Arch. Min. Sci. **63** (2018), 1, 75-82

Electronic version (in color) of this paper is available: http://mining.archives.pl

DOI 10.24425/118886

IGOR KOROBIICHUK*#, VALENTYN KOROBIICHUK**, PETR HÁJEK***, PAVEL KOKEŠ***, ANDRZEJ JUŚ*****, ROMAN SZEWCZYK****

INVESTIGATION OF LEZNIKOVSKIY GRANITE BY ULTRASONIC METHODS

BADANIA WŁAŚCIWOŚCI GRANITU LEZNIKOVSKIEGO ZŁOŻA METODĄ ULTRADŹWIĘKOWĄ

The samples of Leznikovskyi granite deposit from different parts of the quarry were exposed to pull and compression test. The test findings showed that the samples do not only have different shades of red but also mechanical properties. The unloaded ultrasound examination of samples was also performed. 31 rock samples were exposed to compression test. The influence of the explosion-based mining technology on mechanical properties of the rocks was identified. The findings of experimental research of the rock sound velocity dependence on rock compression were presented. The research findings can be applied in diagnostics of construction elements made of natural stone in the course of installation.

Keywords: granite, natural stone, compressive strength, tension, velocity of sound

Próbki granitu z Leznikovskiego złoża uzyskane z różnych części kamieniołomu poddano próbom ściskania i rozciągania. Sprawdzono również prędkość rozchodzenia się dźwięku wewnątrz próbek obciążonych i nieobciążonych. Przeprowadzone badania wykazały, że próbki różnią się nie tylko odcieniami czerwieni, ale również właściwościami mechanicznymi. W wyniku przeprowadzonych prób ściskania 31 kamiennych próbek zidentyfikowano wpływ wybuchów wykonywanych podczas wydobywania skały na jej właściwości mechaniczne. W pracy przedstawiono eksperymentalne charakterystyki prędkości rozchodzenia się dźwięku w próbkach w funkcji naprężeń ściskających, którym są one poddawane. Charakterystyki te mogą być zastosowane w diagnostyce elementów konstrukcyjnych wykonanych z kamienia naturalnego podczas ich instalacji.

Słowa kluczowe: granit, kamień naturalny, siła ściskająca, naprężenia, prędkości dźwięku

* WARSAW UNIVERSITY OF TECHNOLOGY, INSTITUTE OF AUTOMATION AND ROBOTICS, BOBOLI 8, 02-525 WARSAW, POLAND

** NATIONAL TECHNICAL UNIVERSITY OF UKRAINE “KYIV POLYTECHNIC INSTITUTE”, 37, AVENUE PEREMOGY, KYIV, UKRAINE, 03056

*** CZECH TECHNICAL UNIVERSITY, FACULTY OF CIVIL ENGINEERING, DEPARTMENT OF BUILDING STRUCTURES, THAKUROVA 7, 166 29 PRAGUE 6, CZECH REPUBLIC

**** WARSAW UNIVERSITY OF TECHNOLOGY, INSTITUTE OF METROLOGY AND BIOMEDICAL ENGINEERING, BOBOLI 8, 02-525 WARSAW, POLAND

***** INDUSTRIAL RESEARCH INSTITUTE FOR AUTOMATION AND MEASUREMENTS PIAP, JEROZOLIMSKIE 202, 02-486, WARSAW, POLAND

Corresponding author: igor@mchtr.pw.edu.pl

1. Introduction

Granite is an intrusive igneous rock which is widely distributed throughout Earth's crust at a range of depths up to 31 mi (50 km) (Natural Stone Council, 2008). Granit as a natural stone represents many environmentally friendly attributes, including high esthetic quality, durability, easy maintenance and recyclability at the end of life cycle. Granit is widely used in the construction as an aggregate in production of concrete. Granit is also used in construction of multi-storey buildings for sheathing the building facades (Korobiichuk, 2016). Thus, such material as a finishing material makes it possible to get really high-quality and high-strength facades that will not change their appearance even after a long period of time. Besides, it is used in the making of monuments and memorial plates, and even in the manufacture of design furniture of original style. Despite the fact that this type of granite as the material for furniture making is expensive, the designers use it in their creations.

Medium-grainedred stone looks rich and pompous compared with gray or black stone. However not every type of granite can be "rich" in the full sense of the word. Leznikovskiy Granite is exactly the case when the high price and excellent qualities merged in this fossil of the deepest entrails of the Earth (Natural Stone Council, 2008; Korobiichuk, 2016; Ukrheolohostrom, 2000; Leznykivsky granite career, 1984).

Leznikovskiy graniteofthe trademark Maple Red is mined in Zhytomyrs'ka oblast (Ukraine),Volodars'k-Volyns'kyi region, village Lezniki. This deposit is one of the hardest, thus it is difficult to extract its minerals. This factor, as well as an incredibly time-consuming and expensive stone processing, has made it one of the most expensive granites in this category (Bakka, 1974).

Fig. 1. Leznikovskiy granite of the trademark Maple Red

2. Experimental investigation of Leznikovskiy granit

Since Leznikovskiy stone is extracted at the operating crushed-stone quarry, the question arises: how to determine the strength of natural stone of products without destroying them. This work aims to address the issue.

In the process of the study the natural stone samples were taken from three sections of the eastern part of the quarry, the bottom of the quarry and the western part (Fig. 2).

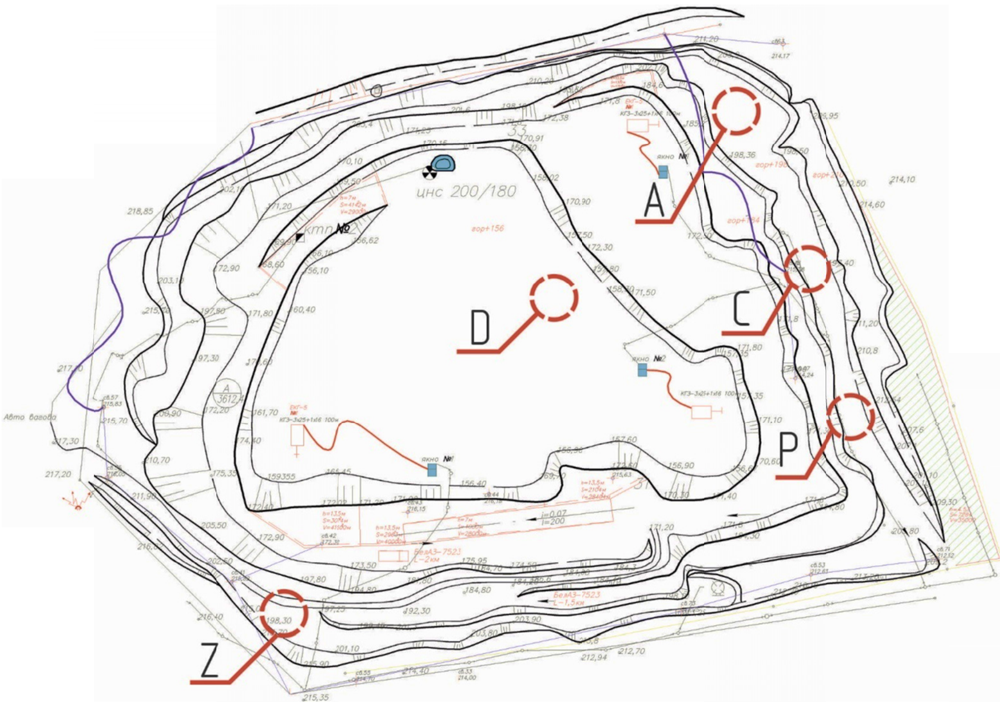

Fig. 2. The scheme of sampling on the quarry plan
A, C, P, D, Z – the group numbers of selected samples

Square bars (Fig. 3b) were cut from the selected samples (Fig. 3a).

The samples of natural stone were conventionally divided into four groups (Fig. 4). The samples with a pink tinge were attributed to a group 1. This group can be attributed to the weathered rock or those which were exposed to corrosion. The rocks which have a pale pink colour that differs from the declared trademark of the quarry were attributed to a group 2.The rocks which colour corresponds to the declared trademark (fresh rock) were attributed to a group 3. The rocks that have a slight deviation of the colour from the declared trade mark were attributed to a group 4.

The samples of different colours were taken from different parts of the quarry. The samples were tested for tension and compression (Korobiichuk & Kisyel, 2012; European standard EN 1926:2006, 2006) (Fig. 5). The analysis of the data showed that the samples 1 have the lowest compressive strength and tension, the samples3 – the highest.

a *b*

Fig. 3. Type of natural stone samples
a – the kind of the sample selected at the quarry; b – the form of the stone bars made of the quarry samples

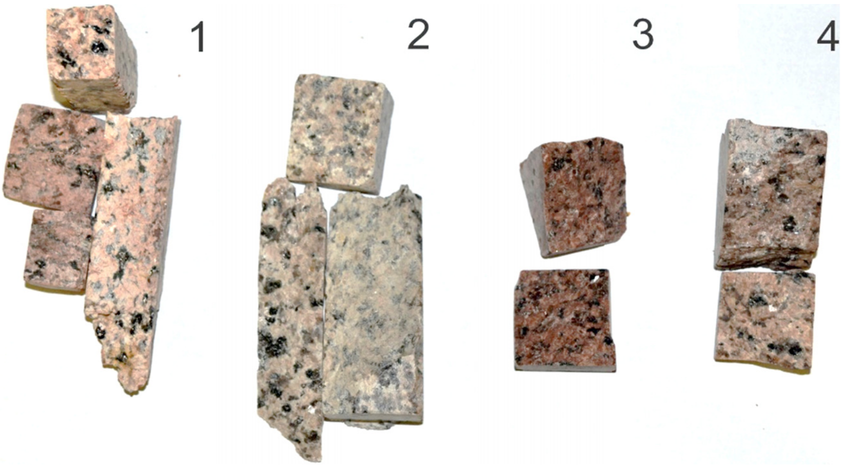

Fig. 4. Division of the samples by colour

Before the test for tension and flection the surface sounding of the samples was carried out. The average results are shown in Fig. 6.

There were tested 31 samples of fresh rock on compression according to standard techniques (Korobiichuk & Kisyel, 2012). Received data are shown in Fig. 7. After the analysis they were sorted to groups (A, C, P, D, Z) and averaged.

The evaluation results on the compression strength of the rock show (Fig. 8), that the strongest rocks are from the western part of the quarry – Z. The less durable samples are D, these samples were collected from the bottom of the quarry. This variation of data can be explained by the

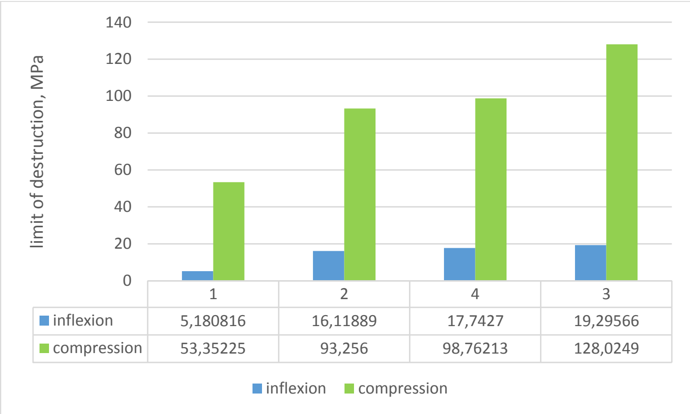

Fig. 5. Average data of rock strength
1, 2, 3, 4 – Classification according to Figure 4

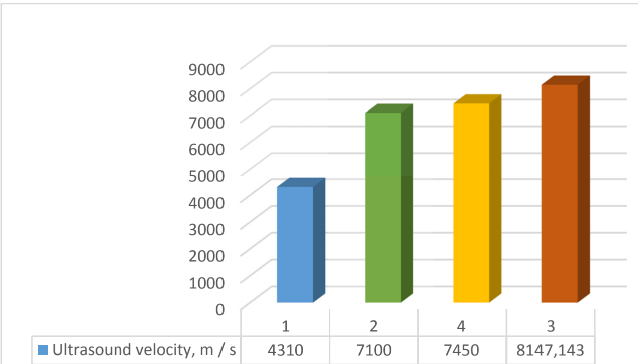

Fig. 6. Average data of ultrasonic surface sounding of granite samples without loading

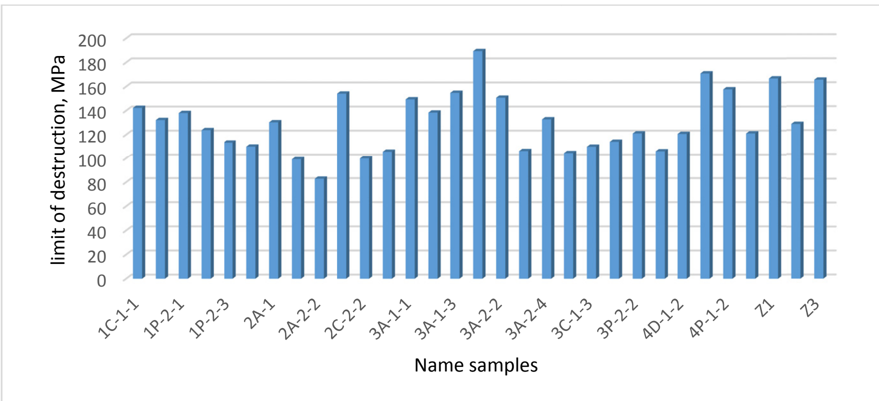

Fig. 7. Compressive strength of rock

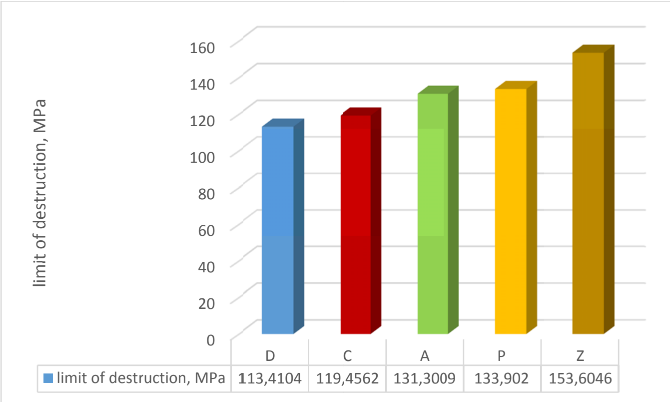

Fig. 8. The averaged results of the strength of the fresh rocks samples from different parts of the quarry
A, C, P, D, Z are the rock samples taken from the quarry areas according to Fig. 2

influence of the technology of mining operations that are connected with explosions. Thus, the areas, which are far away from the mining operations, have stronger rocks.

The samples which corresponded the trademark in colour were taken to study the dependence of compressive load on the natural stone samples and the velocity of sound, and the following methodology (European standard EN 13161:2001, 2001; *Guidelines for the determination...*, 1970; Korobiichuk, 2011) of conducting the experiment was used:

I. Workplace preparation for tests, all the necessary equipment was installed near the press.
II. The velocity of the longitudinal wave V_{work} is was measured in all the available samples of the tested rock.
III. The sample was set under the press (Fig. 9). Thus, the acoustic contact of ultrasonic sensors with the sample is the best. For this purpose, the device with the handle for surface sounding of instrument Pulsar 2.1 was used (*Catalog Pulsar 2.1*). For investigation of the dependence of the velocity and attenuation of the longitudinal waves in the direction

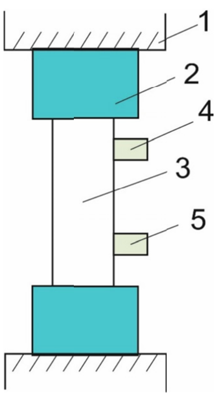

Fig. 9. The schemes of measuring the velocities by longitudinal profiling method
1 – loading device (press); 2 – matrix; 3 – the test sample; 4 – radiator; 5 – receiver

perpendicular to sonic, ultrasonic sensors are fixed in the central part of the sample for the entire test period.

IV. The load equal $0.1\sigma_{br}$ was created in thesample (where σ_{br} is the breaking tension). The first timing is taken.

V. Using the intervals equal $0.1\sigma_{br}$, the voltage in the sample was adjusted to $(0.4\text{-}0.5)\sigma_{br}$, then the sample is discharged at the same intervals to the voltage equal $0.1\sigma_{br}$. At the same time the indications are taken after each interval.

VI. The sample was loaded to destruction after the first cycle of charge-discharge. The indications of time and amplitude are taken at intervals $(0.1\text{-}0.2)\sigma_{br}$. The results of the measurement are shown in Fig. 10.

In some cases, ultrasonic velocity drops sharply before the destruction (Cerrillo et al., 2014; Vasconcelos et al., 2008). Growth of ultrasonic wave propagation in the samples can be explained by the fact that the voids and pores are compressed under the pressure in natural stone. In some samples, the speed was increased to a certain level and it was constant up to destruction. On average, the velocity of the ultrasonic wave is increased for a given trademark of granite by 8-12%.

The propagation velocity changes depending on the pressure on granite samples can be described by the formula:

$$v = 167.47\ln(P) + 7379.7, \text{ m/s}$$

where v is the surface wave propagation velocity, m/s; P is loading onthe sample, MPa.

Thus, building elements which are made of natural stone can be diagnosed during the installation, it is necessary to mark the typical points of sounding, as granite has heterogeneous structure and the propagation velocity of ultrasonic waves in one construction can vary. In the constructions that have already been mounted it is possible to diagnose their strength only approximately.

The data obtained in this publication will allow the authors to continue the study of this type of granite and other trademarks of granite and building materials.

Conclusions

1. It has been determined that within one quarry there could be the types of granite different in their properties both in colour and strength;

2. The most durable is the indigenous granite (granite colour that corresponds to the trade mark);

3. The strength of the granite, which is prone to corrosion, is more than 50% of the indigenous granite;

4. The strength of the granite, which has a colour that differs from the declared trademark, is lower than of the indigenous granite by 10-15%;

5. The strength of the indigenous granite in different parts of Leznikovskiy quarry varies within wide limits (50-70%), it is obvious, that the technology of granite extraction directly influences the stone strength;

6. The propagation velocity of surface waves in Leznikovskiy granite depends on its strength;

7. The dependence of propagation of the surface ultrasonic wave in the indigenous granite on the compression force is described by a logarithmic function;

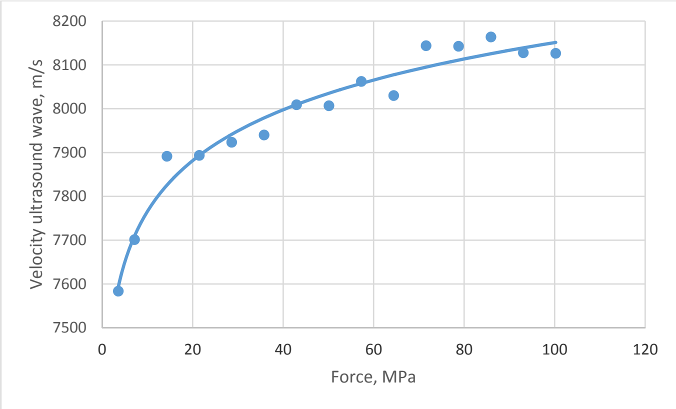

Fig. 10. The dependence of propagation velocity of the ultrasonic wave on the load on fresh rock samples (3 in Fig. 3)

8. Within the same product made of Leznikovskiy granite due to heterogeneity of the structure of the ultrasonic velocity can vary between 10-15%, so it is necessary to fix the points of the sensors.

References

Natural Stone Council, 2008. Granite Dimensional Stone Quarrying and Processing: A Life-Cycle Inventory.

Korobiichuk I., Korobiichuk V., Nowicki M., Shamrai V., Skyba G., Szewczyk R., 2016. *The study of corrosion resistance of Pokostivskiy granodiorites afterprocessing by various chemical and mechanical methods*. Construction and Building Materials, 114, 241-247.

Ukrheolohostrom, 2000. *Local report in terms of reserves in areas of the western and the eastern*.

Leznykivsky granite career, 1984. *Lyznikivskyy granite for extraction of crushed stone and along the block of stone in Volodarsk -Volyn region in the Zhytomyr region*. Book 1, 180.

Bakka N., 1974. *Prediction of blockiness in the fields of facing granite by mountain geometric methods*. Dnepropetrovsk, 166.

Korobiichuk V., Kisyel O., 2012. *Geometrization of associated minerals in conditions of Leznykivsky granite career; and and mining geometric analysis of its parameters*. Bulletin of the National University of Water Management and Nature Resources Use, 2 (58), 175-184.

European standard EN 1926:2006, 2006. *Natural stone test methods – Determination of compressive strength*. 2006.

European standard EN 13161:2001, 2001. *Natural stone test methods – determination of flexural strength under constant moment*.

Guidelines for the determination of stress state of rocks in the array ultrasonic method, (1970). Mining and Metallurgical Institute, Apatity.

Korobiichuk V., 2011. *Principles of interpretation of ultrasonic measurements in tight array*. Bulletin of the National University of Water Management and Nature Resources Use, 4 (56).

Catalog Pulsar2.1http://www.interpribor.ru/devices/catalog/pulsar21_22.pdf.

Cerrillo C., Jimenez A., Rufo M., Paniagua J., Pachon F.T., 2014. *New contributions to granite characterizationч by ultrasonic testing*. Ultrasonics 54 156-167. doi: 10.1016/j.ultras.2013.06.006.

Vasconcelos G., Lourenco P.B., Alves C.A.S., Pamplona J., 2008. *Ultrasonic evaluation of the physical and mechanical properties of granites*. Ultrasonics 48, 453-466. doi:10.1016/j.ultras.2008.03.008.