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Diabase from Drača open pit mine in central Serbia - quality assessment for building stone purposes

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Diabase from Drača open pit mine in central Serbia - quality assessment for building stone purposes

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Abstract. Vast masses of basic rocks are present as tectonic blocks and slices along the Eastern deep fault of the Vardar zone of Serbia. They are predominantly comprised of gabbro, with smaller part made up of diabase, and occurrences of granite, aplite and pegmatite dykes. Basic rock masses are trending along the line Kragujevac (Ždraljica)-Velika Pčelica-Bogalinac ~8 km west of Rekovac. A significantly smaller diabase massif is present along the same tectonic line, further toward SE, at Prevešt village by Kalenička River, approximately 13 km south of Rekovac. Drača open pit mine is situated in this diabase massif. Geologic explorative works have confirmed the reserves of 1 846 695 t of stone mass for building purposes. For over a decade, Drača mine has been producing various types of building stone, mainly graded stone aggregate with favourable physico-mechanical properties for road-construction works. Chemical analyses and petrographic study have shown typical composition and fabric for this type of rock. Main constituents are plagioclase and pyroxene, with opaque minerals as accessory and varying secondary minerals – chlorite, calcite, in some places epidote and limonite. Pyrite enrichment is visible in some areas of the massif. Chlorite, calcite, epidote and pyrite are the products of propylitic alteration. Although products of alteration are present throughout the rock mass with variable intensity, as is typical for the basic rocks of the former ocean floor sequences, petrologic properties are favourable for building stone purposes. Physico-mechanical properties of diabase have favourable values and varying scattering degrees. Dry state uniaxial compressive strength average values from seven analyses vary in the range 130-169 MPa. Resistance to abrasion average values vary in the range 9.04-17.07 cm³/50cm². Apparent density varies within the span 2759-2926 g/cm³ and real density 2804-2951 g/cm³. Water absorption values 0.08-1.04 %. Resistance to weathering through testing of stability using Sodium-sulphate values vary from 0.00 to 0.15 % and through frost resistance from 0.00 to 0.04 %. Porosity values are almost constant at 0.8 %. In more altered parts of the rock mass, porosity reaches 1.6 %. Graded crushed aggregate has favourable values of Los Angeles coefficient 14.2 and 14.3 % for gradation B. Taking into consideration all performed tests and analyses, it is concluded that diabase from Drača mine can be used as a building stone for production of aggregate for use in concrete and for road-construction (asphalt paving mixtures for moderate, light and very light traffic load as a top wearing layer; for lower and upper bearing layers; for classic and modern road foundations); for production of crushed and hewn stone for building; crushed stone for railroad ballast. Also, it can be and is used as a raw material for production of stone wool for thermal insulation purposes.

1. Introduction

Geology of the axial belt of Serbia is generally shaped by the complex processes of the Vardar ocean evolution – a part of the Neotethys ocean, within the time period of ~180 Ma – from Middle Triassic,



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when the ocean domain started opening, to Upper Cretaceous-Neogene boundary, when it closed through the sequence of convergence-collision-suture formation, and even subsequent obduction processes that lasted until Oligocene-Miocene transition into extension [1]. The ocean closure marked the tectonic structure of Serbia through three main tectonic lines – deep regional faults extending mostly NNW-SSE: the Eastern, the Central and the Western deep faults of the Vardar geotectonic zone [2].

The activated spreading ocean floor (mid-oceanic ridge) sequence is known to include peridotite mantle rocks, gabbro intrusions, basaltic extrusions with diabase and spilite (known as ophiolitic sequence), topped by ocean floor sediments which form ophiolitic melange in further evolution of the closing oceanic domain [3]. The ending of the Vardar ocean evolution through the collision and continued compressional processes resulted in significant thrusting and obduction of its floor formations onto younger formations along the Eastern deep fault of the Vardar zone.

In central Serbia, at approximately 130 km south from Belgrade and 8 km west of Rekovac, the Eastern deep fault is marked by the presence of vast thrust masses comprising ophiolitic blocks and slices that originated at the Vardar ocean floor. These masses are situated along the line Ždraljica-Velika Pčelica-Bogalinac. Their overall surface is around 21 km². Obducted masses comprise elongated tectonic slices of Jurassic ophiolitic melange and ophiolitic sequence mostly made up of basic rocks formation thrust over Cretaceous flysch of Gledičke Mountains. The basic rocks mass is described in the Basic geologic map of Serbia booklet, section K34-7 [4] as "Gabbro-diorite-granite association", said to contain intrusions of pyroxene-olivine and pyroxene gabbros with gabbro-porphphyry veins, diabase rim facies and veins, rare occurrences of granite and quartz-diorite small magmatic bodies and pegmatite and aplite veins.

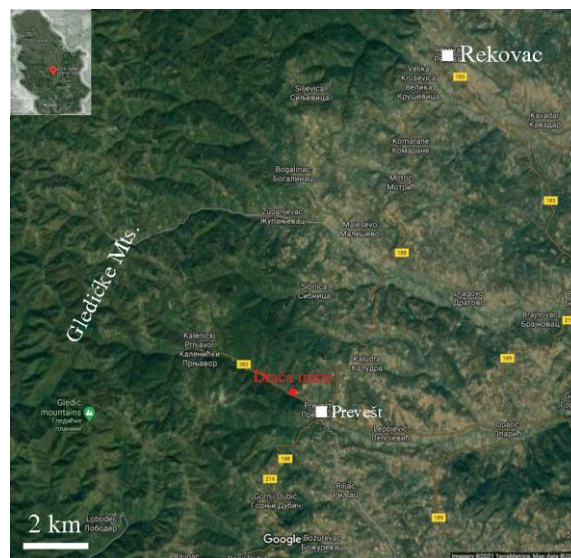


Figure 1. Satellite image of Drača mine location (inset: location in Serbia)

Further along the Eastern deep fault, there is also an isolated smaller mass of diabase, ~13 km south of Rekovac. Its surface barely reaches 1 km². Within this rock mass is an open pit mine Drača, near the village Prevešt (figure 1), opened for the purpose of mining of diabase to be used as a building stone and a raw material for stone wool production. Diabase block is tectonically incorporated and thrust over younger flysch formation and partly overlain by Miocene lacustrine sediments of Levačko-belički basin. The Kalenička River divides the rock mass into two unequally sized parts at the surface (figure 2). The smaller, northern rock mass is the location where exploitation

of stone has been ongoing since 2009. The performed geologic explorative works have proven the reserves of 632863 m³ i.e. 1846695 t of diabase as a building stone [5].

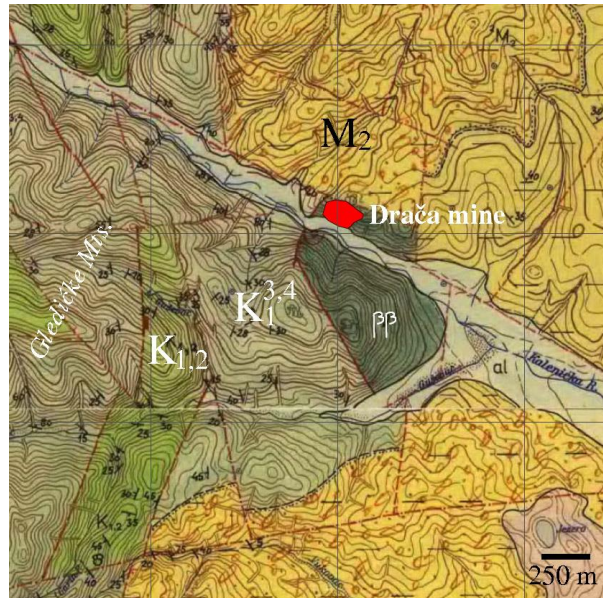


Figure 2. Simplified geologic map of the area around Drača mine (Key: K_{1,2} and K_{1,3,4} – Cretaceous flysch sediments of Gledičke Mts.; M₂ – Miocene lacustrine sediments; ββ – diabase; Modified after D. Nikolić)

2. Laboratory examinations and results

Diabase rock mass properties have been examined in the laboratories of the IMS Institute in Belgrade for the purpose of establishing its potential for use as a building stone. These examinations include petrographic examination, testing of technical (physico-mechanical) properties and chemical analyses.

2.1. Petrographic examination

Petrographic examinations are performed in the Stone and aggregate laboratory of the IMS Institute. Microscopic analysis is performed on thin sections with polarizing microscope Ernst Leitz RP 48.

Macroscopically, the rock is dark gray in colour, with a greenish tinge. In the dark groundmass, very small grains of salic and mafic minerals can be seen, and also (in some samples) aggregations of fine-grained pyrite. Fractures and veinlets are usually less than 1 mm thick, less frequently up to few millimetres. They are variously oriented, and infilled by white and light green precipitates. On being hit, the stone cracks along the fractures or irregularly, forming moderately rough surfaces with sharp edges. Upon contact with cold 5% HCl acid, the stone doesn't show the immediate reaction. In some parts of the rock mass there are secondary veins of varying composition and thickness. Monomineral epidote veins reach up to 10 mm; complex silica-carbonate veins tend to sporadically expand into vugs containing a crystal geode with chalcedony, calcite and/or quartz, ±pyrite. Some geodes can have a central void (within the chalcedony-lined rock walls ±quartz crystals), while the others can be completely filled up by calcite crystal aggregate. Pyrite grains can be fresh or altered. The grains formed around secondary veins, within the host rock, are fresh, while the grains within the secondary veins are mostly oxidised.

Microscopic analysis has shown that the rock consists of plagioclase and pyroxene as main constituents (figures 3 and 4). Plagioclase phenocrysts are elongated prismatic and subhedral. Grain size is most often (1.5x0.3) mm, or smaller. They form typical network of intersecting crystals resulting in ophitic texture. Grains can be fresh or altered in a varying degree. Alteration type of

plagioclase grains is typically calcification and saussuritisation. Pyroxene grains are subhedral to anhedral, filling up the interspaces within the plagioclase network. Grain size is most often (0.3x0.2) mm and up to (2x0.5) mm. Groundmass can be altered in a varying degree – most often chloritised. Accessory and/or secondary opaque (metallic) minerals are present as uniformly distributed small, xenomorphic grains. Secondary minerals chlorite and calcite can be present. When present, small cracks and pores are filled up by fine-grained calcite.

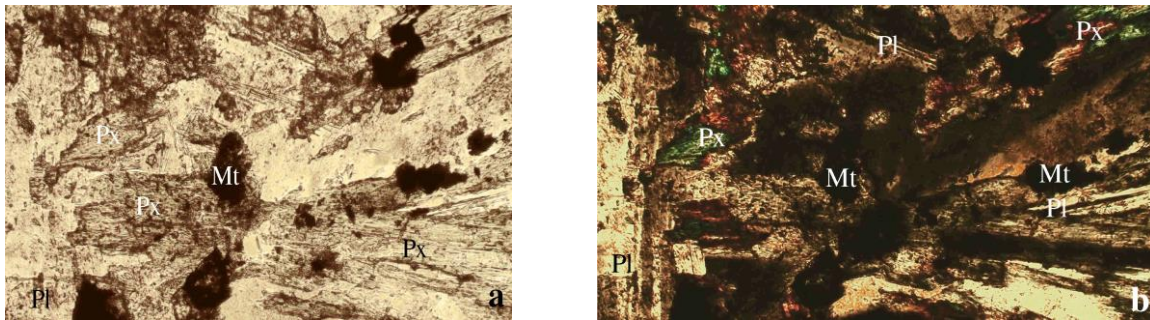


Figure 3. Photomicrograph of the sample 2017: a. PPL, b. XPL (Pl – plagioclase; Px – pyroxene; Mt – opaque metallic minerals). FOV 2 mm

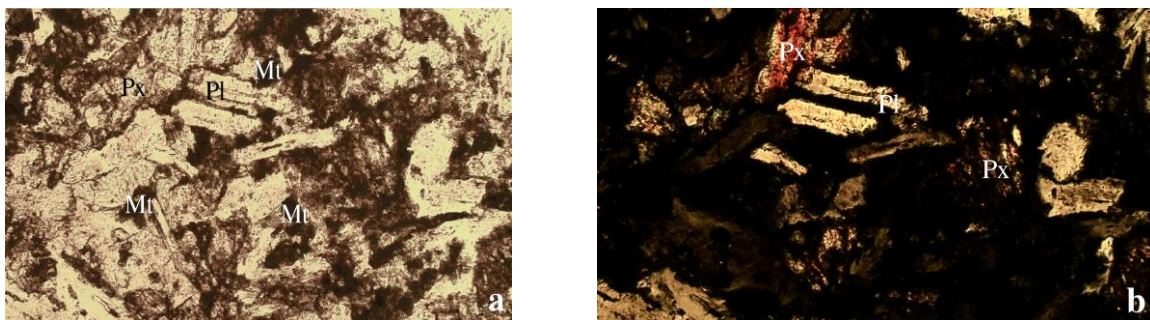


Figure 4. Photomicrograph of the sample 2018: a. PPL, b. XPL (Pl – plagioclase; Px – pyroxene; Mt – opaque metallic minerals). FOV 2 mm

2.2. Testing of technical properties

Testing of the technical (physico-mechanical) properties of diabase rock mass has been performed in the Stone and aggregate laboratory of the IMS Institute on occasion over the time period of several years, providing the sequence of seven analyses. The properties to be tested are prescribed by the Serbian standards. The obtained results are shown in Table 1 as average values. Additional testing of Los Angeles coefficient (resistance to crushing and abrasion), performed on graded aggregate samples has given values of 14.2 and 14.3 % for gradation B.

2.3. Chemical analyses

Chemical analyses (Energy-dispersive X-ray fluorescence) have been performed at Chemistry, mortar and binders laboratory of the IMS Institute. The aim was primarily to establish the contents of main constituents and loss on ignition (Table 2), as a measure of alteration of the rock mass. Three analysed samples include a. the stone sample with the most favourable technical properties ("2017 A" in Table 1), b. the one with the least favourable ("2018" in Table 1), and c. the sample of the rock mass with a secondary hydrothermal vein containing calcite, epidote, pyrite and possibly chalcedony.

Table 1. Results of technical properties testing (average values) with additional remarks on the alterations observed within the rock mass.

Analysis No.	Year of testing	Apparent density (g/cm ³)	Real density (g/cm ³)	Porosity (%)	Water absorption (%)	Dry state compressional strength (MPa)	Resistance to abrasion (cm ³ /50cm ²)	Frost resistance via Na ₂ SO ₄ (%)	Frost resistance via freezing and thawing (%)	Alterations observed on a microscopic level
1	2016 a	2861	2885	0.8	0.31	164	11.56	0.15	0.03	calcitisation and saussuritisation of plagioclase and chloritisation of matrix
2	2016 b	2834	2857	0.8	<u>0.08</u>	161	9.99	0.04	0.01	intense alteration of plagioclase, pyroxene and matrix
3	2017 a	2833	2857	0.8	0.23	<u>169</u>	<u>9.04</u>	<u>0.00</u>	<u>0.00</u>	calcitisation and saussuritisation of plagioclase
4	2017 b	2898	2922	0.8	0.24	163	11.96	0.03	0.01	intense chloritisation of matrix
5	2018	2759	2804	1.6	1.04	130	17.07	0.03	0.01	calcitisation of plagioclase
6	2019	<u>2926</u>	<u>2951</u>	0.8	0.16	143	10.48	0.05	0.00	partial calcitisation of plagioclase
7	2020	2893	2941	1.6	0.30	144	13.17	0.03	0.04	intense chloritisation of matrix
Constraints according to Serbian standard for road construction [6]	-	-	-	-	highway and moderate tl ≤0.75 light tl ≤1	highway ≥160 moderate tl ≥140 light tl ≥120	highway ≤12 moderate tl ≤18 light tl ≤35	all tls ≤5	-	-

Note: bolded values represent the least favourable, while the underlined ones represent the most favourable values from the aspect of building stone.

Key: tl – traffic load

The preparation of samples involved drying until constant mass at (105±5)°C, milling in Herzog-Siemens mill type Simatic C7-621, pressing into pellets under 20 t in Specac T-40 hydraulic press to

produce stable pellets. The binder used is "XRF cereox". Quantitative and qualitative analysis is performed with the Spectro Xepos Energy-dispersive XRF (EDXRF) instrument with a binary cobalt/palladium alloy thick-target anode X-ray tube (50 W/60 kV) and combined polarised/direct excitation. Apparatus Spectro Xepos is used with method "FP oxides pellets". Control software is Spectro XRF Analyzer Pro and CRM used "NIST CRM Basalt rock 688".

Table 2. Results of EDXRF analyses of diabase samples (contents: a. 2017 A; b. 2018; c. rock mass with hydrothermal vein; d, e – chemical compositions of diabase from d. Deli Jovan Mt. in Eastern Serbia and e. Zlatibor Mt. in SW Serbia given for comparison – taken from Vukov [7, p. 164]).

Analyte	Contents (%)				
	a	b	c	d	e
SiO ₂	51.20	50.32	42.51	48.14	48.81
Al ₂ O ₃	13.10	13.22	18.25	14.55	16.68
Fe	6.82*	6.12*	5.83*	11.5***	8.02***
CaO	6.40	7.73	20.57	9.57	10.83
MgO	6.75	12.40	2.57	6.80	5.22
Na ₂ O	6.19	4.12	0.37	2.95	3.00
K ₂ O	6.40	0.02	0.01	1.57	1.20
SO ₃ **	0.16	0.25	2.39	-	-
P ₂ O ₅	0.46	0.13	0.09	0.18	0.35
MnO	0.19	0.24	0.09	0.14	0.20
TiO ₂	0.19	1.08	0.77	1.88	0.01
LOI _{1000°C}	1.53	3.71	5.82	-	-
Σ	99.39	99.34	99.27	-	-

*total Iron content shown as elemental Iron

**total Sulphur content shown as SO₃

***Fe₂O₃+FeO

3. Discussion

Petrographic study has shown typical composition and fabric for this type of rock. Main constituents are plagioclase and pyroxene, with opaque minerals as accessory and varying secondary minerals – chlorite, calcite, in some places epidote and limonite. Pyrite enrichment is visible in some areas of the massif, most prominently within or around the secondary hydrothermal veins. Chlorite, calcite, epidote and pyrite are the products of propylitic alteration, typically occurring within the basic (and other types of) rocks at the ocean floor, where heated sea water rich in Sodium penetrates the hot magmatic bodies and alters the primary minerals [8]. Although products of alteration are present throughout the rock mass in variable degree, as is typical for the basic rocks of the former ocean floor sequences, petrologic properties are favourable for building stone purposes. Photomicrographs (Figures 3 and 4) of the samples with the most (2017) and least (2018) favourable technical properties do not show significant differences apart from the grain size, which is coarser in sample 2017.

Physico-mechanical properties of diabase have favourable values and varying scattering degrees. Dry state uniaxial compressive strength average values from seven analyses vary in the range from 130 to 169 MPa. Values over 160 MPa permit its use as a raw material for production of graded aggregate to be used in road construction for asphalt-bound wearing top layer for highway; from 140 to 160 MPa for roads with moderate traffic load and from 120 to 140 MPa for roads with light and ultra-light traffic load. Resistance to abrasion average values vary in the range from 9.04 to 17.07 cm³/50cm². Values below 12 cm³/50cm² enable its use as a raw material for production of graded aggregate to be used in road construction for asphalt-bound wearing top layer for highway; from 12 to 18 cm³/50cm² for roads with moderate traffic load and below 35 cm³/50cm² for roads with light and

ultra-light traffic load. Apparent density varies within the span 2759-2926 g/cm³ and real density 2804-2951 g/cm³. Water absorption values vary between 0.08 and 1.04 %. Values below 0.75 % permit its use as a raw material for production of graded aggregate to be used in road construction for asphalt-bound wearing top layer for highway and roads with moderate traffic load, and below 1 % for light and ultra-light traffic load. Resistance to weathering through testing of stability using Sodium-sulphate values vary from 0.00 to 0.15 %. All traffic loads demand values below 5 %. Frost resistance values vary from 0.00 to 0.04 %. Porosity values are almost constant at 0.8 %. In some parts of the rock mass, porosity reaches 1.6 %. It is not entirely clear what causes the occurrence of higher porosity values.

Criteria for other uses of diabase as a building stone are more easily met – such as graded aggregate for production of concrete, for lower and upper bearing layers; for classic and modern road foundations; for production of crushed and hewn stone for building; and crushed stone for railroad ballast – and are tested on cited types of products (graded aggregate, railroad ballast stone etc.). The results of such testings are not shown in this paper, but they are being performed regularly in the IMS Institute and have shown favourable results.

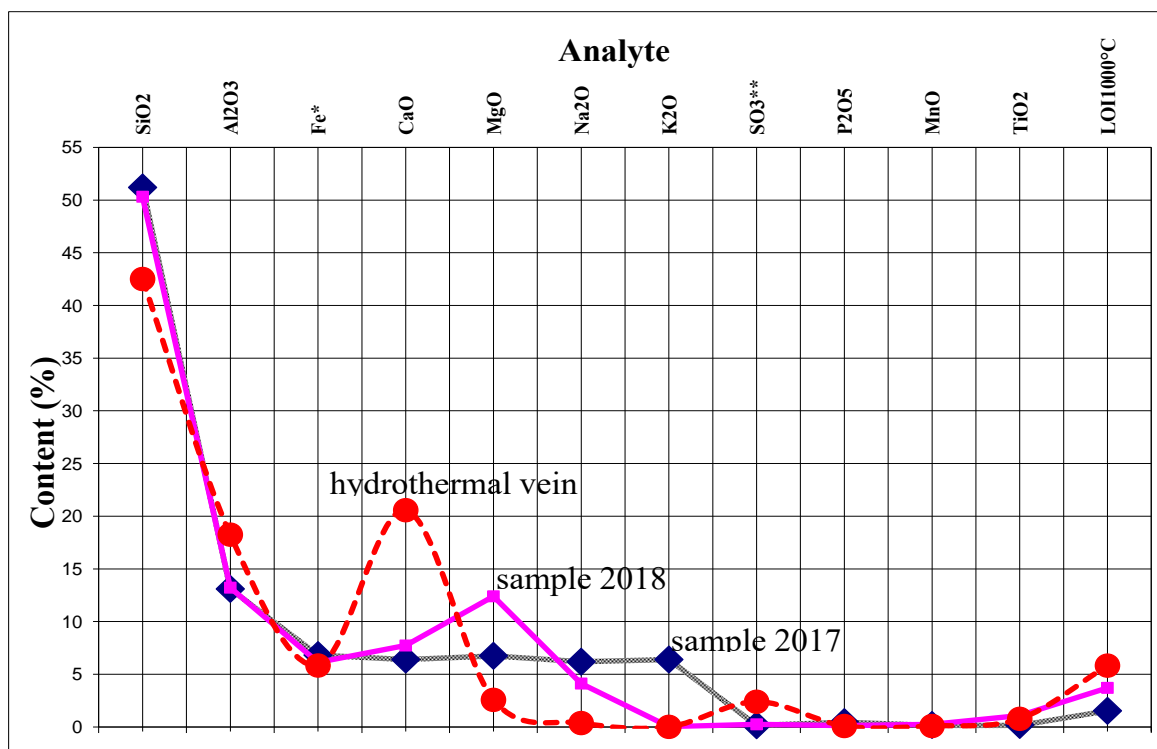


Figure 5. Differences between the contents of the main chemical constituents in the samples 2017, 2018 and a sample with hydrothermal vein.

Chemical analyses have shown that SiO₂, Al₂O₃, Fe_{elemental}, CaO, S_{total}, P₂O₅ and MnO contents are rather similar in both diabase types (samples 2017 – with the most favourable technical properties and 2018 – with the least favourable technical properties), while there is an increase in CaO, MgO and TiO₂ contents from the sample 2017 to 2018, and a decrease in Na₂O, K₂O, P₂O₅ contents. The increase in loss on ignition (LOI) from 2017 to 2018 is also notable. It might be ascribed to the greater contents of alteration products containing hydroxy group (such as zoisite, epidote, sericite, chlorite, clays), carbonate and other minerals unstable at 1000°C, which are "hidden" within the matrix and therefore not observable in microscopic analysis. The sample with hydrothermal vein has a higher content of CaO, Sulphur, Al₂O₃ and loss on ignition (LOI), and lower SiO₂, MgO, Na₂O contents than

the host rock alone (Figure 5). Compared to additional chemical compositions of two diabases from Serbia (taken from [7]), the most conspicuous differences are the significantly higher content of alkalis ($\text{Na}_2\text{O}+\text{K}_2\text{O}$) in sample 2017 and significantly higher content of MgO in the sample 2018.

4. Conclusions

Taking into consideration all performed tests and analyses, it is concluded that diabase from Drača mine can be used as a raw material for production of aggregate for use in concrete and for road-construction: asphalt-bound paving mixtures for highways (if and when its technical properties meet the cited criteria) and for roads with moderate, light and ultra-light traffic load as a top wearing layer; for lower and upper bearing layers; for classic and modern road foundations; for production of crushed and hewn stone for building; and crushed stone for railroad ballast.

It appears that alteration of the rock mass – its type or intensity – does not affect directly the improvement or decline of the stone's technical properties i.e. quality of the stone for building industry. Decrease in quality is observed only in the cases when there is a significant increase in porosity. When there is only a partial alteration (calcitisation and saussuritisation) of plagioclase grains present, the technical properties are most favourable for building purposes – the highest values of compressive strength and the lowest values of loss due to frost action and abrasion, and of water absorption. Better technical properties go along with the larger grain size of the main constituents – plagioclase and pyroxene. Also, it appears that porosity is not (entirely) caused by alteration.

There is a weakly pronounced trend of decrease in quality over the years of continual mining process. It can only be inferred that the formerly mined upper parts of the massif were more silicified, although petrographic analyses have not confirmed this hypothesis.

Acknowledgment(s)

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References

- [1] M. Toljić, U. Stojadinović, and N. Krstekanić, "Vardar zone: new insights into the tectono-depositional subdivision", *2nd congress of geologists of Bosnia and Herzegovina* in Laktaši, p. 60-73, 2019.
- [2] S. Vukašinović, "Some new data on geologic-tectonic pattern of Šumadija (based on aeromagnetometry)", *7th congress of Yugoslav geologists* in Zagreb, Book 1, p. 547-560, 1970.
- [3] P. Robinson, J. Malpas, Y. Dilek, and M. Zhou, "The significance of sheeted dike complexes in ophiolites", *Geological Society of America - GSA Today*, Vol. 18, No. 11, p. 4-10, 2003.
- [4] D. Dolić, M. Kalenić, B. Marković, M. Dimitrijević, R. Radoičić, and Č. Lončarević, "Basic geologic map of Yugoslavia 1:100000 explanatory booklet for section Paraćin K34-7", 53 p., *Savezni geološki zavod – Belgrade*, 1981.
- [5] G. Zlatanović, "Drača kod sela Prevešt", unpublished informative booklet, 3 p., Geološki zavod – Beograd, 2021.
- [6] SRPS U.E4.014 Technical requirements for asphaltic concrete pavements. *Službeni list SFRJ*, 44 p., 1990.
- [7] M. Vukov, "Magmatske stene". *Rudarsko-geološki fakultet – Beograd*, 487 p., 1998.
- [8] R. Taylor, "Ore Textures: Recognition and Interpretation", *Springer*, 58 p., 2009.