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EXPERIMENTAL DETERMINATION OF ELASTICITY MODULE AND POISSON'S RATIO OF TAMPING STONE DEPENDING ON COMPOSITION AND TYPE OF FILLER

ЭКСПЕРИМЕНТАЛЬНОЕ ОПРЕДЕЛЕНИЕ МОДУЛЯ УПРУГОСТИ И КОЭФФИЦИЕНТА ПУАССОНА ТАМПОНАЖНОГО КАМНЯ В ЗАВИСИМОСТИ ОТ СОСТАВА И ВИДА ЗАПОЛНИТЕЛЯ

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Abstract*. The paper represents results of the research making it possible to apply dynamic modulus E_{dnm} for E_{stc} evaluation. Equations of correlative relationship between E_{stc} and E_{dnm} result from the correlation analysis of the data of static and dynamic tests of 162 rock samples.*

The research has been carried out as a part of activities intended to improve mine working stability using load-bearing reinforced rock shells.

Keywords: *load-bearing reinforced rock shell**,** tamping stone, Young's modulus, Poisson's ratio.*

Introduction.

The properties, characterizing strength behavior of a tamping stone, are its important physical and mechanical indices. There are following criteria of its deformational parameters: the ratio of tensile (or compressive) stress to the longitudinal strain or Young's modulus and the negative of the ratio of transverse strain to lateral or axial strain or Poisson's ratio [1-6]. The closer indices of the values to the rock mass being tamped is, the higher efficiency of the tamping activities is; i.e. the lower the expenditures, connected with mine working stability provision, are [7-9].

Currently, ultrasonic (dynamic) method is popular to determine Young's modulus and Poisson's ratio. The method makes it possible to control non-destructively elastic characteristics of a tamping stone [10-12]. Moreover, it improves accuracy while simplifying identification of rock elasticity parameters; in addition, it provides an opportunity to avoid the use of labour-intensive statistical procedures.

It is obvious that the elastic characteristics of a tamping stone, following from statistical and dynamic loading, vary in their values because of differences in the stone nature of deformation.

While considering the results of expansion pressure of a tamping stone, the latter stipulates determination of dependence between dynamic elasticity modulus E_{dnm} and statistical elasticity modulus E_{stc} [13-15].

Testing procedure.

It is known that propagation speed of elastic waves depends upon elasticity modulus of a material.

In terms of the known values of Poisson's ratio and longitudinal wave velocity, elasticity modulus of a material is identified using formula [5]

$$E_{dnm} = V_p \rho \frac{(1+\nu)(1-2\nu)}{1-\nu}, \qquad (1)$$

and

Poisson's ratio is identified on the formula

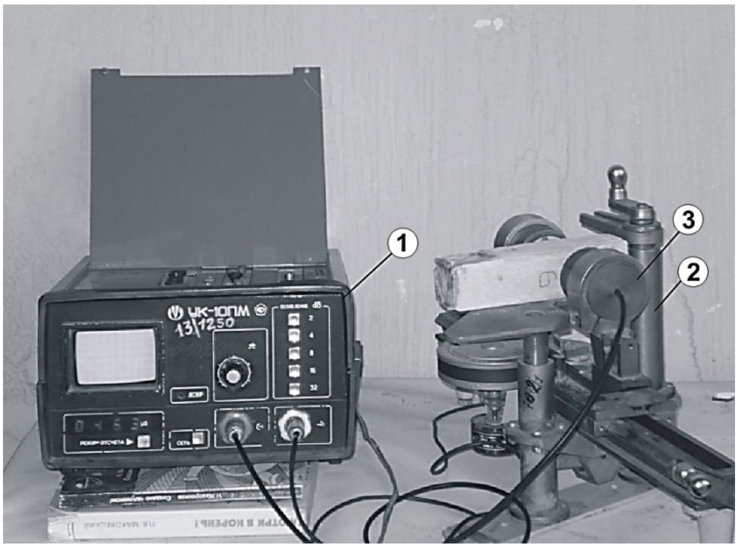
$$\nu = \frac{0{,}5V_p^2 - V_s^2}{V_p^2 - V_s^2}, \qquad (2)$$

where V_p is longitudinal wave velocity, m/s; ρ is density; ν is Poisson's ratio; and V_s is share velocity.

The research involved a method identifying longitudinal wave velocity and share velocity in a sample.

УК-10ПМ device, shown in Fig. 1, was applied to determine propagation velocities of longitudinal waves and share waves within the samples of a tamping stone. The device is meant for laboratory testing of physical and mechanical characteristics of materials and structures as well as experimental models of samples made of the analyzed material.

Structurally, the mechanism consists of electronic assembly and a sample holder with electric transducers.



1 – electronic assembly; 2 – sample holder; and 3 – vibration transducers

Fig. 1 - УК-10ПМ device to identify propagation velocities of longitudinal waves and shear waves

162 samples in the form of 40×40×160 mm beam were manufactured for the analysis (Fig. 2). Demountable moulds were applied to manufacture the samples. Table 1 demonstrates both composition and physical and mechanical characteristics of a tamping solution as well as the sample stone for the testing.

Strength characteristics of a tamping stone followed requirements of DSTU B.V.2.7-89 (GOST 26798.1-96) [16, 17]. For that purpose, test beams, manufactured previously to identify both Young's modulus and Poisson's ratio, were applied. A method to determine velocities of longitudinal waves as well as shear waves within a sample was used.

Table 1.

Composition and physical and mechanical characteristics of the tamping solution and stone

Additive, %	Mass ratio C:A:S:W	Flowability, cm	Water gain coefficient, %	Setting up time, h-m		Self-stressing, MPa	Strength, МПа	
				Initial set	Final set		$\sigma_{изг}$	$\sigma_{сж}$
7	1.0:0.25:3:1.8	13.5	1.0	2-40	5-05	0.86	8.56	34.8

Fig. 2 - Dismountable mold to manufacture test beams

The method measures time during which elastic impulse passes through a tamping stone sample (Fig. 3).

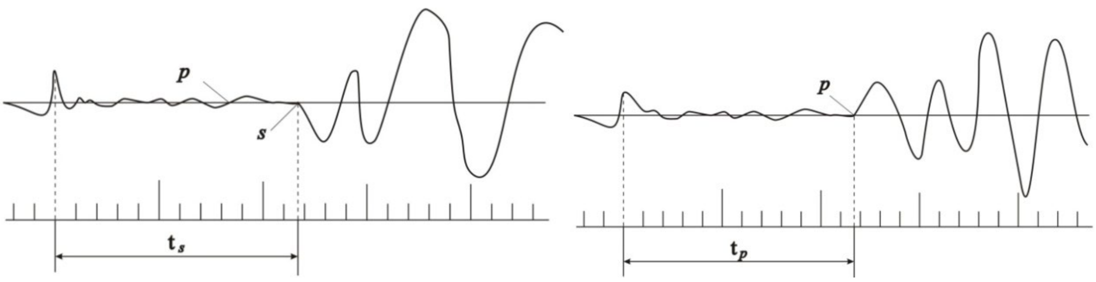


Fig. 3 - General view of oscillogram pattern of elastic vibrations determining the moment of longitudinal wave and shear waves arrival

To do that, vibration converters are pressed to opposite ends of the sample with the help of a sample holder.

Travel time of a longitudinal wave is measured from a delivery moment to a moment of the first arrival in terms of the time criteria.

Define propagation velocity of longitudinal wave on the formula using a sample length *l* between transducers

$$V_p = l/(t_p - t_3), \quad (3)$$

where t_3 is time of the pulse delay within the electronic module housing being t_3=2 µs for УК-10ПМ device; and t_p is arrival time of the longitudinal wave.

Then, use of a pivot turn of a receiver of ultrasound waves helps achieving total disappearance of longitudinal wave arrival and clear arrival of shear wave phases.

The time criteria help measure arrival time of the separated shear wave t_s. Propagation velocities of longitudinal and shear elastic waves were identified using test beams manufactured in accordance with DSTU B.V. 2.7-86-99 (GOST 26798.1-96) [16, 17].

9 of the 162 samples were applied to determine propagation velocities of elastic waves of the samples obtained in terms of free linear expansion of tamping solutions (3 samples for each composition of the solution, i.e. 9 samples) when the tamping solution was hardening under the conditions of complete restriction of the expansion.

Arithmetic mean value of testing results of each sample type was assumed as a propagation velocity of elastic waves [18, 19].

Table 2 demonstrates results concerning determination of propagation velocities of longitudinal elastic wave υ_p; share elastic wave υ_s; elasticity modulus E; and Poisson's ratio v.

Table 2.

Results concerning determination of elastic characteristics of a tamping stone under conditions of free expansion of the test samples

Measurement number	Time of wave arrival, µs		Wave velocities, m/sec		Poisson' s ratio, $\nu_q^{(n)}$	Young' s modulus, $E_q^{(n)}$, hPa	ν_q	E_q, hPa
	longitudinal wave t_P	share wave t_S	longitudinal wave $\upsilon_P \cdot 10^3$	share wave $\upsilon_S \cdot 10^3$				
1	13,7	26,3	2,9	1,6	0,28	8,3		
2	13,7	26,3	2,9	1,6	0,28	8,3	0,29	8,2
3	12,9	25,8	3,1	1,6	0,31	7,87		
4	14,1	27,9	2,8	1,4	0,30	7,42		
5	14,1	27,9	2,8	1,5	0,31	7,4	0,3	7,4
6	13,9	27,2	2,9	1,4	0,30	7,42		
7	15,3	29,4	2,6	1,4	0,31	7,38		
8	15,1	29,6	2,6	1,3	0,31	7,31	0,3	7,3
9	15,4	30,1	2,6	1,3	0,30	7,31		

The calculation results were rounded off with an error of 0.01 MPa.

Conclusions.

Following equation of correlative relationship between E_{stc} and E_{dnm} results from the correlation analysis of the data of static and dynamic tests of 162 rock samples

$$E_{stc} \approx 0.7\ E_{dnm} + 13.8 \cdot 10^2,\ MPa.$$

Analysis of bending and compressive tests has also supported that the sample hardening under conditions of complete expansion restriction factors into certain changes in strength characteristics compared to the samples experiencing their hardening in a free state.

It has been shown that increase in self-stressing of hardening injection improves bending strength. In this context, the increased bending strength has been identified as well as the decreased compressive strength.

If share of phosphogypsum-limestone sinters increases from 5-10% then bending strength increases by 10-13%. Thereby, compressive strength of a tamping stone experiences no decrease while varying within ± 2%.

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***Аннотация**. В статье представлены результаты исследований возможности использования динамического модуля E_{dnm} для вычисления E_{stc}. В результате корреляционного анализа произвольной выборки данных статических и динамических испытаний 162 проб горных пород получены уравнения корреляционной связи между E_{stc} и E_{dnm}.*

Данные исследования были выполнены в рамках проведения работ по повышению устойчивости горных выработок с применением армопородных грузонесущих оболочек.

***Ключевые слова:** грузонесущая армопородная оболочка, тампонажный камень, модуль Юнга, коэффициент поперечных деформаций (коэффициент Пуассона).*