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INFLUENCE OF VOLUME WEIGHT ON GABBRO UNIAXIAL COMPRESSION STRENGTH

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ABSTRACT

Jablanica gabbro represents the highest quality architectural building stone in Bosnia and Herzegovina. Knowledge of the physical and mechanical characteristics of gabbro is an important prerequisite for the proper usage of this rock material. This paper presents a brief review of the geological characteristics Jablanica gabbro deposit, with distinct mines where exploration is performed. Paper presents the study of volume weight and uniaxial compressive strength of the standard samples, with a detailed statistical processing of the results. The obtained values of volume weight and uniaxial compressive strength are placed in correlation, in order to define the relationship between these two parameters. Correlation analysis did not produce the characteristic correlation, but pointed to the existence of dependence between these two parameters.

Key words: *gabbro, uniaxial compression strength, volume weight*

INTRODUCTION

Jablanica gabbro is exploited for more than a hundred years and it is one of most appreciated non-metallic mineral resource in the former Yugoslavia. Many well-known monuments in the former Yugoslavia, and many in the world, are made of Jablanica gabbro. Gabbro is an igneous rock of extraordinary physical and mechanical characteristics, which enables wide application in architecture and construction. The gabbro deposit has been the subject of controversy between various geologists for many years, starting from the definition of its forms, to the determination of age, or time of appearance [1]. On the gabbro deposit there are five active mines, where mining is performed on gabbro as architectural stone. A large amount of excavated material, as discarded material, is being deposited on the slope beneath the quarry, due to the inability of utilization of this material as architectural stone. Deposited gabbro is now used as crushed rock. When testing the physical and mechanical characteristics of gabbro, from particular quarry, there were differences in the behavior of rock material in particular, the standard prescribed, tests. Thus, material from one quarry has a different value of strength in relation to material from other quarry.

GEOLOGICAL CHARACTERSITICS OF THE DEPOSIT

Gabbro massif Jablanica occupies an area of about 17 km². Valley of Doljanka River represents the northwestern and western border with Triassic limestone, while the massif is cut by the river Neretva.

Gabbro mass penetrates Triassic sediments, and for the most part is in contact with kampilic marl limestone, marl and limestone. On the west side is surrounded by permotrias sediments and partially Middle Triassic limestone, while the southern part of the gabbro in touch with Midlle and Upper Triassic dolomites and limestone.

According to petrologic research it was found that the composition of the gabbro massif consists of: plagioclase, hypersthenes, olivine, biotite, clinopyroxene, amphibolites and in rare cases quartz. Gabbro occurs most often in the form of spherical blocks of fresh gabbro. On the surface outcrops, the rock is gray on fresh fracture. Because of the tectonic contact between gabbro Jablanica with the surrounding rocks, it is difficult to determine the shape of gabbro intrusive, and also its position on the stratigraphic way. According to intrusive primary compared to Tovarnica, you can see the contacts that are quite steep, based on which we can assume that this is a stock, as it was claimed by the Austrian geologists a long time ago.

Gabbro grain size is from 1-4mm, the structure is panidiomorf, while the texture usually massive. Because of the influence of mineral composition, in gabbro mass Jablanica stands out more varieties of gabbro: olivine, normal, hipersten, biotite and amphibolites.

Jablanica gabbro is bound by the age with Middle Triassic magmatism, because the isotopic method determined the age of 250-253 million years, which belongs to the Permian, while the geological research placed between the Upper and Lower Triassic [2].

GABBRO DEPOSIT

At the Jablanica gabbro intrusive exploitation takes place in four quarries (Car, Suljo Čilić, Padešnica and Velja stijena), which are located on the left bank of the Neretva River (Figure 1). In the intrusive, three categories of gabbro which represent a useful component occur. In this rock mass, gabbros with massive texture occur, which are usually less cracked and blocks can be up to several hundred m^3.

Gabbros with a foliation represent intact gabbro mass with small cracks and the usage of the rock mass is greater. Problems arise if this category gabbro occurs in the area of the fault zones, because then in the gabbro thin parallel and frequent cracks, which reduces the number of usable blocks [2].

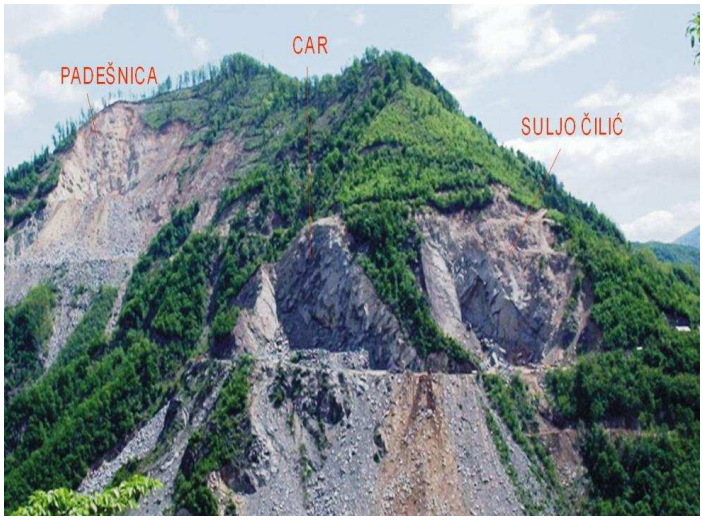

Figure 1. Panoramic wiev of left bank of Neretva with mine quary Padešnica, Car i Suljo Čilić

Majdan " Suljo Čilić " located on the left bank of the Neretva River. Basic plateau is at 440m above sea level and the height of the working slope is 100m. Working front is basically about 90 meters wide and narrowing towards the working levels. The opening of this quarry was affected by the quality of the rock mass that occurs in this zone. Most of the rock mass in the quarry zone „Suljo Čilić“ is

presented monolithic gabbro. The widespread use of gabbro from this deposit began in 1979, because the mineralogical composition of this variety of gabbro did not meet the requirements that have ruled previously on the market. Gabbro from the quarry "Suljo Čilić" is mostly gray color with dark gray and bright stripes, mainly medium grain [3].

Majdan "Car" is located little more than 50 m from the quarry "Suljo Čilić", with working plateau about 10 m higher in relation to the working quarry plateau "Suljo Čilić". Contours of the open quarry take the form of a triangle and a longer open profile in the direction of the deposit "Suljo Čilić". Gabbro in quarry "Car" is a medium grain, gray color with a foliation like gabbro in the deposit "Suljo Čilić", so it is possible that it is the same variety of gabbro. Dipping of the foliation in the quarry "Car" is generally 32 / 50-60˚.

The very rock mass in the quarry "Car" is intersected by a series of parallel cracks that diagonally cross foliation, with elements 220 / 50˚.

Due to the cracking of the rock mass, ie the large number of cracks appear, exploitation blocks from this quarry is conditioned by the relationship between the crack and the orientation of foliation that affects the quality of rock blocks. Subvertical cracks occur in the deposit which extends parallel to the foliation while between them fresh hornbeam monolithic blocks, whose size depends on the spacing between the cracks, can be extracted.

Majdan "Padešnica" is located at a higher elevation in relation to the quarry "Car", with the main plateau at the altitude of 505m. Majdan has the shape of an equilateral triangle and in it there are two horizons (505-550 , 550-650 nm). From the aspect of engineering-geological characteristics of the quarry all varieties of gabbro are present. The largest part of the rock mass in the quarry is presented by cracked gabbro. Almost the entire horizon 505-550m is represented by cracked gabbro while grussified gabbro occurs at a higher horizon. In grussified gabbro spherical blocks appear which during heavy rains slide ("float") in altered rock mass. These blocks are often of good quality and are further treated in the commercial blocks of regular shape. In contrast to the quarry "Suljo Čilić" and "Car", from the quarry "Padešnica " foliation is not clearly expressed and in some parts is practically invisible. The cracked Gabbro is dominated by vertical and subvertical cracks with elements 110/70˚ and 190/80˚. Cracks are especially pronounced at the lower horizon and are distinguished by the joint continuity and spacing in relation to cracks from quarry "Car" and "Suljo Čilić". In some parts of the distance between discontinuities is so small it looks like schistose. In this quarry the variety "Padešnica crna" is occurring.

Majdan "Velja stijena" is located with the main plateau at an altitude of 530m with working slope height of 130m. From the aspect of engineering-geological characteristics on the quarry all varieties of gabbro can be extracted. Quarry has the shape of an equilateral triangle. Most part of the quarry is represented by cracked gabbro, while on the west side of the quarry grussified gabbro with blocks spherical occurs. Fe-Mg minerals in gabbro, can appear in the form of spherical accumulation. Foliation in gabbro quarry „Velja stijena“is clearly expressed with orientation 50/50-70˚. Orientation constituents in the material are usually parallel. The dominant set of cracks in this quarry has a dipping 80 / 84˚ [3].

VOLUME WEIGHT OF GABBRO

Volume weight is one of the most important physical properties of the rock mass. Volume weight is equal to the mass of the rock (m) and its volume (V). Petrologists, instead of the concept of Volume weight, are using the concept of volumetric density. Influential factors on Volume weight are: mineral composition, assembly (structure and texture) and porosity [4]. All these factors are conditioned by the process of the formation of the rock mass, which may, for example, due to rapid cooling of magma followed by spreading water vapor obtain porous structure and vice versa. Volume weight is, according to the standards expressed in (kN/m³), while the density is expressed in (g/cm³). For each quarry in Jablanica gabbro, the tests of volume weight were conducted, where the mean volume

weight and statistical distribution of the results are determined. Tests of volume weight were made for the comparison of volume weight from individual quarries and correlation of the data obtained in order to determine the possible mutual influence of volume weight on the uniaxial compressive strength. Tests of volume weight, for each quarry, were carried out on samples of dimensions 5x5x5 cm, which were obtained by cutting, by wet process, larger pieces of the rock mass. Dimensions of the samples were determined by standards for testing technical and decorative stone [5]. Below are the results of volume weight test for each quarry individually, where γ represents the volume weight. In addition, a statistical distribution of values and confidence coefficient [6], for the measurement of the mean volume weight are shown (Figure 2, 3, 4, 5, 6) [7].

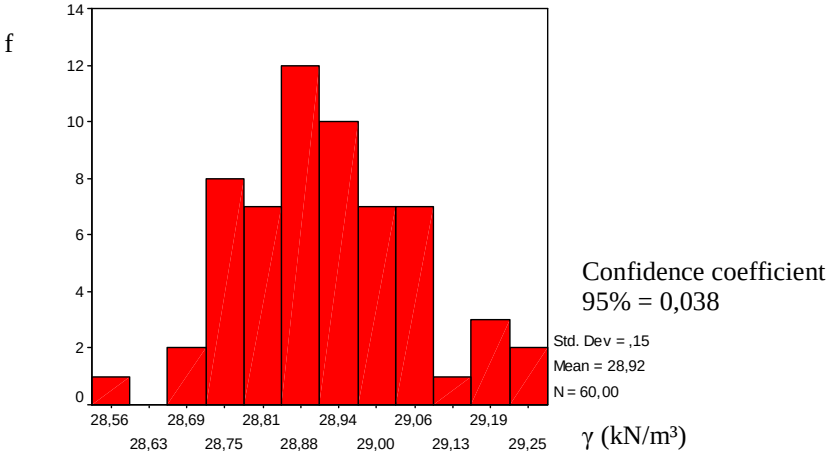

Figure 2. Display of statistical distribution volume weight measurement results in quarry " Car "

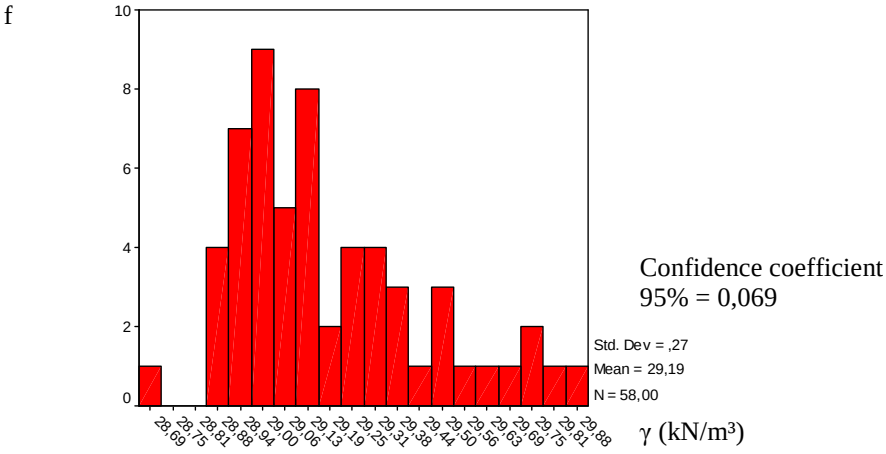

Figure 3. Display of statistical distribution volume weight measurement results in quarry "Suljo Čilić"

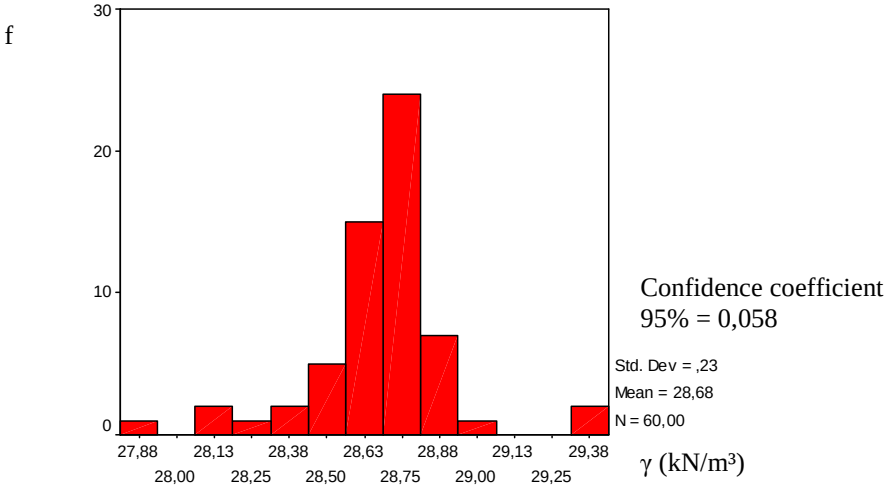

Figure 4. Display of statistical distribution volume weight measurement results in quarry " Velja stijena "

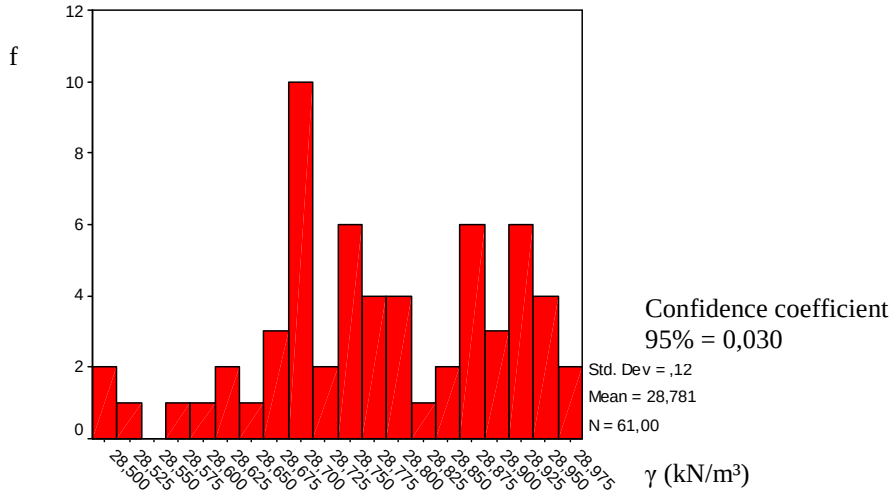

Figure 5. Display of statistical distribution volume weight measurement results in quarry " Padešnica "

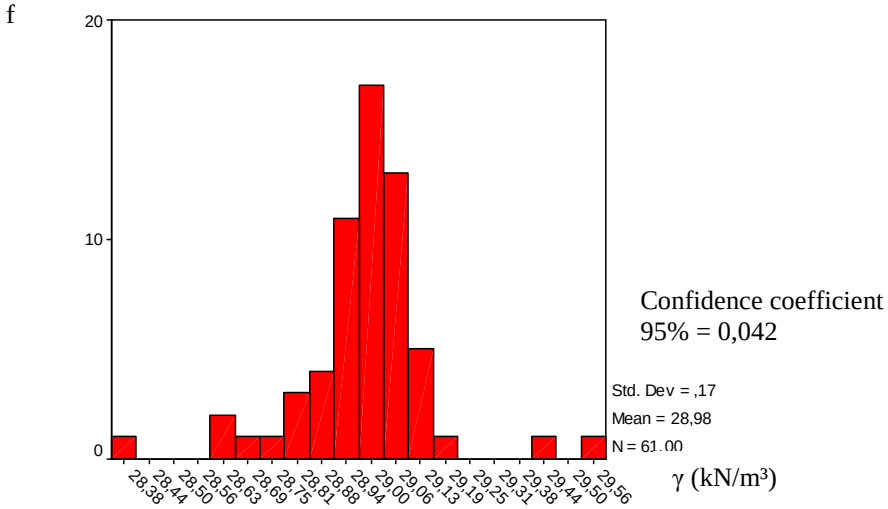

Figure 6. Display of statistical distribution volume weight measurement results in quarry " Padešnica crna"

UNIAXIAL COMPRESSIVE STRENGTH OF GABBRO

The strength of the material is defined as material's resistance to applied forces that deform the material and cause it to rupture.
For strength, we can say that it is a relative term because it can be defined only with the knowledge of the influencing factors on the strength, of which as important can be extracted [3]:

- Sample size, which is determined by man according to the apparatus for testing or according
- to the standard that he uses
- The shape of the sample, cylindrical samples from cores or samples cut from the block (prismatic
- and cubic)
- Quality of surface along which the load is applied, (subject to the terms of cutting, polishing
- surfaces, etc.)
- Size of lateral load (if the lateral load is greater the greater is the strength of the sample)
- Ratio between the height of the sample and the sample width (greater height in relation to the width
- the lower strength)
- Rate of loading (experiments that last for a shorter period of time give higher strength values than

- experiments that last longer period of time, for samples of the same size and shape)
- Porosity of rocks (higher porosity - less strength, because along the pores created by the secondary
- cracks in the process of loading)
- Moisture content (with the increase of moisture strength decreases)
- Structure and texture of samples and mineral composition

Tests of uniaxial compressive strength of Jablanica gabbro samples were carried out on samples with dimensions 5x5x5 cm, which are prescribed by the relevant standards. The study included 300 test samples and 60 test samples for each quarry in gabbro massif. All samples were tested in exactly the same conditions, the same apparatus, in order to eliminate some of the influencing factors listed. Samples from all quarries were examined under a press, in the measuring range of 1,000 kN with accuracy readings of force at fracture of 1 kN and with the same degree of loading per unit time. The compressive strength was obtained as the force exerted on the surface of the sample at the time of fracture. Distribution of value measurement of compressive strength is shown in the histograms of distribution according to selected parameters. Each "mode" or pillar in the histogram, indicating a minimum of one influential factor on strength. The results were statistically analyzed and calculated with a confidence coefficient for computationally obtained mean values [6]. The tables also express the percentage of probability that the mean of the measurements is found in, under specified +/- range of results (eg. mean value 244 MPa, 95 % is likely to be the mean value of future measurements found in the range of 244 +/- 7.7 MPa) [7]. Tests were conducted on samples in the dry state, and test results for each quarry are shown below (Figure 7, 8, 9 10, 11).

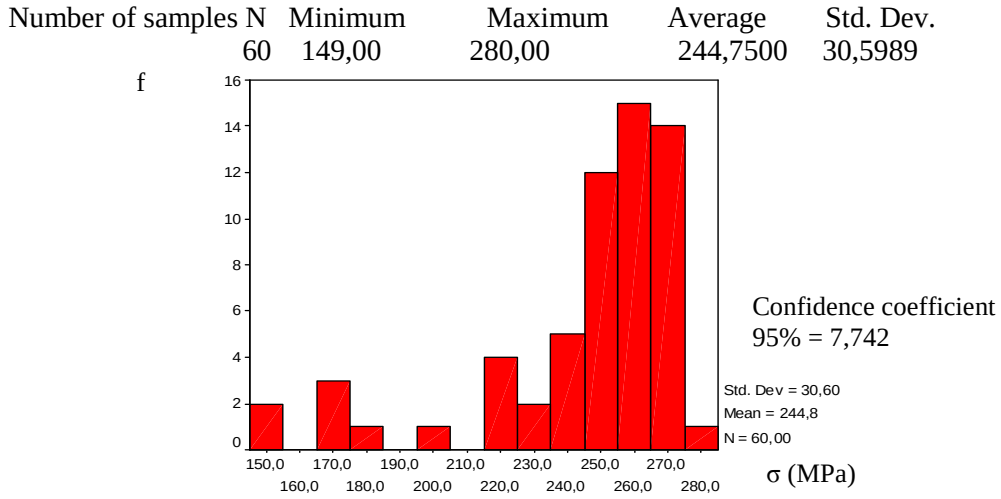

Figure 7. Histogram distribution of uniaxial strength for quarry „Car“

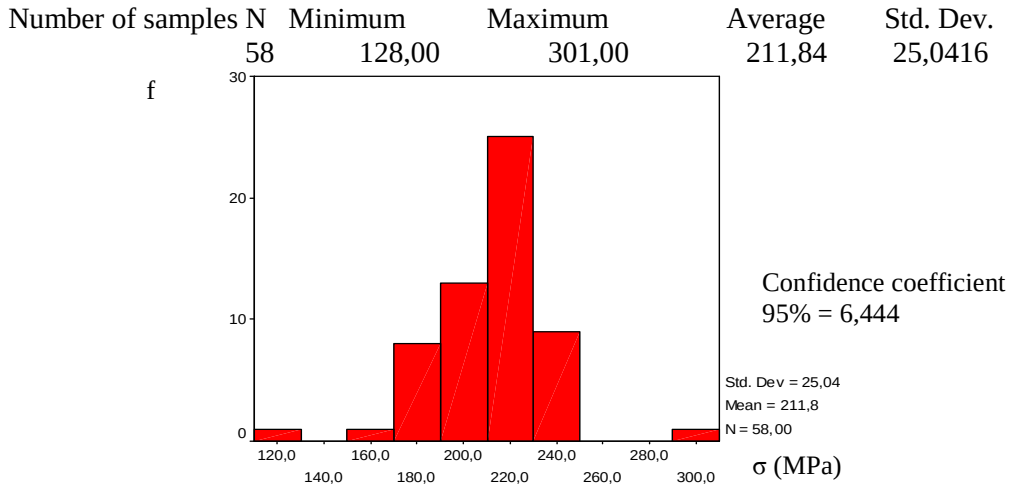

Figure 8. Histogram distribution of uniaxial strength for quarry „Suljo Čilić“

Number of samples N	Minimum	Maximum	Average	Std. Dev.
60	143,00	268,00	225,2500	28,1579

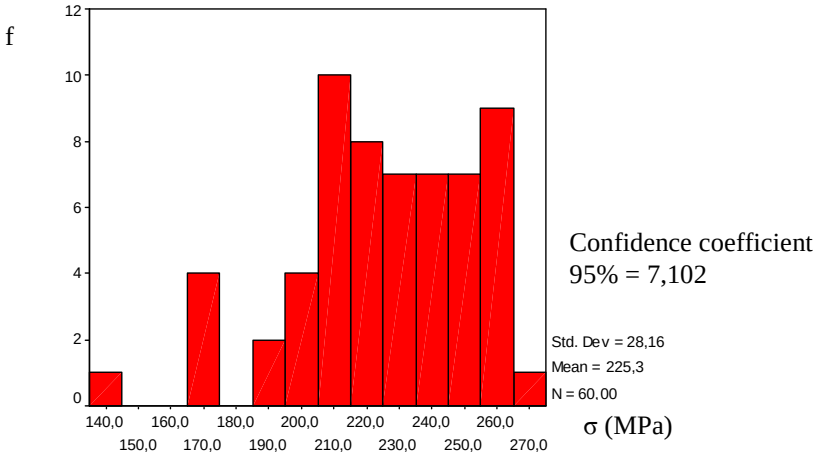

Figure 9. Histogram distribution of uniaxial strength for quarry „Velja stijena“

Number of samples N	Minimum	Maximum	Average	Std. Dev.
58	181,00	304,00	256,586	28,5006

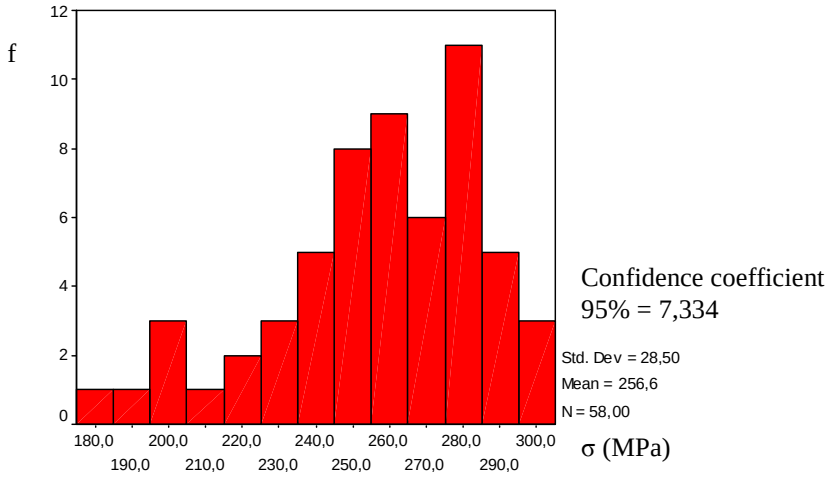

Figure 10. Histogram distribution of uniaxial strength for quarry „Padešnica“

Number of samples N	Minimum	Maximum	Average	Std. Dev.
60	171	301,00	269,416	25,5205

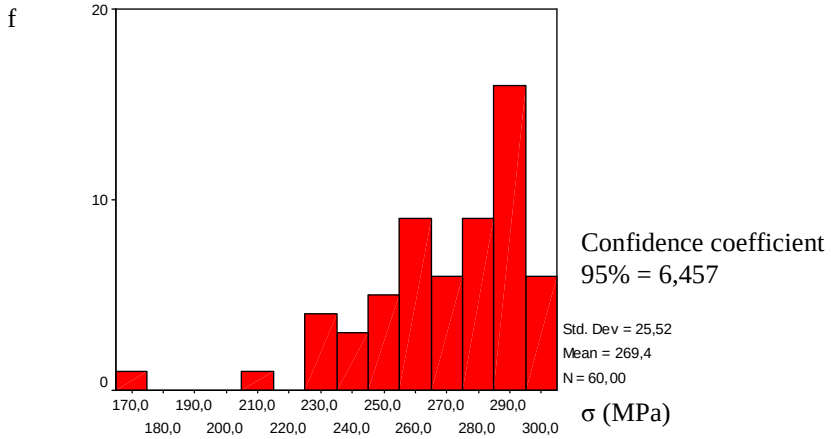

Figure 11. Histogram distribution of uniaxial strength for quarry „Padešnica crna“

CORRELATION BETWEEN UNIAXIAL COMPRESSIVE STRENGTH AND VOLUME WEIGHT

The volume weight of rock material, expressed through volumetric weight affects the strength of the rock. For example, as the material is thicker, it has a higher volume weight, the rock strength is greater. The diagrams present relations between two parameters for each gabbro quarry (Figure 12, 13, 14, 15) [7].

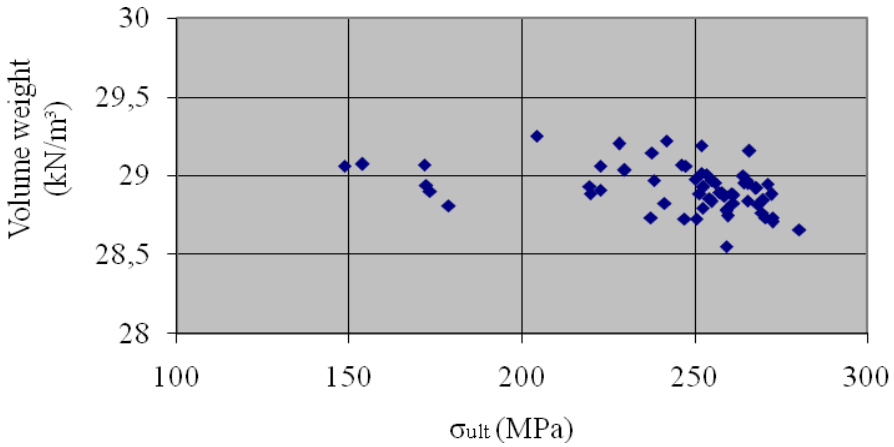

Figure 12. Correlation of volume weight and uniaxial compressive strength of gabbro from quarry "Car"

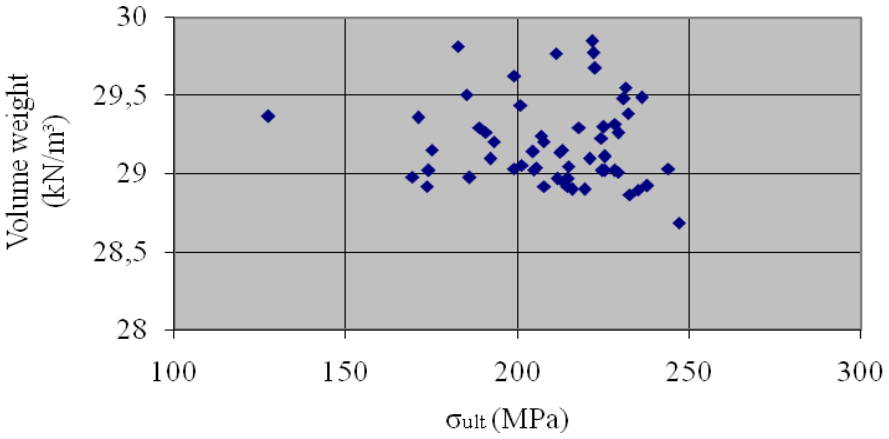

Figure 13. Correlation of volume weight and uniaxial compressive strength of gabbro from quarry "Suljo Čilić"

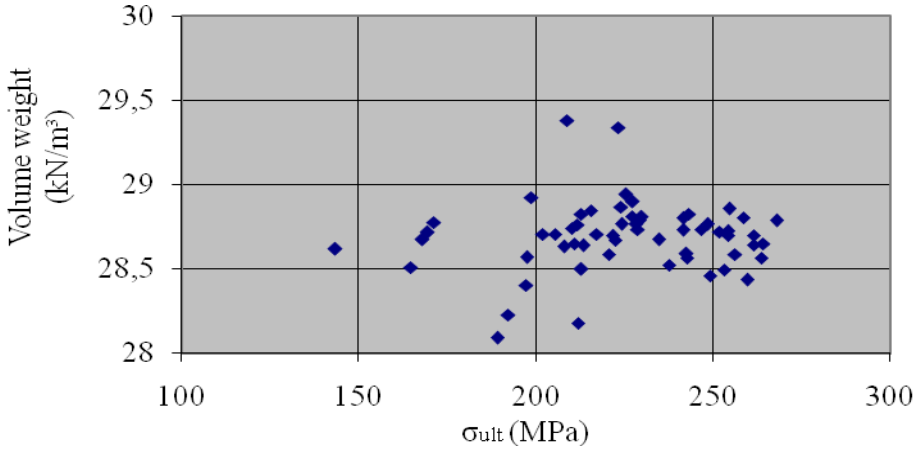

Figure 14. Correlation of volume weight and uniaxial compressive strength of gabbro from quarry "Velja stijena"

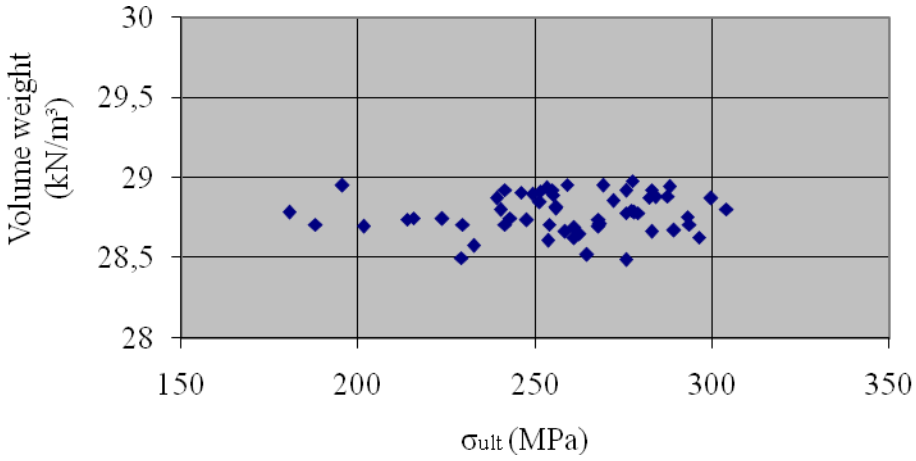

Figure 15. Correlation of volume weight and uniaxial compressive strength of gabbro from quarry "Padešnica"

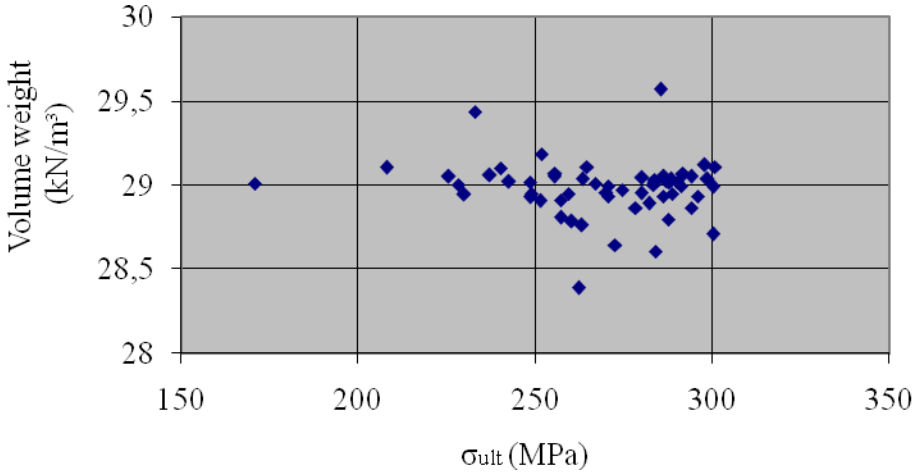

Figure 16. Correlation of volume weight and uniaxial compressive strength of gabbro from quarry "Padešnica crna“

CONCLUSION

The existence of a correlation between volume weight and uniaxial compressive strength would allow us, on the basis of measuring volume weight of the samples, to determine which of them will have a higher or lower strength than the second sample. The correlations diagrams between uniaxial compressive strength and volume weight from deposit of Jablanica gabbro, show the differences between the diagrams for individual quarries. The biggest scatter of results is present in the diagram related to gabbro quarry "Suljo Čilić" (Figure 13), while the least scatter of results is shown in the diagram related to the quarry "Padešnica crna" (Figure 16).

This may be due to differences in grain size that build the tested specimens, because the quarry " Suljo Čilić" gabbro classifies as extremely large-grained, and in the quarry "Padešnica crna" as a fine-grained and middle-grained gabbro. Volume weight, on diagrams for the quarry " Suljo Čilić", varies in the range of 1 kN/m³, while strength varies up to 80 MPa, while the diagram measurements at other quarries have larger range of strength values (up to150MPa), and lower range of volume weight (to 0,5kN / m³)(Figure 13). However, regardless of a small range of volume weight values, there are wide variations in the value of the uniaxial compressive strength, so that samples having the same volume weight have a difference in strength of 100MPa. This is the most present in the diagram related to gabbro quarry "Padešnica crna" where almost all measurements are on one line, because the volume

weight varies in a very small range (+/-0,2kN/m³), while strength varies in the range of 80 MPa (Figure 16).

Slightly wider scattering of volume weight is present in the diagrams related to gabbro "Padešnica" (Figure 15) and "Car"(Figure 12), while the scattering in gabbro strength for this quarry is up to 120 MPa. Larger scattering of volume weight results are present on diagram related to the quarry "Velja stijena" (Figure 14), and the largest in the diagram related to gabbro quarry "Suljo Čilić", while the scattering of uniaxial compressive strength gabbro is slightly less (up to 80MPa). The values of correlation coefficients for all the data presented in the diagrams are very close to zero. Based on this result arrangement on diagrams and low value of the correlation coefficient, it can be concluded that there is no clear correlations between volume weight and uniaxial compressive strength of the tested specimens from deposit of Jablanica gabbro.

Research of factors influencing change in volume weight, especially in the distribution diagrams where there are multiple modes, are focused on the impact of structural composition of gabbro, which certainly has a direct impact on changes in strength. Although not proven correlations between volume weight and uniaxial compressive strength, this work opens the series of questions that require scientific explanation and response to this phenomenon, which is the subject of further investigations [7].

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