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## SADRŽAJ



U FINANSIRANJU ČASOPISA UČESTVOVALO MINISTARSTVO PROSVETE, NAUKE I TEHNOLOŠKOG RAZVOJA REPUBLIKE SRBIJE

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## CONTENT



**THE FINANCING OF THE JOURNAL PARTICIPATION IN THE MINISTRY OF EDUCATION, SCIENSE AND TEHNOLOGICAL DEVELOPMENT**

# COMPOSITE MATERIALS BASED ON E - GLASS WOVEN TEXTILE STRUCTURES AS REINFORCEMENT

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**Abstract:** *Textile composites are materials composed of two basic elements, one which is called a matrix or basic material, which is a continuous phase and the other element or component i.e. reinforcement (textile preforms), often referred as dispersed phase. Textile preforms are different textile structures made by using traditional textile processes such as weaving, knitting, braiding, stitching, etc. Textile preforms not only play a key role in the transformation of fiber properties into complex composite performance, but also affect the easy or difficult infiltration of matrix and consolidation. In this paper three different types of two dimensional E-glass woven structures as reinforcement for composite materials are discussed. The tensile strength and elongation of E-glass fabrics in the longitudinal and transverse directions was experimentally determined according to the standard ASTM D 5035. Characterization of the structure of woven textile materials i.e. the way of interlacing of warp and weft with binocular microscope was also made. The structural characteristics of the fabrics have a major influence on the physical and mechanical properties of the fabrics and their performance in the final composite. They are usually determined by the yarns from which they are made, as well from the process parameters of the weaving machines.*

**Key words:** composite, E- glass woven textile structure, plain weave, twill weave, basket weave, tensile strength.

# KOMPOZITNI MATERIJALI NA BAZI E- STAKLENIH TKANINA KAO POJAČIVAČA

**Apstrakt:** *Tekstilni kompoziti su materijali sastavljeni od dva osnovna elementa, od kojih se jedan naziva matrica ili osnovni materijal (kontinuirana faza), a druga komponenta, tj. ojačivać (tekstilne predforme), naziva se disperziona faza. Tekstilne predforme su različite tekstilne strukture napravljene korišćenjem tradicionalnih tekstilnih procesa, kao što su tkanje, pletenje itd. Tekstilne predforme ne igraju samo ključnu ulogu u transformaciji svojstava vlakana u složene kompozitne performanse, već i na lakoću ili teškoću infiltracije matrice, kao i na konsolidaciju. U ovom radu razmatraju se tri različita tipa dvodimenzionalnih tkanih struktura sa E-staklenim vlaknama kao ojačanje kompozitnih materijala. Prekidna snaga i elongacija E-staklenih tkanina u podužnim i poprečnim pravcima eksperimentalno su određeni prema standardu ASTM D 5035. Takođe je napravljena кarakterizacija strukture tkanih tekstilnih materijala, odnosno načina preplitanja osnove i potke sa binakularnim mikroskopom. Strukturne karakteristike tkanina imaju veliki uticaj na fizičke i mehaničke osobine materijala i njihove performanse u finalnom kompozitu. Obično ih određuju prediva iz koje su izrađeni, kao i procesni parametri mašina u procesu tkanja.*

**Ključne reči:** kompoziti, tekstilna struktura od E- staklenih vlakana, platno, keper, panama, prekidna snaga.

## 1. INTRODUCTION

Composite materials reinforced with textile preforms are called textile composites [1]. It is important to understand that for most of the composite materials, the reinforcement provides the required mechanical properties of the composite material, such as the high stiffness and strength, flexural strength, etc. The matrix is necessary for connecting, maintaining the position and orientation of the reinforcement, to transfer the load between the reinforcement in all directions and to protect them from mechanical abrasion and negative environment [2, 3]. Textile composites are being widely used in advanced structures in many industrial applications because they possess outstanding physical, thermal and favorable mechanical properties, particularly light weight, high stiffness and strength, good fatigue resistance, excellent corrosion resistance and dimensional stability [4].

The well known textile structures used as reinforcements for advanced composites are woven, knitted, braided and nonwoven fabrics [5]. In recent years, the interest in woven fabric from high performance fibers as a reinforcement for textile composite has been greatly increased. This is due to ease of handling, balanced in-plane properties, damage tolerance, impact resistance, etc. The outstanding achievements in the field of computer-aided design and manufacturing have facilitated the adaptation of many traditional textile processes to create 2-D and 3-D textile structures at relatively low production costs.

Woven fabrics are traditionally produced on a loom by mutually interlacement of two sets of yarn: warp and weft into a textile structure. The yarns that are positioned along the length of the fabric are called warp, while the yarns that run along the width of the fabric are known as weft. Warp and weft yarns are mutually positioned perpendicular. A wide variety of weave patterns such as plain, twill, satin, basket etc. can be produced by using different interlacement techniques. The structural characteristics of textile material have a significant impact on the physical and mechanical properties of the fabrics and their performance in the final composite [6, 7]. They are usually determined from the yarns of which they are made, as well as from the process parameters of the weaving machines. The basic structural characteristics of the fabrics include: the material composition of the fabric (types of yarns used for warp and weft), the linear density of yarns used for warp and weft, the density of the fabric in warp and weft direction, the way of interlacing the weft and warp yarns (style or weave pattern), etc. Together, these characteristics determine fabric properties such as drivability and performance in the final composite. Tensile strength of a woven fabric is one of the most important mechanical properties which make them superior for many industrial applications in comparison with knitted and non-woven fabrics [8, 9].

## 2. EXPERIMENTAL TEST

In this study three types of woven textile fabric from E- glass were analyzed. To examine the weave structure of the E-glass fabric, microphotographs on the fabric structure are made by using the ZOOM 645 binocular microscope. These photographs are made in order to see the differences in the structure of the analyzed E- glass fabrics, i.e. the way of interlacing the two basic yarn systems (warp and weft).

Tensile strength of a fabric is defined as a maximum load that it will endure without breaking when subjected to one-axial tensile loading. The tensile strength and elongation of E-glass woven textile structures in the longitudinal and transverse directions was experimentally determined according to the standard ASTM D 5035 [10]. For that purpose computer controlled universal testing machine “Schenk” was used. From each type of E-glass fabric, three specimens with dimensions (200 x 48 mm) were cut in the warp (machine) direction and three specimens in the weft (cross) direction (Figure 1). A test specimen is mounted securely in the clamps of the tensile testing machine and a force is applied to the specimen until it break, which is illustrated in Figure 2. The specimen is centrally located and the long dimension is as nearly parallel as possible to the direction of force application. Values for the breaking force and elongation of the test specimen are obtained from machine on

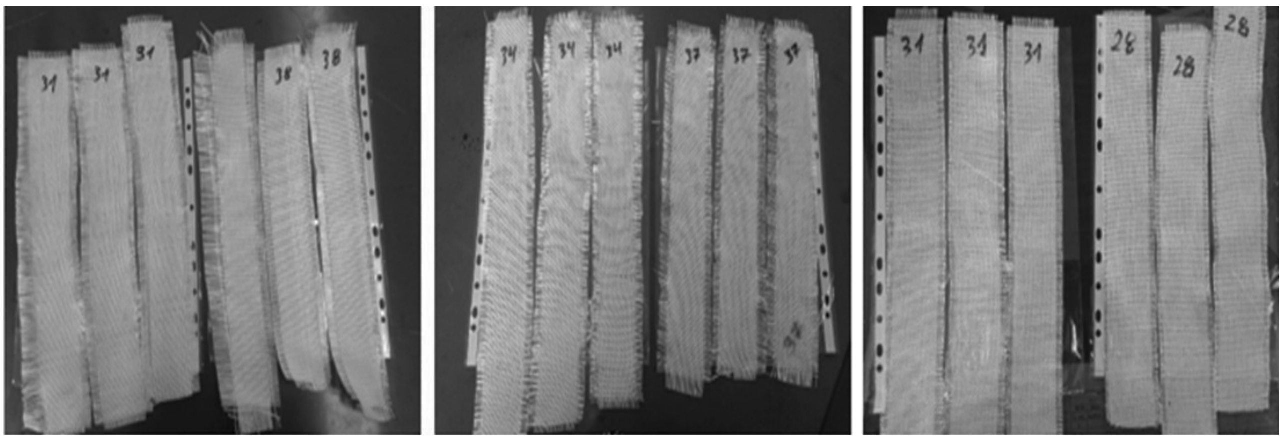

**Figure 1.** Preparation of glass fabric samples for testing the tensile strength

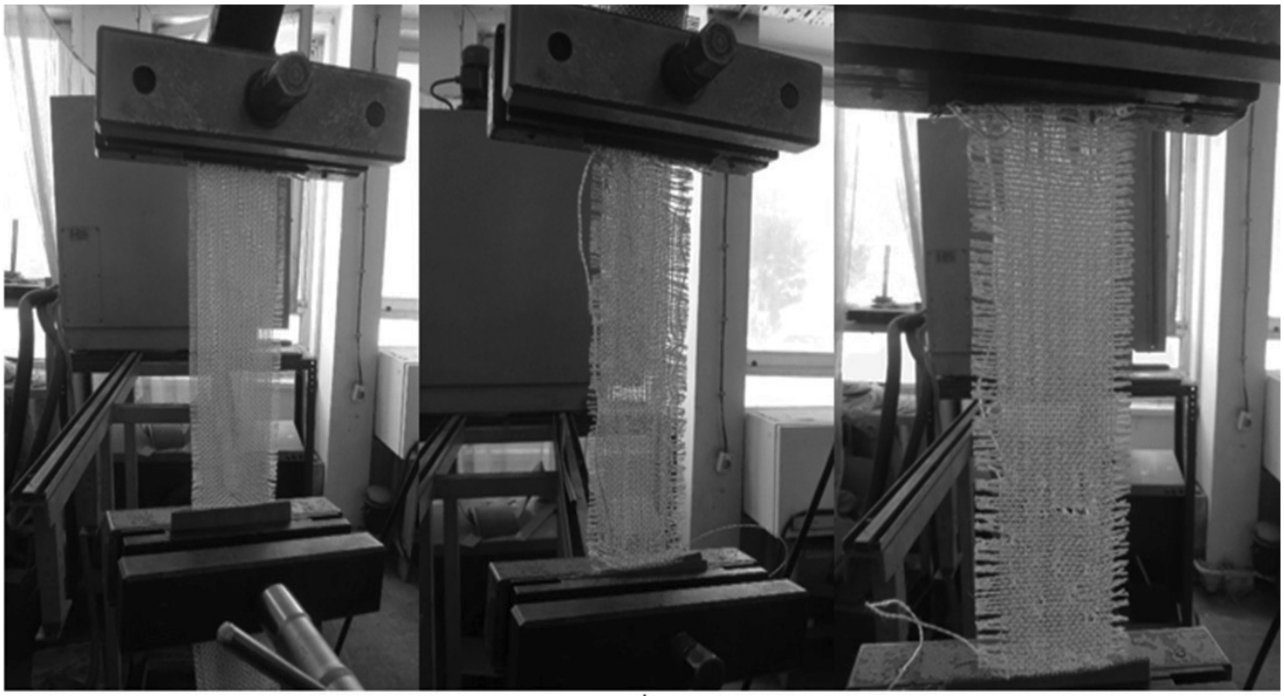

**Figure 2.** Tensile strength test of universal test machine "Schenk"

a computer interfaced with the testing machine. The dimensions of the test samples are different in various standards. The results are average values of three measurements of the tensile strength and elongation of the specimens in the warp and weft direction.

## 3. RESULTS AND DISSCUSSION

The obtained microphotographs on analyzed samples of woven fabric 1, 2 and 3 are presented in Figure 3 respectively. From the obtained microphotographs of the analyzed samples of E-glass fabric, the difference in the way of interlacing of the warp and the weft is clearly seen. In the analyzed E-glass woven fabric three different types of weave pattern are represented.

The first E-glass fabric (sample 1) has a plain weave structure, while the second fabric (sample 3) is woven in twill weave style. These two weave styles belong to the group of basic types of weave structure, which are characterized by simple solutions that at the same time enable formation of fabrics with a fairly tight bond of the warp and weft. In a plain weaving structure, one warp yarn is repetitively woven over and under weft. The plain glass fabric is symmetrical and is distinguished with maximum stability, hardness and reasonable porosity. Twill weave has a looser interlacing and is characterized by a diagonal line created by floated yarns. In a twill weaving structure, each warp yarn floats over two consecutive weft yarns, and under the following one weft yarn. The third analyzed sam-

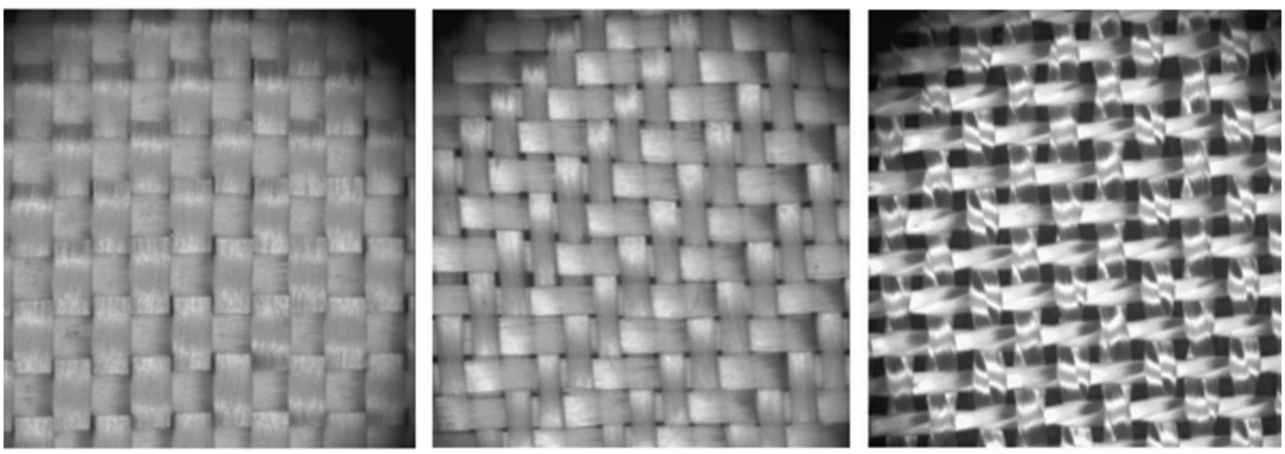

**Figure 3**. Microphotographs from a) sample 1, b) sample 2 and c) sample 3

ple of fabric has a basket weave structure. The basket weave is similar to the plain weave structure. This type of weaving structure has two or more warp yarns interlacing over and under two or more weft yarns. The selection of the weaving design is important because it has a great influence on some fabric properties such as the porosity, air permeability, thickness, elongation and tensile strength.

The results for the tensile strength and elongation of the analyzed E - glass fabrics are presented in Table 1. The results are the mean values of three measurements of the tensile strength and elongation in the warp and weft direction. Tensile deformation ε (%) was determined by the following equation [1]

$$\varepsilon\ (\%) = \frac{\Delta L}{L_o} \cdot 100 = \frac{L - L_o}{L_o} \cdot 100 \qquad [1]$$

Where, $L$ is the change in gauge length, $L_o$ is the initial gauge length, and L is the final length.

From the obtained results (Table 1), can be concluded that all analyzed E-glass fabrics have a greater tensile strength in warp direction than in weft direction. The E - glass woven fabric with plain weave structure (sample 1) has the highest resistance to tensile strength per warp and weft (3079 N and 2333,3 N) respectively. Also, this fabric exhibits relatively high values for tensile deformation per warp and weft (%). This is understandable, because this type of weaving pattern is characterized by the strongest interlacing of the warp and weft. The tensile strength of twill fabric (sample 2) in warp direction is about 20 % smaller than tensile strength of plain fabric but about 18 % bigger than tensile strength of basket fabric. The tensile strength of basket fabric (sample 3) are smaller than plain and twill weave, and this is primarily due to larger empty spaces between the warp and the weft in the weave structures. Tensile behavior of a woven fabric depends on the weave designs.

**Table 1.** Mechanical characteristics of E-glass fabrics

| Sample Number | | | Length, L (mm) | Width, w (mm) | Count weft/ warp | Tensile strength, F(N) | Extension, ΔL(mm) | Tensile deformation, ε (%) |
|---|---|---|---|---|---|---|---|---|
| Sample 1 | Warp | 1-2 | 200 | 48 | 38 | 3327 | 8 | 4 |
| | | 2-2 | 200 | 48 | 38 | 2910 | 10 | 5 |
| | | 3-2 | 200 | 48 | 38 | 3000 | 8 | 4 |
| | | | | | **Average** | **3079,0** | **9,3** | **4,7** |
| | Weft | 1-1 | 200 | 48 | 31 | 2225 | 8 | 4 |
| | | 2-1 | 200 | 48 | 31 | 2125 | 7 | 3,5 |
| | | 3-1 | 200 | 48 | 31 | 2250 | 8 | 4 |
| | | | | | **Average** | **2333,3** | **7,7** | **3,8** |
| Sample 2 | Warp | 1-2 | 200 | 48 | 37 | 2250 | 6 | 3 |
| | | 2-2 | 200 | 48 | 37 | 2767 | 5 | 2,5 |
| | | 3-2 | 200 | 48 | 37 | 2250 | 6 | 3 |
| | | | | | **Average** | **2422,3** | **5,7** | **2,8** |
| | Weft | 1-1 | 200 | 48 | 34 | 1475 | 6 | 3 |
| | | 2-1 | 200 | 48 | 34 | 1525 | 6 | 3 |
| | | 3-1 | 200 | 48 | 34 | 1525 | 6 | 3 |
| | | | | | **Average** | **1508,3** | **6** | **3** |
| Sample 3 | Warp | 1-2 | 200 | 48 | 31 | 2095 | 5 | 2,5 |
| | | 2-2 | 200 | 48 | 31 | 1700 | 7 | 3,5 |
| | | 3-2 | 200 | 48 | 31 | 2150 | 4 | 2 |
| | | | | | **Average** | **2008,3** | **5,3** | **2,7** |
| | Weftl | 1-1 | 200 | 48 | 28 | 1505 | 10 | 5 |
| | | 2-1 | 200 | 48 | 28 | 1052 | 10 | 5 |
| | | 3-1 | 200 | 48 | 28 | 1600 | 10 | 5 |
| | | | | | **Average** | **1385,7** | **10** | **5** |

## 3. CONCLUSION

Tensile strength is one of the most important mechanical properties for the characterization of woven fabric quality and fabric performance. Tensile strength of a woven fabric not only depends on characteristics of the yarns used for warp and weft (their strength, their linear density, twist direction, yarn twist per unit length, etc.) but also depends on structural characteristics of the fabric (weave pattern, warp and weft density, weaving conditions, etc.). From the obtained result for tensile strength of E- glass woven fabrics it can be concluded that all analyzed samples have bigger tensile strength in warp direction than in weft direction. The woven fabric with plain weave structure (sample 1) has the biggest tensile strength in both direction (warp and weft). Plain weave is the simplest and most commonly used basic reinforcement for woven composites. The selection of the weaving structure is important because it has a great influence on fabric properties and performance of composite materials.

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