomena, state sudden changes or the collapse may be avoided. In the approaching of urban development based on the concept of urban resilience, a great potential for the improvement of the resilience is offered by the urban services.

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[16] Has as objective the increase of the specific resilience using the system own abilities to learn and adapt using at least one of the three implementations of sustainable development.

Table 1. Elements of the emerging Work Paradigm

Old Paradigm	New Paradigm
Newtonian	*Quantum*
Body≡machine	*Body≡*
Hierarchical control	*Networking*
Structure	*Processes*
Chief	*Facilitators*
Action	*Increasing*
Learning	*Human Relations*
Capital increase	*Interaction*
Human Resources	*Share*
Technological	
Market share	*Share*
Stability	*Resilience*
Conquest of Nature	*Harmony with*
Either/or	*yes-and*
Statique	*Dinamique*
Left Brain	*Whole Brain*
Mechanistic language	*Organic*
Persuasion	*Mutuali*
Dependent/Codependent	*Interdependent*
Serve Self	*Serve Self, Other*
Masculin	*Mascuin with*
Take and Cajole	*Give and receive*
Conformity	*Originality*
Linear only	*Linear and*
Logic	*Logic and*
Sell	*Serve*
Additive	*Emerget*
Plan	*Plan and*
Unknown is to be	*Unknown is to be*
Finite play	*Infinite play*
Head	*Mind, Body,*
Skip and Separation	*Convergence and*
Interesting	*Fascinating*
Survive	*Thrive*
Fear waves	*Ride waves*
Outside-in	*Inside-out/*
Deny shadow in system	*Us shadow as*
Transactional	*Transformational*
Obligated	*Inspired*
Cooperation	*Co-creation*

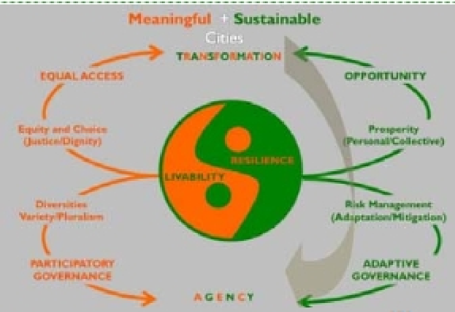

Fig.1. Susenably+Resilience urban development [8]
(created at the MAS-initiated and Rockefeller Foundation)

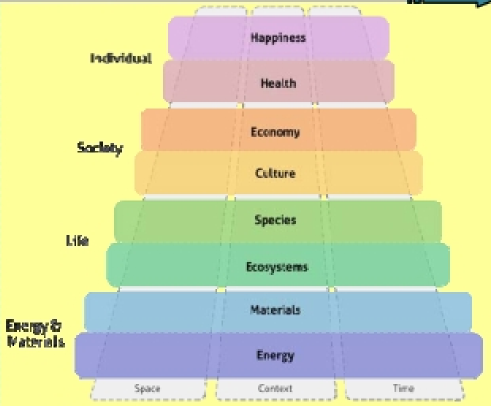

Fig.2. Holistic aproche+Simbiosis in development+…[7]

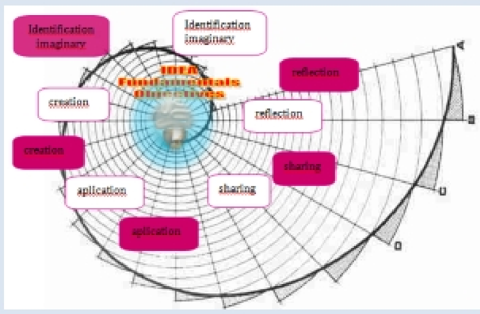

Fig.3. Spiral urban development [4]

Several paradigm changes resultant in urban development:
- *Electric energy generation systems : centralized→at local communities level*
- *Rain water management:*
- *centralized→locally*
- *Water management: separatedly (water supply system; sewage system) →integrated.*
- *Utilities control: separated →integrated;*
- *…*

Table 1. Elements of the emerging Work Paradigm

Conclusions

The sustainability concept limits impose the introduction of the concept of urban resilience in order to operationalize the urban sustainable development.

The delimitation between the two concepts of urban development is not obvious. In order to transpose in practice the concept of urban resilience its normative and descriptive foundation is necessary.

Defining the concept of urban resilience, a practical approach for the improvement of sustainable development of urban systems, is proposed.

It is time to pass to another concept of urban development, balanced, and based on an evolutional concept more complex. Example: evolutional spiral, which should have a target, an organizational structure, controllable through the quantity of accumulations and jump.

REFERENCES

[1] Sofonea L.A., M. Cozma, V. Cotorobai, E. Helerea, Meta-conceptul Rezilienţa: Aspecte tehnice-tehnologice, astro-nomice, biotice, etno- logice, sociale, politice, militare, medicale, axio-logice; epistemo-logice, istorio-logice. O organigramă.

[2] Cotorobai V. ş.a., Sisteme de gestiune integrată a apei, Conferinţa de Instalaţii pentru Construcţii şi Economia de Energie, Iaşi, 1998.
[3] Danah Zohar, Autor: Ian Marshall, Spiritual Inteligence, Bloomsbury Publishing PLC (288p) ISBN 978-1-58234-044-9, 2011.
[4] Cotorobai V., Sustainable development of the urban systems and urban resilience ⇒ the city of the future., Internaţional Conference, 2014, Chisinau, Moldova Republic;
[5] D. Rossetti di Valdalbero, European Commission, DG RTD* Global Europe 2050 and EU Resilient Cities, 7th European Conference on Sustainable Cities and Towns, Geneva, 2013.
[6] Barnett G. X. Bai, Urban Resilience, CSIRO Sustainable Ecosystems, 2007.
[7] Tom Bosschaert, Sustainability innovation framework, Symbiosis in Development (SiD), Except Integrated Sustainability, 2013.
[8] Rowe M., Urbanophilia and the End of Misanthropy: Cities Are Nature, Awareness, Comunities, Design, Livability, Networks, Resilience, Wat is urban nature?
[9] Jacob J., The Natura of Economics, Random House, 2000,
[10] Limpton B., The Biology of Belief – Unleashing the Power of Consciousness, Matter & Miracles, 2005

MINIMUM-INVASIVE ENERGY RETROFIT APPROACHES FOR OWNER COMMUNITITES IN RESIDENTIAL BUILDINGS

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***Abstract**: The main goal of the presented project is the development of a planning process and tool for the sustainable energy supply of residential multi-ownership building blocks.*
The Fraunhofer-Institute for Building Physics IBP is developing a toolkit that will, overall, provide a step-by-step guide to retrofitting multi-occupancy buildings, including all relevant resources, guidance and information. The outputs of its work will provide a comprehensive ‘one-stop-shop’ resource for households, building managers and energy agencies to negotiate the complexities of retrofitting multi-occupancy housing.
As a final step of the process, a catalogue of the needed measures is being formulated, in order to offer the optimal planning and implementation course for the building complex, noticing all of the relevant stakeholders. The expected result is an intelligent flexible energy efficiency improvement process, which should be applicable in many other different cases.
Meanwhile intelligent solutions for the residential buildings energy supply are omnipresent, however their use is hindered frequently: mostly not by technological hurdles, but by complex stakeholder constellations and objections. The envisaged method aims to implement an enabler for such sustainable energy supply of settlement complexes via delivering a reliable decision basis. It combines technical, juristic and economical topics, in order to offer a strong tool – a solution for project developers, engineers and each other type of stakeholders in the intelligent planning process. A sustainable building and spatial development is possible!

***Key words**: energy efficiency, (historic) apartment blocks, multiple ownership, integrated retrofit concepts*

1. Introduction

Multi-occupancy houses with large amount of residing single owners inside are a great challenge regarding to common energy retrofit actions and finding strategies for their further sustainable operation. This phenomenon promises to be active for a long time, as long as the discussion about their energy efficient renovation is active as well. Frequently, it is difficult to bring the various ownership interests to a common decision for the implementation of common retrofit measures. To continuously improve the energy

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efficiency of multi-family residential buildings in the coming years, our research team has initiated a research project on this topic.

In order to always be able to achieve such kind of an agreement within owner communities, a guiding toolkit is being developed. It should help all the involved "project actors" to explain the possibilities and opportunities of energy efficient renovation and to develop a catalogue of meaningful and cost effective measures for the specific building. Mostly, caused by the needs in the complex residential structure inside the owner community, a package of individual minimal invasive retrofit measures has to be developed. First of all, in this case a minimal financial volume is to be invested to facilitate a common agreement.

The experience in the field of working with owner communities has shown, that comprehensive energy retrofit actions, planned to bind the most of the owners in a multi-occupancy multi-single-owner houses, mostly do not get realized in the practice. Firstly - because of their high price and secondly - because of the resulting need to take common decision regarding the retrofit actions.

A very important aspect of the project is the monitoring and investigation of the moisture in the researched buildings, because it's level determines the healthy indoor climate.

A part of the project actions is subsidized by the EU-IEE.

2. Study

Regarding to the main goal of the project – to investigate as much as possible representative multi-occupancy ownership buildings, the chosen demonstrative case studies represent the residential building era of the 50s, 60s and the 70s, which buildings accommodate a large part of the urban society in Germany.

2.1. Description of the actions and the case studies

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2.2. Demonstrational case studies

Aachen

The case study Aachen consists of 60 flats. Built in 1970, the building is a typical representative of its age: low total energy standard, by having following problems:

- Non insulated inner walls between the flats and the staircases
- Large glass surfaces in the staircase area
- Non insulated cellar ceiling
- Non insulated roof rooms

The social structure of the object doesn't enable fast and huge common retrofit actions: the average age of the owner communities' members is over 65 years. This fact justifies the low financial power and the low decision ability of the owner community. The property manager company, responsible for the object, manages to act adequately regarding to the daily needs. But starting a discussion about any further common energy retrofit actions causes massive internal difficulties. Not only owners, but also some younger tenants reside in the building complex. Those have different needs, which fact is caused by their different lifestyle – short active phases at home, long sleeping phase and a longer absence phase in their daily schedules. It causes difficulties, for example, when the housekeeper sets the heating and hot water system.

Normally it has an active Phase in the period 06:00 – 22:00 and a night-time setback, which responds to the typical needs of working residents. But the older residents, mostly retired persons, do have longer evening-waking-periods (often till 01:00 am, according to some statements of interviewed owners and property managers during the project) and later awakening times (08:00 am). For setting a meaningful energy-saving working schedule for the heating and hot water system, there should be a night-time setback for heating and hot water for at least 5-6 hours. But in this specifice case it durates only 4 h.

But not only the daily schedule, also the different comfort sensibility levels determine the complexity of defining a common heating scheme for such a building. Both of those arguments lead to the conclusion, that a highly individualized energy retrofit action package may be the best solution. It contents indoor insulation, micro thermal component activation of problematic areas, individual heating control and decentralized ventilation with heat recovery would be the right answer to this case. All those could be implemented without running the process of a common decision making within the owner community for saving energy costs.

This measure package could be used almost in a similar way for both the other demonstration objects.

Fig 1. Case Study in Aachen. Google Maps 2013.

Berlin

The investigated object in Berlin is an architectural monument and was designed by the famous German architect Hans Schwippert especially for the International Building Exhibition IBA, built 1957 in the representative Hansaviertel in Berlin. Its characteristic two-story flats and the resulting high-ceiled corridors are equipped with large balconies and glass surfaces. The inefficient A/V-correlation, the huge window surfaces and the non-insulated façade are planned and built according to the building standards of the 60s. The whole external facade surface is protected by the monument regulations and cannot be changed. Indoor insulation, individual climate control system and central heating station optimization are the possible retrofit measures here.

Fig. 2. Case study in Berlin. Wikipedia 2013.

Bonn

The demonstration case study in Bonn is built in th 70s of the last century and is a typical representative of its age: huge window areas, poor insulated concrete façade and an oil boiler heating system. Its owner community consists of about 60 households, mostly the former inhabitants from the time the building complex was erected. As a logic consequence of this fact, the financial budget for eventual common energy retrofit measures is minimal.

The actual credit and subsidy conditions in Germany are not suited to help much the owner community to reach the actual energy efficiency levels.

Regarding to the conditions of its building substance, an improvement of the thermic shell, the glazing and the implementation of an intelligent climate control system would be needed.

Fig. 3. Case study in Bonn. Bing Maps 2013.

2.3. Social aspects and goals of the project

There are several main investigated social phenomena, which determine the user behavior and the social characteristics of the investigated owner communities.

They are:

- Ownership structure: owner or tenant or a combination
- Residents' age
- Size of the households
- Educational/professional profile
- Business profile
- Length of the residential period in the house

Most important of the factors, predefining the user behavior of the residents in the investigated building type regarding to the energy efficiency, is the ownership situation in every single flat. The experience shows, that mostly renters (in this sense investors), whom one or more flats belong, are interested in energy retrofit initiatives. On the annual owner community meeting at an investigated object in Bonn could be observed, that this type of residents showed a strong interest for energy retrofit actions of any type. They are followed by the tenants and on the last place – the owners. This phenomenon is caused by the age group they belong to. The tenants are mostly young or middle aged persons and families with an active lifestyle, who are also mentally open for innovative energy retrofit actions. The owners, very often former residents from the time the investigated building was built, do not prefer to pay attention to the energy efficiency and any deep renovation actions in their flats or in the façade area. The reasons for it are to be searched in the financial and psychological area.

The understanding about energy efficiency, its meaning for the society and the nature strongly depends on the educational level of the residents. Owners and/or residents with a relatively low educational basis do not realize any of the possible benefits of an energy retrofit action:

- Reduction of the energy costs;
- Positive development of the indoor comfort rate;
- Positive consequences for the building substance in the case of adequate retrofit actions, extending the building lifetime;
- Positive environmental effect, caused by the reduced amount of primal energy usage

A highly important factor, determining the possible energy retrofit actions, is the presence profile of the residents. The younger residents, mostly tenants and working persons, have a much more active lifestyle than the elder residents, mostly owners. So the younger residents wake up at 5 or 6 a.m., go to work at 8 a.m. and get back home at 6 p.m., going to sleep at 10 p.m.. In comparance to this scheme, the elder residents, mostly already retired, have a very long waking-phase: from 7-8 a.m. till 1 a.m. So the usual timing settings for the heating and hot water facilities, which normally have night-time setback, do not fit to those houses, because one of the groups, mentioned before, would be discriminated by not having hot water or heating a the right time. Therefore the facilities and/or systems should have a night-time setback phase. In this case an individually regulated heating system should be implemented, in order to reach an optimal effect for all affected residents.

The last of the mentioned factors, important for the energy efficiency behavior of the residents, is the actual occupancy period of the specific household or the household community. The longer the residents already have lived in this building, the less they are prepared to "give up" their home and its design, in order to improve its energy efficiency.

One of the main findings of the project is, that energy retrofit actions, bringing a reinvest to their owners and/or investors in maximum five years, are most possible to get realized by the owner communities. There are some reasons for this conclusion:

- If the residents are in the age range of 65-70, they are not prepared to do any massive investments in their home, because of their financial situation and their life expectance.
- The energy retrofit investment models, durating longer than five years, are often based on exaggerated energy price expectations, which are not always realistic. So the investment result is not always the expected one.
- The bank institutes, helping households or owner communities to retrofit energetically their buildings, often do not accept too long periods of repayment, especially when a huge contingent of them are more than 70 years old.
- The subjective expectation of the owners, that an innovative action should show its financial benefits in a short period of time after the investment, is a very important motivation factor, as well. So the effective energy retrofit measures should be reinvested in a short time, in order to proof their practical monetary efficiency.

2.4. Technical goals and measures

Possible individual minimal invasive energy retrofit measures, not needing common decisions to be taken from the majority of the owner community, nor any costly measures:

- installation of an indoor insulation
- decentralized ventilation with heat recovery
- individual intelligent heating/lightning control system
- installation of local low-energy-consumption heating wires at the hygrothermic problematic spots: thermal bridges, outer corners, window periphery etc.,
- activation of passive climate control elements, mostly in order to adsorb the water vapor peak volumes, like for example humidity buffering plasters

2.5. Motivation factors for energy retrofit in the investigated type of buildings

The motivation for energy retrofit measures in multi-occupancy ownership buildings in Germany is based mostly on the financial motivators, not on the idea for a “green life”. That is why the indicators for saved energy here, as well as the energy savings calculation methods, are mostly monetary based, and not on the CO_2 savings.

3. Further goals of the project

By implementing individual energy retrofit measures in multi-occupancy ownership residential buildings, a multiple danger of building substance and health damages exists, especially because of the variety of humidity transport regime conditions in every retrofitted apartment. Regarding to this prediction, several complex 3d-hygrothermal simulations are to be done. After the simulation phase, a real-time monitoring of the project demonstration objects should be realized.

ENVIRONMENTAL IMPACT OF A REINFORCED CONCRETE BEAM: A LCA CASE STUDY

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***Abstract**: Due to the consumption of significant amounts of non-renewable energy and raw materials, the environmental impact of the construction sector has nowadays become an important challenge in modern society. Of all the stages of a structure's life cycle, the extraction and processing of raw materials and the manufacturing of the construction materials account for the most negative ecological impact. All the materials used in this sector have a certain environmental impact, but concrete is regarded as a special case, as it is one of the very frequently used construction materials worldwide. The aim of this paper is to analyse the environmental impact of a reinforced concrete (RC) beam from a cradle-to-gate perspective by conducting a Life Cycle Assessment (LCA) study.*

***Key words**: environmental impact, construction sector, reinforced concrete beam, life cycle assessment.*

1. Introduction

Out of all economic activities, the construction industry is considered to be one of the most polluting. This sector uses approximately 50% of all the raw materials extracted worldwide. The environmental impact of a structure's life cycle is highly influenced by the materials utilised for construction. Thus, the extraction and processing of raw materials and the manufacturing of construction materials have an important role in achieving the environmental aspect of the sustainability concept in this sector [1-4].

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Concrete is regarded as being one of the most used materials in the construction sector. Numerous studies estimate that approximately a ton of concrete is produced for every person, in one year, [5]. The impact of concrete on the environment is mainly achieved by the use of cement as the primary constituent material in concrete mixtures. It is estimated that about a ton of CO_2 is produced from all phases of extracting and processing a ton of cement [6]. Between the years 1950 and 2010, the consumption rates of cement increased five times (Fig. 1), and between 1990 and 2005, the carbon footprint was nearly doubled. If the current ratio of cement consumption is maintained, the negative ecological impact is expected to double every five years [5, 6]. Thus, the use of concrete has an important role in achieving the environmental aspect of the sustainability concept at a global scale.

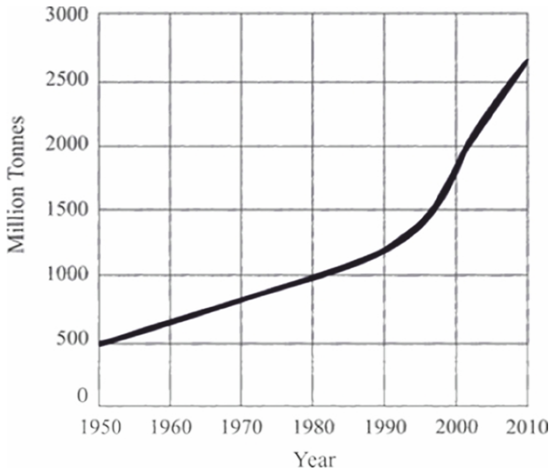

Fig. 1. Annual cement consumption rates [1, 5]

In order to reduce the negative influence of concrete on the environment, in the recent years, the manufactures have optimised the cement composition by making use of complementary cementing materials like fly ash and blast-furnace slag. The primary benefit of using these two pozzolanic by-products which are carbon-neutral materials is that the environmental impact of concrete is reduced. Another benefit is considered to be the possibility of diverting these complementary materials from the landfills. [5, 6].

2. LCA case study

The LCA studies are considered to be the best tools for assessing the environmental feature of the sustainability concept in the construction sector. Depending on the analysed period from the life cycle of a product, in this case the life cycle of a reinforced concrete (RC) beam, there are four types of LCA studies: Cradle-to-Grave, Cradle-to-Gate, Cradle-to-Cradle and Gate-to-Gate. The present study uses the Cradle-to-Gate approach defined by the assessment of a partial product life cycle, from the extraction of raw materials (cradle) to the manufacturing stage (gate), before the transportation to the consumer. In the construction sector, this method only includes the following life cycle stages (Fig.2), [7, 8]: extracting and processing of raw materials; manufacturing of the construction materials; transportation of the construction materials from the factory to the building site; actual building process and completion of the structures to the serviceable stage.

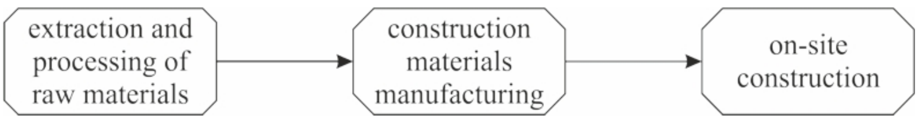

Fig. 2. Analysed period from the life cycle of the beam

This environmental study was conducted on a RC beam (Fig. 3) with the length equal to 5700 mm and a rectangular cross section of 300x450 mm. The concrete grade used is C20/25 with the density of 2500 kg/m^3. The reinforcing cage consists of:

- the tension reinforcements made of 3 steel bars of 16 mm diameter;
- the compression reinforcements made 3 steel bars of 14 mm diameter;
- the shear reinforcement made of steel stirrups of 8 mm diameter spaced at 100 and 150 mm, as illustrated in Fig. 3.

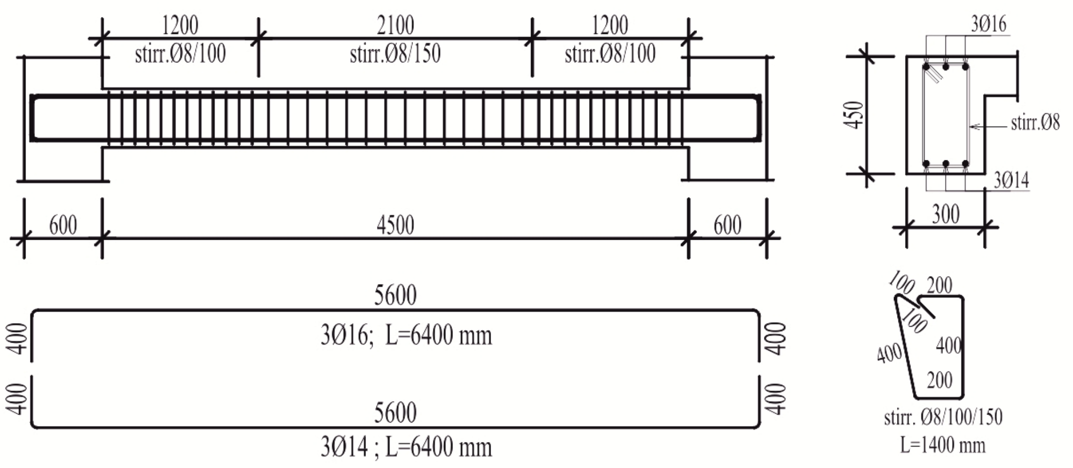

Fig. 3. The geometric characteristics of the reinforced concrete beam (dimensions in mm)

The analysed RC element is assumed to be a part of the framing system of a building of flats from Iasi, Romania. A Euro 4 diesel truck has been used for the transportation of construction materials from the concrete plant and from the steel storehouse to the construction site. Depending on the type of carried materials, different transportation distances were adopted (Table 1).

Table1. Distances of transport for the RC beam materials

Construction material	Transport distances [km]
Concrete C20/25	15
Φ8 steel stirrups	10
Φ14 steel rebars	10
Φ16 steel rebars	10

The transportation of steel reinforcements from the factory to the storehouse and also of diesel fuel from the refinery to the gas station has not been considered. Also, recent research works have shown that the influence of the equipment on the overall environmental impact of a construction product is approximately 1% [8-10]. Thus, the energy used by specific tools and machines operated in the on-site construction stage and their associated emissions are not taken into consideration.

3. Results

The LCA study was performed by using the GaBi 6 software [11]. In order to assess the environmental impact, the CML 2001 – April 2013 methodology has been applied. The quantified environmental problems are global warming and the effects of the life cycle stages of the RC beam on human environment (health risks). In the CML methodology these aspects are represented by the following impact categories:

- Global Warming Potential (GWP 100 years) in [kg. CO_2-Equivalent], (Fig. 4);
- Human Toxicity Potential (HTP inf.) [kg. DCB-Equiv.] (Fig. 5).

The environmental impact category *Global Warming Potential* presents the influence of total emissions from a life cycle of a product on the global greenhouse effect for a time horizon of 100 years. Using different factors, all air emissions are transformed in kilograms of carbon dioxide equivalent [11, 12].

The *Human Toxicity Potential* impact category refers to the negative effects of the products’ life cycle stages on the human environment (human health risks). All emissions are transformed to kilograms of dichlorobenzene (DCB) equivalent, describing the exposure and effects of harmful substances for an infinite time horizon [12].

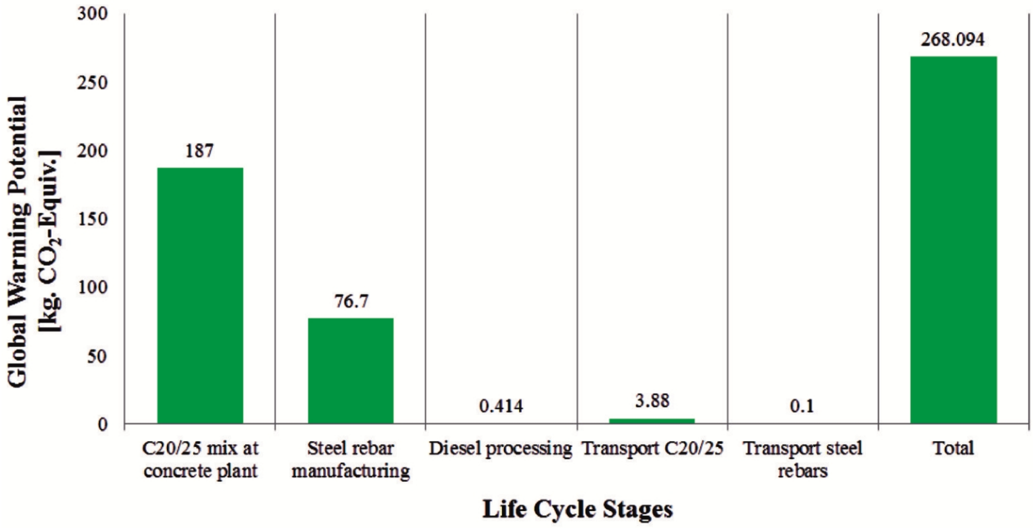

Fig. 4. Global Warming Potential of the RC beam

As presented in Fig. 4, the manufacturing of C20/25 concrete (extraction and processing of raw materials, producing the component materials and fabrication phase) has the highest influence over the whole product’s life cycle environmental impact, accounting for almost 70% of the total CO_2-Equiv. emissions.

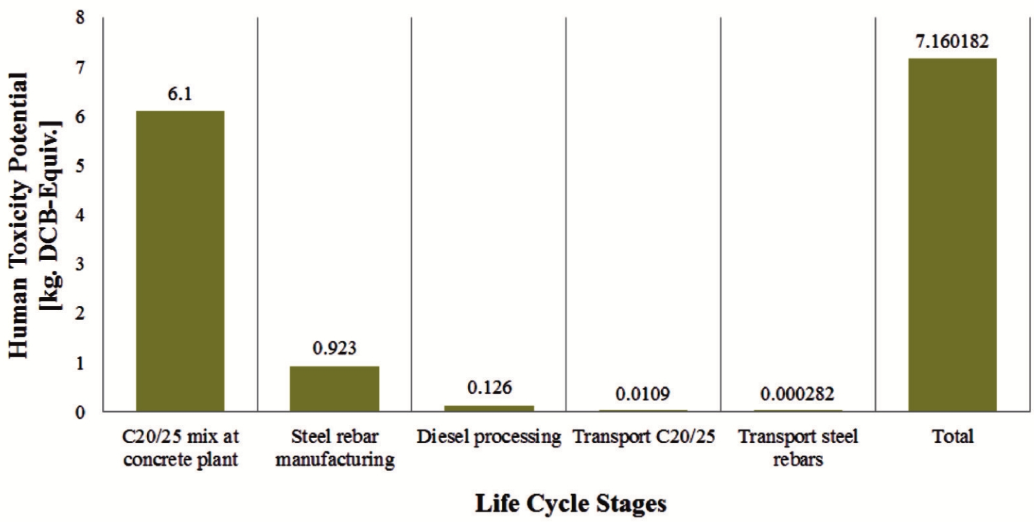

Fig. 5. Human Toxicity Potential of the RC beam

The implication on the total human health risk potential of all analysed phases of the RC beam life cycle is represented in Fig. 5. The emissions related to the stage of manufacturing C20/25 concrete present the highest human health risk, this phase being responsible for over 85% of the RC beam impact.

Conclusion

The construction sector has an important negative influence over the natural environment. This ecological impact is highly influenced by the quantities of raw materials and non-renewable energy used for manufacturing construction materials. Concrete is one of the most used materials in this sector and it is considered to have the highest environmental impact.

As the results of this LCA study show, the manufacturing of C20/25 concrete mixture stage has the highest environmental impact. This ecological influence is a result of using cement as the primary constituent material in concrete mixtures.

In order to reduce the environmental impact of concrete and to include this material in the efforts of achieving the aspects of the sustainability concept in the construction sector through a sustainable development of this industry, it is necessary to reduce the quantities of cement used in concrete mixtures by replacing certain amounts of it with carbon-neutral materials.

REFERENCES

[1] Maxineasa S. G., N. Taranu. Traditional building materials and fibre reinforced polymer composites. A sustainability approach in construction sector, Bul. Inst. Polit. Iasi 2, 2013, 55-68.

[2] Ewing B., S. Goldfinger, M. Wackenaged, M. Stechbart, S. M. Rizk, A. Reed, J. Kitzes. The Ecological Footprint Atlas 2008, Oakland: Global Footprint Network, 2008.

[3] Messari-Becker L., K. Bollinger, M. Grohmann. Life-cycle assessment as a planning tool for sustainable buildings. In: A. Strauss, D.M. Frangopol, K. Bergmeister (Eds.), Life-cycle and sustainability of civil infrastructure systems. Proceedings of the Third International Symposium on Life-Cycle Civil Engineering (IALCCE 2012), Taipei, Taiwan, 2012, 1558-1562.

[4] Pacheco-Torgal F., J. A. Labrincha. The future construction materials research and the Seventh UN Millennium. Development goal: A few insights, Constr. a. Build. Mater. 40, 2012, 729-737.

[5] Mehta P. K., H. Meryman. Tools for reducing carbon emissions to cement consumption, Struct. Mag. 16, 2009, 11-15.

[6] Estrada H., D. H. Borja, L. Lee. Sustainability in Infrastructure Design. In: Jain R., L. Lee (Eds.), Fiber Reinforced Polymer (FRP) Composites for Infrastructure Applications, Springer, Dordrecht, Netherlands, 2012, 280 p.

[7] Maxineasa S. G., N. Taranu, P. Ciobanu, S. Popoaei. Application of life cycle assessment to civil engineering, Proc. 13th Int. Scientific Conference – VSU’ 2013, Sofia, vol. II, 2013, 188-193.

[8] Dumitrescu L., S. G. Maxineasa, I. M. Simion, N. Taranu, R. Andrei, M. Gavrilescu. Evaluation of the environment impact of road pavements from a life cycle perspective, Environ. Eng. a. Manage. J., vol. 11, no. 4, 2014, 449-455.

[9] Zapata P., J. A. Gambatese. Energy consumption of asphalt and reinforced concrete pavement materials and construction, J. Infrastruct. Syst., 11, 2005, 9-20.

[10] Dumitrescu L., N. Taranu. Environmental assessment software for concrete application, Proc. 7th Int. Symp., "Computational Civil Engineering 2009", Iasi, Romania, 2009, 240-248.
[11] VanDuinen M., N. Deisl. Handbook to Explain LCA Using the GaBi EDU Software Package, PE AMERICANS LLC, 2009, On line at: http://isites.harvard.edu/fs/docs/icb.topic636070.files/GaBi%20EDU%20handbook%20-%20v1.pdf.
[12] Goedkoop M., M. Oele, A. de Schryver, M. Vieri. SimaPro Databases Manual. Methods Library, Pre Consultants, 2008, 52 p. On line at: http://www.pre-sustainability.com/download/manuals/DatabaseManualMethods.pdf.