



**CHARACTERISTICS OF ROCKY MASSIF IN ASPECT OF INTENSITY FROM SEISMIC WAVES
ASSOCIATED WITH BLASTING**

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ABSTRACT

In previous studies carried out on a large number of scientists and experts in these area that connects the physical laws of oscillation of the ground and blasting as the mining operation, it was found that the oscillation of the ground and the intensity of seismic tremors caused by blasting series depend of the physical – mechanical characteristics of the rock massif.

This physical – mechanical characteristics are related to their geological structure and the secondary deformation and micro cracks in the rocky massif. The measurement, analysis and calculations are approximate curves through which we can easily recognize (predicted) the parameters of seismic tremors when performing any type of blasting series.

Key words: *blasting, oscillations, seismic tremors, geotechnical parameters, rocks massif*

Introduction

The energy generated by the explosion of some quantity of explosives, have broken and breaking rocks, cracks form and various deformations in the surrounding rocks. Around of blasting place and outlying areas the generate detonated wave, causing elastic deformation, concentrically arranged around the mining area.

These (seismic) waves passing through a rocky massif cause oscillations of the particles from the ground and surrounding buildings. Blasted series performed on open pit mines and underground mines, cause different effects on the environment in terms of intensity of the shocks, air shocks etc.

Establishment of seismic waves

The explosion that occurs with a certain amount of blasting explosives establishes a large amount of energy. In a short time interval this energy causes (creates) an enormous power, which can be used for destruction of rocks. Some of that energy, in the form of seismic waves, is lost in the rocky massif.

These two zones are characterized by a number of different cracks and fissure systems, after which occurs a complete tearing of the link between parts of the rock mass and change the physical and mechanical characteristics of the rock mass.

By blasting to destruct rocks, most of the energy produced in the explosion is consumed, while only small part is lost in the form of elastic waves in rock mass. The effect of elastic seismic wave is movement of particles of the rock mass from its equilibrium position with a certain amplitude and frequency, within the limits of elastic deformation.

Such displacement of particles doesn't cause the appearance of cracks, only a shock, therefore, the zone in which this phenomenon occurs is called the zone of aftershocks. (III)

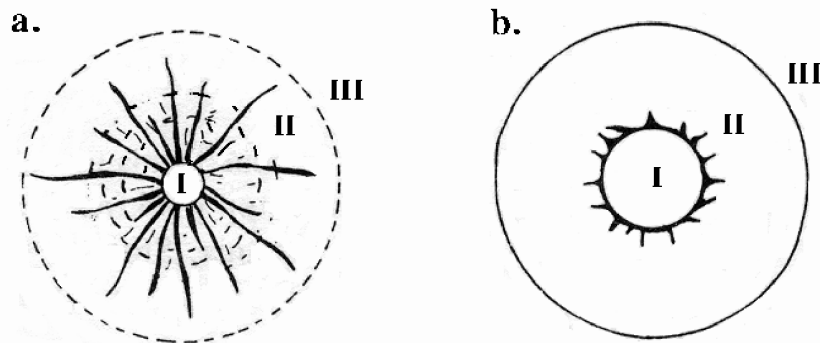


Figure 1. Deformation zones in mine blast area,
a) in homogenous and solid rocks, I - zone of fine crushing and grinding, II - zone of destruction, III - Shock Zone - seismic zone, b) in plastic and non-aligned rocky material, I - extrusion zone, II - zone of plastic deformation, III - elastic deformation zone

In terms of seismicity (physical process), the fracture zone is particularly significant because the elastic waves that lie in this zone have the capacity of seismic waves, and their actions have consequences with the same character as seismic waves caused by earthquakes.

The physical parameters (elements) that are related to the construction of the earth, largely affect natural behaviour of seismic waves, the range and the harmful effects on urban and industrial buildings on the ground surface and the underground facilities.

The research on the nature and the laws of the seismic wave and energy released, indicating that the physical, mechanical, structural and hydro geological characteristics of the rock masses have a very big impact on the effects of seismic waves. Therefore, in all studies, despite the consumed quantity of explosives, the distance from the measuring point to the explosion, the depth of the centre of the blast, the direction of the measurement, significant attention has been paid to the structural construction of the rocky massif and physical - mechanical characteristics of the same.

Nature of seismic waves

The internal equilibrium of the earth's crust commonly disrupts excavation or dynamic impact on the surface of the ground. The properties of seismic waves depend on the one hand on the mechanism of the explosion and created internal energy in the centre, and on the other side on the elastic properties of the environment through which these waves lie.

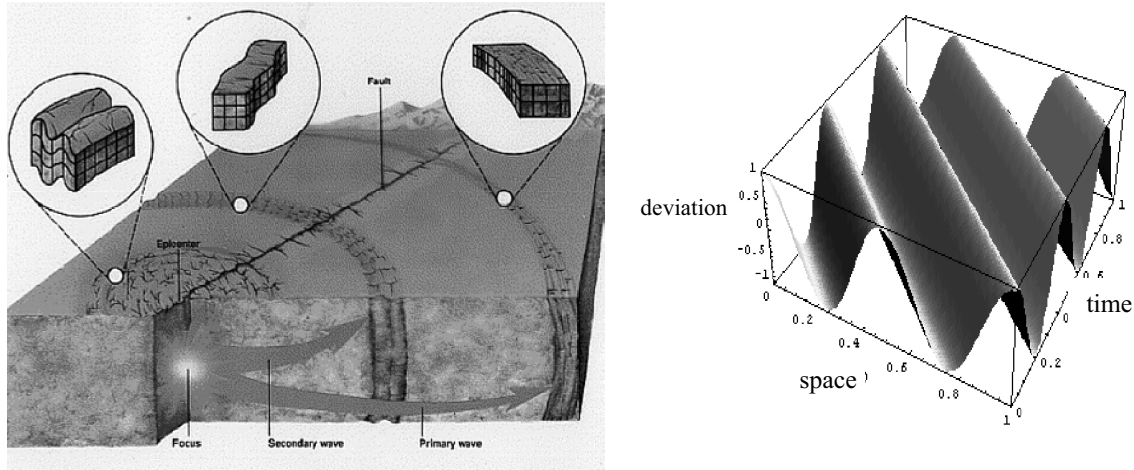
Surface that limits the source and weakens the wave that moves through the middle, changes its position and forms function of time. If the source has punctuate form, the modified surface will be with spherical shape and be called spherical front.

The radius of the sphere spread function of time, and the coefficient of proportionality is the speed of propagation of waves through the appropriate type of rock massif.

The radius of the wave front changes with time and is equal to the distance from the source to the front of start (Figure 2).

The lines that "pass" through focus and are normal in terms of the wave front, are called seismic rays.

Elastic wave on its way through rock mass gradually weakens and loses its energy (causing smaller strain in the rock), until at some distance from the site of blasting it fully throttles and disappears. In the surrounding areas of blast, the shock wave has such power to cause a variety of stresses that have larger than physical – mechanical (strength) properties of rock mass (pressure, stretch, shear, etc.) for, at a certain a distance to cause only elastic deformations in the rock mass.



*Figure 2. Deformations in the earth's crust with movement of waves in space
 And time with an accurate deviation*

These seismic waves, generated at each blasting depend, at great length, on the percentage of unusable work (lost power) generated during detonation. This percentage depends on drilling - blasting parameters and as lower this percentage is, the greater utilization of energy from the explosion. . . . Passive energy is actually working unused from blast and this phenomenon manifests is most known as a seismic effect of the explosion. It is linked to the creation of elastic oscillations of the particles in the rock mass in a very wide area (spread concentrically) around the site of an explosion occurred.

Seismic waves lie at the centre of the explosion (hypocentre) in the form of concentric spheres, until they reach the earth's surface. When the waves reach the surface, causing the surface of the ground changes, which are called defined as seismic tremor. According to the behaviour in propagation, seismic waves can be classified into two groups, namely: spatial (bulk) that extend through the rocky massif and surface waves that move along the ground surface.

Spatial waves can be:

- Longitudinal (longitudinal) and
- Transverse elastic waves.

In longitudinal waves particles oscillate in the direction of propagation of elastic waves.

Because the rocky massif occur alternately compressive and tensile stresses. This is the reason why this wave is also called compression - tensile or longitudinal wave, and in seismology is marked as P - wave.

The speed of propagation of longitudinal seismic waves depends on: the module of elasticity of the rock material (E), bulk mass (γ), acceleration (g), and define analytical expressions:

$$V_p = \sqrt{\frac{E \cdot \gamma}{g}} \quad , \quad (\text{m/s}) \quad (1)$$

The values of the speed of propagation of longitudinal seismic waves, of some rock types are shown in Table 1.

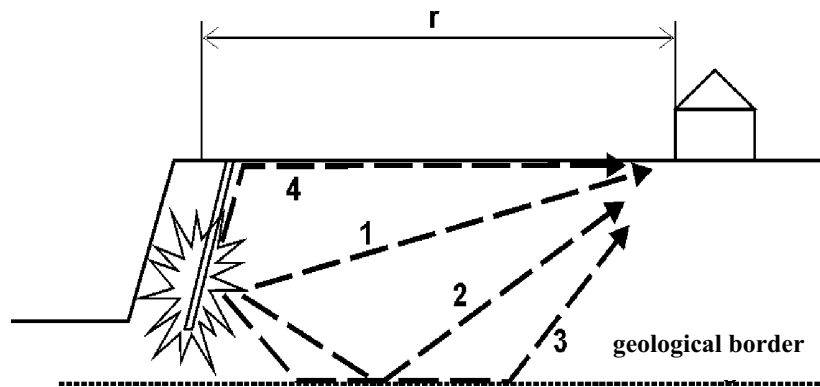


Figure 3. Types of seismic waves, 1. - Longitudinal (P), 2 - Rejected or reflected, 3 - Broken or violated, 4 - Surface wave (S)

In cross seismic waves particles oscillate perpendicular to the direction of propagation of elastic wave, the rocky material that causes shear. These waves are called waves and shear or transverse waves in seismology still as S - waves. The speed of the transverse waves r is less than the speed of longitudinal waves and is given by the expression:

$$V_s = \sqrt{\frac{E \cdot \gamma}{2\gamma(1 + \nu)}} \quad (\text{m/s}) \quad (2)$$

Surface waves are formed when seismic waves arrive at the surface of the ground, where encounters a rare - acoustic environment (air), which leads to the occurrence of violations and denial of waves. Thus formed waves extend through the ground surface and are called surface waves. The direction of movement of the particles can be in all three directions (longitudinal, cross and vertical). After surface extending different types of surface waves, the most significant is the wave of the Rally, i.e. Rally waves or seismological known as R - waves.

Table 1. Values of spreading velocities of seismic longitudinal waves

Type of material	Velocities of seismic longitudinal waves, V_p (km/s)
Granite	5,0 ÷ 5,7
Limestone, sandstone	2,5 ÷ 4,5
Gypsum	1,7 ÷ 3,0
Gravel	0,9 ÷ 2,1
Sandy soil	0,6 ÷ 1,6
Clay soil	0,5 ÷ 1,5
Shaken soil	0,2 ÷ 0,5
Water	1,73
Air	0,34

The picture No. 4 presents a schematic representation of deformations of rock masses under the influence of different seismic waves.

According to the speed of propagation of seismic waves through rock mass, the fastest is the longitudinal wave, the transverse wave is somewhat slower and surface wave is slowest. Because of this, the earthquakes are clearly three different shocks, because the source of the wave large enough distance, the time in arrival is difference.

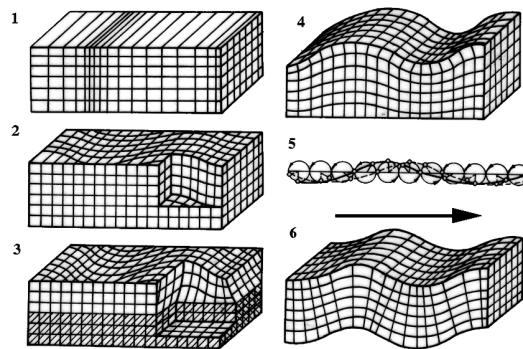


Figure 4. Schematic representation of deformations of rock material caused by different types of seismic waves

1- Longitudinal (pressed wave), 2- transverse -shear wave, 3- surface wave of Love's type, 4- influence of surface wave from waves Rally type, 5- direction of movement of particles in the waves Rally, 6- surface wave resulting (arrow shows the direction of movement of the wave)

The intensity of the tremor caused by mining can be established (defined) by measuring one of the three basic parameters that characterize the oscillations induced ground, such as:

- Movement of soil particles (x)
- Speed of oscillation of particles of soil (v)
- Accelerating of movement environment (a)

The size of these three parameters indicating the intensity of the force that caused these parameters actually represent basic dynamic parameters of a concussion and can be defined as:

- **Offset** - the distance at which the particle moves away from its equilibrium position during oscillation. It is expressed in (mm) or part (mm).
- **Speed** - movement of particles during the oscillation and is expressed in (mm/s) or (cm/s).
- **Acceleration** - indicates the rate of change of speed of movement or motion of particles. It is expressed in parts of the acceleration of gravity ($g = 9,81 \text{ m/s}^2$)

Influence of geological factors

The geological features of the ground for a site where mining is a factor naturally conditioned, so it is necessary that the parameters of mining to adapt to the circumstances on the ground. . The size of the fluctuation of soil particles strongly depends on the type and structure of the ground i.e. earth's crust through which ranges detonating wave caused by blasting.

Higher frequencies of oscillation are characteristic of solid, compact, homogeneous rocks, and lower values are characteristic of soft, degraded or cracked and young alluvial formations of rocks. This conclusion is, according to numerous data measured through various rocky ridges of different sites and this is confirmed by readings velosingrame witch are recorded from corresponding measurements.

When blasting is done in one, and measurements of effects are in different geological environment, the seismic wave from the blasting site to the place of registration goes through different geological environments.

Based on the previous analysis we can conclude that the seismic intensity increases with dwindling strength of rocks and rocky material. For example in many solid rocks as sedimentary and igneous rocks (granite, basalt , marble) effects of seismic tremors significantly small compared with soft and crumbling rocks such as sandstone, clay, humus, sand and others. If the rock contains a higher percentage of water the negative consequences are even greater.

This also means that massive solid rock mass allows transfer energy over longer distances, i.e. rapid propagation of seismic waves without deadening.

Based on the data obtained for the intensity of seismic waves can define the degree of seismology by type of rocky massif. Based on these surveys all rocks are divided into seven (7) categories.

In tab. 2 presents the values rising level of seismology categories of rocks in terms of granite as standard (under S. C. Medvedev).



Table 2. Degree of seismology by type of rocks

Category of the rock	Rock	Increasing the degree of seismology (n) in degrees
I	Granit (0
II	(limestone)	0,0 - 1,0
III	(soil of sandstone	1,0
IV	(gravel soil)	1,0 - 2,0
V	(sandy soil)	1,0 - 2,0
VI	(clay soil)	1,0 - 2,0
VII	(shaken soil)	2,0 - 3,0

Based on the previous table are calculated increases in the level of seismology (n) of different rocks and the values are given in Tab .3

Table 3. Speed of seismic waves depending on the type of rock

Type of rock	Speed of longitudinal waves[km/s]	Increasing the degree of seismology, (n)
I. HARD ROCK		
- Granite, limestone, diabaz	5,6	0
Hard gneisses	3,5 - 4,5	0,2 - 0,4
- Sandstone	2,2 - 3,0	0,5 - 0,8
- limestone, soft, dolomite	1,5 - 2,3	0,7 - 1,1
II .SOFT ROCK		
- Gypsum	2,4 - 3,0	0,6 - 0,8
- Lapor	2,0 - 2,6	0,7 - 1,0
III. SOIL OF DIMENSION STONES		
-	1,3 - 2,1	0,9 - 1,3
	1,2 - 1,4	1,0 - 1,4
	1,1 - 1,7	1,1 - 1,5
IV. SANDY SOIL		
	1,1 - 1,6	1,2 - 1,4
	1,0 - 1,4	1,3 - 1,6
	0,7 - 1,2	1,4 - 1,8
V . CLAY SOIL		
	0,9 - 1,5	1,2 - 1,6
	0,8 - 1,4	1,3 - 1,7
	0,7 - 1,2	1,4 - 1,8
VI .SOIL SATURATED WITH WATER		
	-	1,6 - 2,0
	-	2,0 - 2,4
	-	2,4 - 2,8

Measurement and analysis of the obtained values

The practical measurements are of the physical parameters of the seismic performed in the one open-pit copper mine in the andesite work environment. When it is calculated and reduced distances for certain facilities that are located in the trench



When over solid mass is located dilapidated, shaken and degraded environment which is significantly different from the solid surface speed of oscillation of the ground surface of the ground, can be several times larger than the solid surface. The reason for that is many times the violation and reflection of seismic waves from the surface of the ground or from solid ground.

In the table 4 are given calculated values of maximum speeds of oscillation of ground and reduced distances of separate measuring points for one blasting series in andesite rock massif.

Based on these values are calculated reduced distances for a specific location or facility which is monitored during blasting in one open pit.

Table 4. Calculated values of maximum speeds of oscillation of ground and reduced distances of Separate measuring points

Blasting series	Level	Distance, m	Max. velocity of oscillation, mm/s			Maximal speed of oscillation, mm/s	Reducing distance, R, m
			V_V	V_L	V_T		
S-35	MM-1/ 659,43	95	27,666	19,375	8,414	34,809	5,63
	MM-2/ 660,42	165	10,067	12,233	9,465	18,455	9,78
	MM-3/ 659,71	245	5,026	5,576	3,070	8,110	14,52
	MM-4/ 659,30	297	2,778	2,403	2,088	4,225	17,6
	MM-5/ 658,88	452	1,178	1,956	2,277	3,224	26,80
	MM-6/ 641,05	637	0,539	1,251	1,230	1,835	37,76
	MM-7/ 640,25	665	0,503	0,709	1,244	1,517	39,42

Conclusion

Physical – mechanical characteristics are related to their geological structure and the secondary deformation and micro cracks in the rocky massif. The measurement, analysis and calculations are approximate curves through which we can easily recognize (predicted) the parameters of seismic tremors when performing any type of blasting series.

Seismic and other effects that are caused by the detonation of a quantity of explosives are dependent of many factors, besides the blasting parameters the most important parameters are physical-mechanical characteristics of rocks, structural features of rocks etc.

Literature

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