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ESTIMATION OF RESISTANCE OF STONE AGGREGATES TO RECRUSHING

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The stone aggregates of dolomite, andesite and spilitized diabase were tested to estimate their response to abrasive-impact strain. Standardized and non-standardized estimation of recrushing action were utilized in the experiment. The focus of the study was to improve the estimation of resistance to the recrushing process. The assumption that there is a relationship between the degree of recrushing of the stone aggregates and the grain surface before recrushing was confirmed. The investigation was performed by the use of the standardized method according to the HRN Standard (Los Angeles). For the complete evaluation of the aggregate several other methods in accordance to HRN were also applied. The values obtained are found to be the result of several factors which include structural, textural and mineral properties, as well as genesis, tectonics (postgenetic strain producing the micro-cleavage and cataclasis) and recrystallization. The influence of the size, shape together with the interrelationship of crystals and micro-blocks on the physical and mechanical properties were determined by electronic microscopy.

Ključne riječi: Kameni agregati, dolomit, andezit, spilitizirani dijabaz, otpornost na habanje i udar (Los Angeles), ocjena pregranulacije

Kameni agregati dolomita, andezita i spilitiziranog dijabaza podvrgnuti su ispitivanju na udarno habajuća opterećenja. Korištene su normirane i nenormirane metode ocjene pregranulacije. Posebna pažnja posvećena je poboljšanju ocjene otpornosti prema pregranulaciji. Potvrđene su pretpostavke da postoji ovisnost stupnja pregranulacije kamenih agregata o površini zrna agregata prije predrobljavanja. Ispitivanje je obavljeno normiranom metodom prema normativu HRN (Los Angeles). Za potpunu ocjenu agregata korištene su i druge metode ispitivanja prema HRN-u. Utvrđeno je da su dobivene vrijednosti posljedica strukturno-teksturnih i mineralnih značajki, geneze, tektonike (postgenetskih naprezanja koja uzrokuju mikroraspucanost i kataklaziranje) i rekristalizacije. Elektronskim je mikroskopom utvrđen utjecaj veličine, oblika i međusobne povezanosti kristala i mikroblokova na fizička i mehanička svojstva.

Introduction

The stone aggregates are prone to recrushing during the test of their resistance to abrasion and impact. Built into different substances or objects which later undergo various kinds of stress and strain, they all show the same characteristics. This is particularly important when refined stone particles are used for the production of concrete-asphalt materials.

The standardized test method for the resistance of the stone material to recrushing (»Los Angeles«, HRN B.B8.045) is expressed as the ratio of the resulting mass of grains with diameter less than 2 mm in respect to the original sample mass. The obtained value, expressed in percent, is called the Los Angeles Coefficient (LAC). It is determined in the same manner for all samples regardless of their granulometric composition after recrushing. This way of demonstrating the resistance of the stone material to recrushing is neither in accordance, nor in a functional relationship with the original granulometric composition and sampling mass before the analysis.

The study of the influence of diverse physical and mechanical factors as well as petrographical and mineralogical characteristics of the recrushing process during impact-abrasion strain of stone aggregates deserves special attention.

One of the main drawbacks characterizing the carbonate stone materials is poor resistance to crushing, so Ramljak et al. (1982) suggested the necessity for determination of their threshold quality in practice.

Salopek and Tomašić (1990) elucidate the behavior of early-diagenetic and late-diagenetic dolomites submitted to disintegration. In particular, they consider the recrushing process with respect to tectonics and multiple cataclasis of the rock mass in the deposit.

Manifold recrystallization processes considerably effect the change of the physical and mechanical properties of the stone aggregates, both in a positive or negative sense (Tomašić et al., 1990). Sometimes, owing to the process of recrystallization, stronger bonds occur within and among the individual crystal grains in a tectonized part of a deposit compared to the undisturbed portion of the deposit (Malvik, 1988).

Tomašić et al. (1992) investigated the influence of structure, texture and mineral composition, as well as imprints of genetic distinctions and diversified postgenetic processes – particularly tectonics, dolomitization and recrystallization – on the dolomite aggregates during laboratory tests of their resistance to impact and abrasion before and after 25 and 50 cycles of freezing.

Also it is necessary to stress the results of investigations (Ramljak et al., 1995) that corroborate the dependence of the degree of recrushing on the size and shape of grain surfaces of carbonate and eruptive stone aggregates.

Selection and preparation of samples

The tests were performed on the samples of dolomite, andesite and spilite-diabase aggregates. Particular interest was focused on stone aggregates and fine particles from the quarry of Fužinski Benkovac. Due to the lack of other eruptive and metamorphic rocks this stone material should have made more use in the Primorsko-goranska and Istarska Županija for the production of the concrete-asphalt layer on the roads sustaining the heaviest traffic.

The selection of samples was made on assumption that the stone aggregates encompassing a wide range of structural-petrographic characteristics would be of greatest support for the credibility of analysis. For this reason the following stone aggregates were preferentially selected:

1) **spilitized diabase** from the *Hruškovec* quarry (Kalnik mountain), well-known for its great resistance to recrushing;

2) **andesite** from the *Fužinski Benkovac* quarry (Gorski kotar), distinguished as intermediately resistant to the process of recrushing; and, finally,

3) **dolomite** from the *Jarče Polje* quarry (near Karlovac), which is known for its poor resistance to recrushing.

All fractions of the tested aggregates (0/4, 4/8, 8/16, 16/32 mm) were sieved to subfractions (0.09/0.25, 0.25/0.71, 0.71/2.0, 2.0/4.0, 4.0/8.0, 8.1/11.2, 11.2/16.0, 16.0/22.4 mm) which were in turn rinsed on the sieve of 0.09 mm. New samples of precisely defined granulometric composition were composed from foregoing subfractions, which were further used in the resistance to recrushing test.

Apart from the standard granulometric compositions designed for the analysis by the method of »Los Angeles« (grades B, C, D), the samples which granulometric composition matched that of the stone skeletons in asphalt (AB4, AB8, AB11, AB16) were analyzed in the same way.

After 500 turnings in the »Los Angeles« machine, all the samples were submitted to granulometric analysis which was the basis for all further calculations.

Mineralogic and petrographic properties of samples

The rock mass of the *Jarče Polje* quarry consists of intensely cataclazed early-diagenetic altering with late-diagenetic dolomite.

The stone is light-gray to gray-brown in color, heterogeneous in texture, with regular cleavage and slightly coarse splitting planes.

The texture of early-diagenetic dolomite is stromatolitic, dolopelmicritic and dolointrasparitic. The size of isometric dolomite crystals show a prevalence of up to 0.002 mm, while larger crystals (up to 0.5 mm) can be found only in irregular and laminoid fenestres and recrystallized nests filled with microcrystalline druse cement.

The stone is sporadically intersected by subparallel fractures 0.004–0.06 mm wide and at some intervals wider than 0.06 mm. Contacts between dolomite crystals, and the fractures themselves in particular, are occasionally filled with bituminose substance. Cleavage and compressive lamellae are characterised by manifold orientation, which indicates the intensity of cataclasis. Microfractures and stylolitic seams filled with limonite substance can be found throughout the samples. Most of the foregoing phenomena enhance the mechanical disintegration of the rock which in turn results in defective physical and mechanical properties of this material.

Late-diagenetic dolomite is distinguished by microcrystallic structure, the size isometric crystals ranges widely from 0.22 to 0.5 mm. Homogeneity of late-diagenetic dolomite is disturbed by numerous mechanical discontinuities. Such places, sometimes and their intersections as well, reveal milonitized dolomite crystals 0.01×0.01 mm in size. Reduced homogeneity is also indicated by smooth contacts between the original and newly formed crystals, particularly if there is a considerable difference in their size. These phenomena also reduce the physical and mechanical properties of stone so that, taking all into account, strikingly poor resistance of this material to recrushing action is to be expected.

The unaltered andesite from the *Fužinski Benkovac* quarry is grayish-green in color, while the weathered sections can be greenish-brown, reddish-brown or yellowish-brown. The structure is homogeneous. Cleavage is irregular, having rough surfaces. Porphyritic texture can be observed macroscopically.

Under the microscope two varieties were identified; those with granular and those with trachitic structure of the groundmass. Phenocrysts of plagioclase and amphibole vary in dimensions and are altered to a great extent to different secondary minerals.

Phenocrysts of plagioclase are elongated with a maximum size of 0.5×0.4 mm. Some of them reveal zoning and polysynthetic twinned lamellae. Many samples show considerable difference in the intensity of plagioclase fracturing, varying from almost complete segmentation to those without visible fractures, which indicates variable intensities of tectonic stress within the deposit. Plagioclase grains contain secondary albite, chlorite, sericite, epidote, zoisite, calcite and actinolite. Occasionally, secondary minerals almost completely fill the contours of former plagioclase phenocrysts.

Phenocrysts of hornblende are prismatic 0.5×1.0 mm in size. They contain secondary chlorite, calcite, titanite, epidote, zoisite and magnetite. Occasionally, due to the intense processes of alteration, only relics of hornblende are preserved which was determined on the basis of its distinguished shape and cleavage.

The mineral composition indicates that after the consolidation of magma the rock was hydrothermally altered (Vragović & Golub, 1969), particularly along the fractures as well as on the contacts with Paleozoic schist which allowed tarrying of solutions in the rock. Among the numerous alteration processes, calcitization, chloritization and sericitization have had unmistakably the most negative impact on the physical and mechanical properties of stone.

The deformed plagioclases with their margins bent appear in the samples with increased number of postconsolidation fractures. In some cases the whole crystals could be fractured as well. On the contacts between phenocrysts and microcrystallic groundmass sporadic limonitization can be observed, while limonite itself usually fills irregular fractures inside the phenocrysts. Some phenocrysts show irregular extinction indicating deformation of the grain structure. These features also have a negative effect on the physical and mechanical properties of stone, and consequently to its resistance to recrushing.

Spilitized diabase from the *Hruškovec* quarry is gray-green in color, shifting to dark green or dark red. It is intersected with green-white thin veins filled with secondary calcite, quartz and chlorite. Cleavage is irregular with uneven surface. Some samples are distinguished by a homogeneous and others by an amygdale structure.

Microscopic investigation has revealed a numerous structural variations of this stone material (Vrkljan, 1994). Relict diabase textures prevail (ophitic, intergranular, intersertal, hyalo-ophitic) and a minority of samples displays a porphyritic texture with relic microdiabase, arborescent or pilotaxitic groundmass texture. The phenocrysts are rare and, as a rule, small (1.2×0.5 mm in size).

Regardless of the rock texture and structure, the predominate minerals are clinopyroxene and plagioclase. All primary minerals are altered, pyroxenes to a somewhat lesser degree, while plagioclases are completely albitized within the whole area of the deposit. Clinopyroxenes contain some calcite, chlorite, minerals of the epidote-zoisite group, titanite, uralite, magnetite, hematite and limonite, while plagioclases, besides albite also contain calcite, sericite, chlorite and epidote-zoisite.

Table 1. Physical and mechanical properties of the stone samples

LABORATORY TESTS	QUARRY		
	Jarče Polje	Fužinski Benkovac	Hruškovec
Compression strength (MN/m^2)			
– in dry state	104.5	246.2	180.3
– water saturated	100.0	179.6	155.5
– after 25 cycles of freezing	91.8	177.0	147.8
Reduction of compression strength (%)			
– freezing/dry	12.1	28.1	18.0
– water/dry	4.3	27.4	13.8
– freezing/water	8.1	1.5	4.9
Resistance to abrasion after Böhme ($cm^3/50\ cm^2$)	29.20	8.44	9.10
Water absorption (mass %)	1.10	0.64	0.43
Stability to freezing	stabile	stabile	stabile
Density (t/m^3)	2.847	2.717	2.907
Bulk density (t/m^3)	2.733	2.542	2.849
Porosity (vol. %)	3.90	2.38	2.02

Table 2. Physical and mechanical properties of the stone aggregates

LABORATORY TESTS	FRACTION	QUARRY		
		Jarče Polje	Fužinski Benkovac	Hruškovec
Portion of grains of unfavourable shape (mass %)	4/8	13.88	12.32	9.18
	8/11	3.67	9.65	3.55
	11/16	2.37	4.87	4.43
	16/22	2.11	14.72	3.45
Weathered and split grains (mass %)	4/8	6.5	4.8	2.2
	8/11	13.1	6.7	2.0
	11/16	12.8	6.1	1.9
	16/22	11.5	5.2	1.6
Water absorption (mass %)	4/8	1.87	2.57	1.39
	8/11	1.40	2.10	1.14
	11/16	1.34	1.51	1.21
	16/22	1.02	1.43	0.86
Resistance to abrasive impact strain after the LA method (mass %)	grad. D	42.65	22.35	14.20
	grad. C	44.95	16.80	10.50
	grad. B	57.3	14.05	10.87

Rocks with diversified textures differ in the abundance of a specific component. In a majority of samples amygdales can be found which usually contain calcite and chlorite, but also other secondary minerals can occur.

Most samples from this quarry were determined mostly as spilite, while altered diabase can be found only sporadically.

In almost all samples the effects of intense postgenetic tectonics can be observed microscopically (V r k l j a n, 1988). The rocks are abundant with fractures varying in width and are filled with secondary minerals. The lath-shaped plagioclase is often bent and like clinopyroxene, shows irregular extinction. Majority of mineral components, particularly the coarser ones, are intersected with distinct irregular fractures.

In spite of all this, the stone aggregate from the Hruškovec quarry is very resistant to recrushing action, especially owing to its diabase texture which has particularly positive effect in this respect.

Results and discussion

Results obtained by the standard laboratory tests of physical and mechanical properties of the stone samples and aggregates from the quarry of Jarče Polje, Fužinski Benkovac and Hruškovec are displayed in tables 1. and 2. Table 1. contains average values of the test carried out in the period 1984–1994.

Using the comparative analysis of the results obtained by examination of the three different types of fine stone fractions as far as their composition and properties are concerned, an effort was made to evaluate and promote the wider application of the fine stone fraction of »Fužinski Benkovac«, and to emphasise the more favourable characteristics of studied eruptive rock samples compared to dolomite. The fine stone fraction of »Fužinski Benkovac«, with regard to the contemporary standards and criteria, does not fulfil the required quality, mostly due to its lower resistance to recrushing action.

The tables disclose considerable differences in physical and mechanical properties of the tested types of stone. The dolomite from the Jarče Polje quarry evidently lacks the quality of andesite and spilitized diabase. Its physical and mechanical properties are considerably more inferior. The spilitized diabase from the Hruškovec quarry has always been valued as favorable material in the production of the refined stone fraction required for the manufacture of concrete-asphalt. Efforts have also been made to apply andesite in the same way.

Andesite in a dry state, water-saturated state and after freezing (Tab. 1) is distinguished by great compression strength (242.2, 179.6 and 177.0 MN/m^2), even higher than spilitized diabase (180.3, 155.5 and 147.8 MN/m^2). It is interesting that andesite is on average more resistant to abrasion compared to spilit-diabase (8.44 to 9.10 $cm^3/50\ cm^2$), which was confirmed by inspection of numerous results from the previous laboratory test. However, decrease of the compression strength values of andesite in the freezing/dry (28.1%) and water/dry state (27.4%) is considerable in comparison to spilitized diabase (decrease of 18.0% and 13.8%, respectively). This decline is the consequence of increased water absorption (0.64 mass % for andesite, and 0.43 mass % for spilite-diabase). The abundance of weathered grains and grains prone to splitting, as well as those of unfavorable shape, is greater in andesite. Resistance to impact and abrasion (Tab. 2) of grades D, C and B of spilitized diabase is better by 36.5%, 37.5% and 22.63% with respect to the same grades of andesite.

Interpretation of petrographic and structural-textural properties as well as of the results of the laboratory tests of physical and mechanical characteristics (Tab. 1 and 2) and resistance to recrushing was assisted with microphotographs obtained by an electron microscope.

A total of seven samples was photographed with the electron microscope – four samples of andesite (Figs. 1, 2, 3 and 4), two of spilitized diabase (Fig. 5 and 6), and one of dolomite (Fig. 7). The first two samples of andesite were fresh samples from the Fužinski Benkovac quarry, while the other two were taken from the remainder of samples that were previously compression strength tested. One of the samples of each variety had its surface polished, while the fractured surface of the other was left unprepared. Details which would otherwise stay undetected with available magnifications of the petrographical microscope can be seen on the microphotographs.

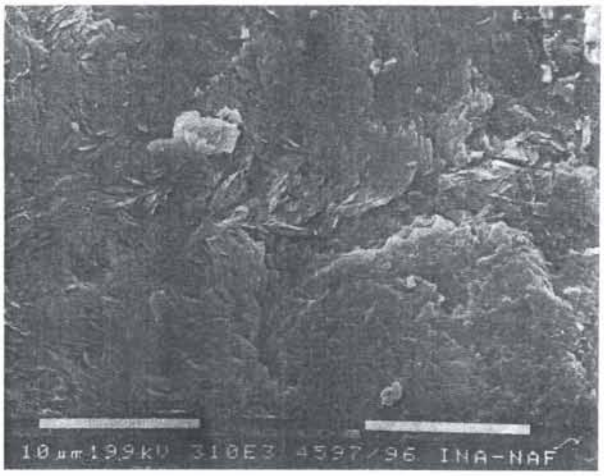

Fig. 1. Polished surface of andesite (bar = 10 µm). Intercrystal porosity is clearly observable. Pores are connected.

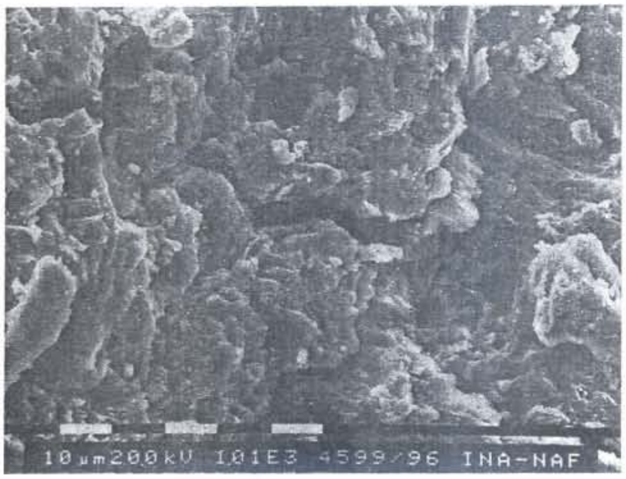

Fig. 2. The surface of andesite appearing following fracturing (bar = 10 µm). Abundant microfractures and intercrystal porosity are clearly delineated and connected. Splitting along microfractures

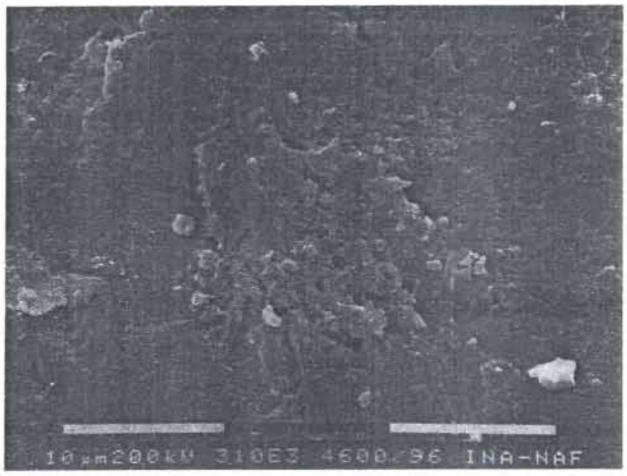

Fig. 3. Surface of polished andesite sample following the compression strength test (bar = 10 µm). Microfractures are clearly outlined and more frequent compared to the sample in Fig. 1.

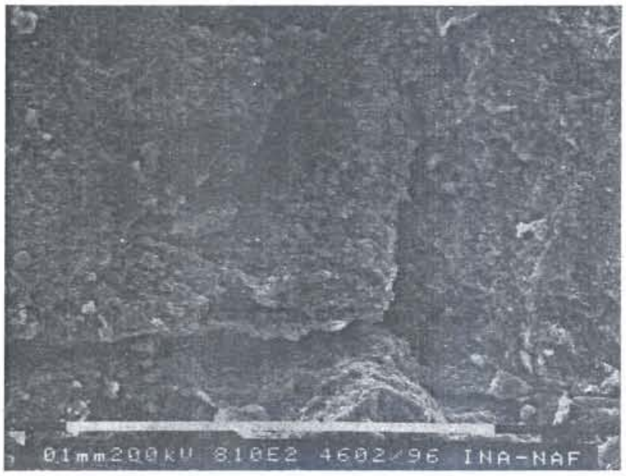

Fig. 4. Surface of the andesite sample following fracturing (bar = 10 µm) and the compression strength test. Strongly outlined microfractures and freshly formed intercrystal porosity among

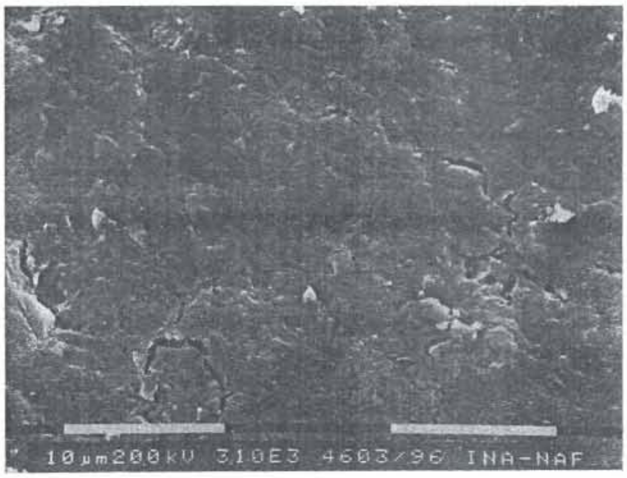

Fig. 5. Surface of spilitized diabase after polishing (bar = 10 µm). Micropores are sparse and sealed, worm-like and bifurcated.

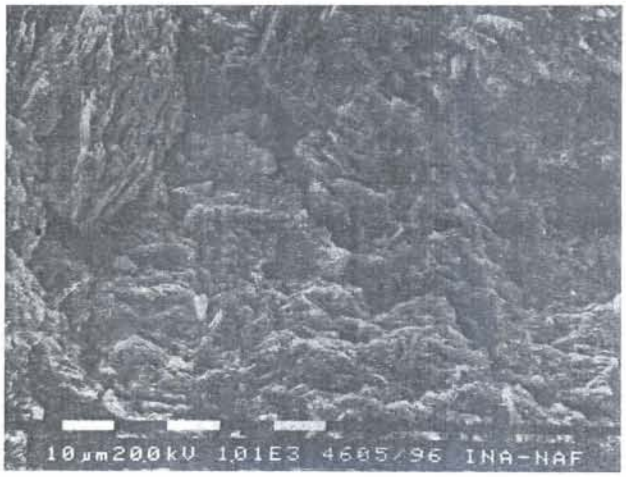

Fig. 6. Surface of spilitized diabase following the fracturing of the sample (bar = 10 µm). Microfractures of this kind are considerably less frequent in diabase compared to andesite, and which are not only of tectonic origin.

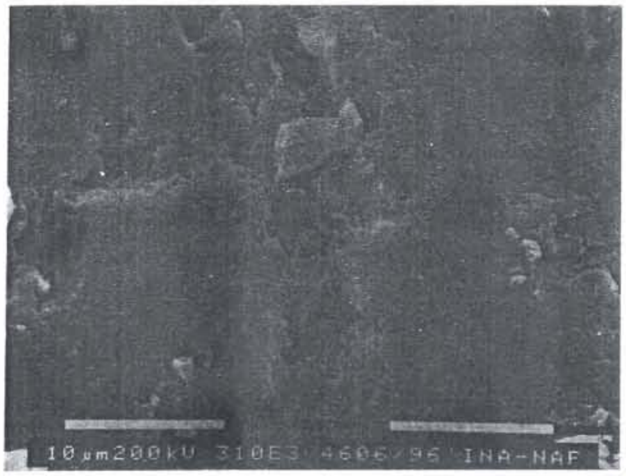

Fig. 7. Surface of dolomite after polishing (bar = 10 µm). Strongly outlined »vuggy« porosity. Crystals of dolomite show a skeletal rim.

deformations of stone. They can be seen macroscopically, although in some cases it can be done only with microscope or electronic microscope.

Both types of rock, andesite and spilitized diabase, are of similar mineral composition, but they differ in texture and numerous processes of alteration and re-crystallization. In the majority of andesite samples the phenocrysts consist of about 50% of rock volume, with plagioclase as the prevailing mineral. In the samples of spilitized diabase phenocrysts are rare. The andesite groundmass is fine-grained, with smaller grain size compared to spilitized diabase. If we reflect on the alteration products it can be noted that the chlorite content is considerably greater in spilitized diabase than in andesite. Nevertheless, the distribution of chlorite, as well as other products of alteration, shows no elements of preferred orientation so that secondary minerals probably do not substantially affect recrushing of the aggregate grains. On the figures displayed the sample surfaces on electron microscope microphotographs do not allow identification of minerals, but physiographics charac-

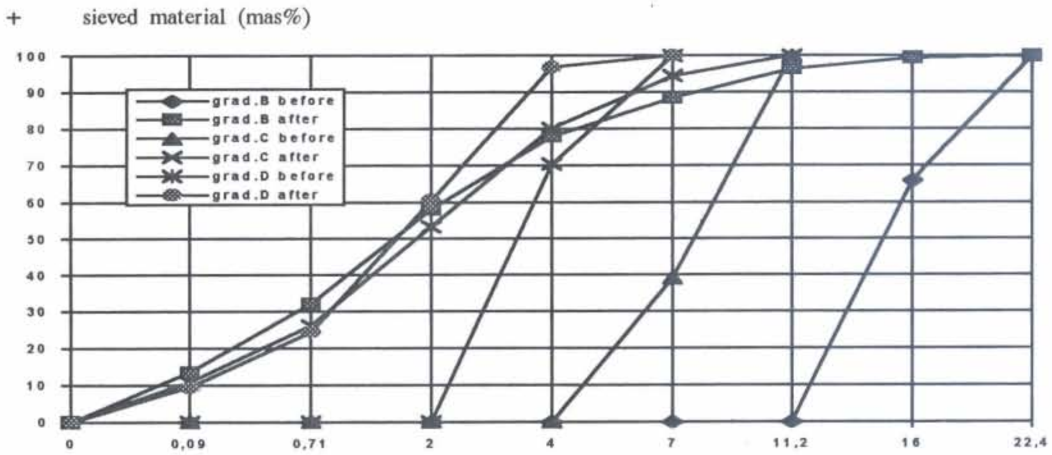

Fig. 8. Granulometric curves of the grades A, B, C composed of the stone aggregates from the Jarče Polje quarry

On the figures numerous details were observed which offer possibility for additional explanation of the results of physical and mechanical properties (Tab. 1 and 2) and recrushing process in the stone aggregates.

The andesite samples tested show frequent and clearly defined microfractures compared to diabase. These fractures are mainly the result of microtectonic stress and, to some extent, re-crystallization and alteration. They cause increased water absorption by andesite samples, as well as stronger decrease of compression strength in the freezing/dry and water/dry conditions. The abundance of weathered grains, grains prone to cleavage and grains of disadvantageous shape (Tab. 2) probably is the result of tectonic stress and unimpeded foliation of the rock mass in the deposit. Foliation is vaguely observable both macroscopically and microscopically.

In the andesite samples submitted to additional stress crystals were artificially cataclazed giving rise to milonites (Fig. 4). The crystal micro-blocks crush and separate producing increased porosity in the selected stone samples.

Micro-blocks are relatively integral and at the same time still well connected deformed crystal aggregates with signs of sharply marked intercrystal porosity. They come as a consequence of postdiagenetic, especially tectonic processes or artificially provoked strains and teristic of single micro-blocks and recently formed pore systems are nonetheless visible. In this respect the applied method is speculative. Micro-blocks are made of the clusters of still connected mineral grains.

It is necessary to stress that, in spite of its numerous disadvantageous petrographic characteristics, as well as its lower physical and mechanical properties (Tabl. 1 and 2) and determined effects of micro-stress, andesite from Fužinski Benkovac regularly proves to be more resistant to abrasion compared to the spilitized diabase from Hruškovec. This is probably due to abundant plagioclase phenocrysts characterized by great hardness, as well as the lesser degree of hydrothermal alteration and weathering, and especially due to the small amounts of unfavorable chlorite and major quantities of small grained minerals. Microlites of the groundmass are more compact and have stronger crystal lattice due to their smaller size and later occurrence. Therefore, the secondary formed pore space and inter-crystal porosity, which causes a fractured structure of the rock mass, has virtually little impact on abrasion resistance of the rock.

To prove that the part of grains with a diameter less than 2 mm in the re-crushed sample (LAC) is not a real indicator of the resistance to recrushing action is demonstrated by the granulometric diagram presented in Fig. 8. The lowest LAC is shown by the grade B although

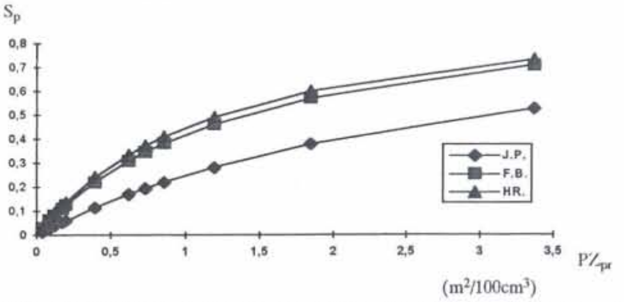

Fig. 9. Dependence between the degree of recrushing and initial grain surface of sample
(J. P. – Jarče Polje, F. B. – Fužinski Benkovac and HR. – Hruškovec)

it has been actually re-crushed the most. This is quite obvious even without calculation of recrushing indices (ratio of surfaces below the granulometric curve before and after recrushing). The diagram displays several granulometric curves obtained from the samples of the stone material from Jarče Polje. The conditions are analogous for the other two quarries (andesite and spilitized diabase) and their granulometric diagrams are not shown.

The parameter required for the actual evaluation of the recrushing resistance action is established from the value of the grain surface (PZ) which is known to be in a functional relationship with the granulometric composition. This surface can be calculated from the reports on the granulometric composition using the following equations:

$$PZ = \sum \frac{6 \cdot m_i \cdot \bar{\rho}}{1000 \cdot \bar{d} \cdot \rho_i} \quad [\mathrm{m^2/100\ cm^3\ of\ crushed\ stone}]$$

where:

- m_i mass part of each fraction [%]
- ρ_i density of each fraction with pores [g/cm³]
- $\bar{d}$ mean diameter [cm] of each fraction calculated from the boundary diameters (d_i and d_{i+1}) using the equation:

$$\bar{d} = 2 \cdot \frac{d_i \cdot d_{i+1}}{d_i + d_{i+1}}$$

$\bar{\rho}$ mean density with pores is calculated from the equation:

$$\bar{\rho} = \frac{100}{\sum \frac{m_i}{\rho_i}}$$

The parameter which demonstrates the degree of regranulation of a particular stone material is calculated as the ratio of the grain surface before crushing (PZ_{pr}) and after crushing (PZ_{po}). The more the stone aggregate is recrushed, the smaller the surface ratio or the degree of recrushing (S_p) will be.

Further analyses were conducted to define the dependence between the degree of regranulation and the grain surface of the sample before recrushing action. The results of these investigations are presented in the Fig. 9.

All the resulting dependance curves (Ramljak et al., 1995) can be described by the following mathematical function:

$$y = \frac{1}{1 + \frac{1}{K \cdot x}}$$

The functional relationship is controled by the coefficient K. This is characteristic for each stone material and it essentially presents the resistance of the stone aggregate to regranulation. So it can also be named the coefficient of resistance to regranulation (K_{opp}).

During the test, coefficients of resistance or recrushing are obtained for various types of stone. The value of K_{opp} is 0.33 for dolomite from Jarče Polje, 0.72 for andesite from Fužinski Benkovac, and 0.81 for diabase from Hruškovec. According to these values and the described procedure for evaluation of regranulation, which is based on analyses of surfaces of aggregates before and after the tests, it is evident that a significant difference between the stone aggregates of andesite and spilitized diabase is small. It is only 11.11%, which is far less in comparison with the differences of calculated values of particular LAC for spilite-diabase and andesite (Tab. 2), where the effects of recrushing are disclosed as a bulk weight of grains with diameter less than 2 mm, or otherwise, in form of the LAC coefficient (»Los Angeles test«, HRN B:B8.045). Their values differ in 36.5% for the grade D; 37.5% for the grade C; 22.63% for the grade B (Tab. 2) and 32.21% on average for all three grades.

Conclusion

It can be concluded on the basis of this study that the standard way of presenting the resistance of a specific stone material does not reveal the actual values.

The resistance involved is much more precisely defined by the coefficient of resistance to recrushing (K_{opp}) which is a numerical expression of functional relationship of the grain surface (granulometric composition) before and after the recrushing action. The previously considered mathematical function:

$$y = \frac{1}{1 + \frac{1}{K \cdot x}}$$

can now be rewritten in the form:

$$S_p = \frac{1}{1 + \frac{1}{K_{opp} \cdot PZ_{pr}}}$$

or:

$$K_{opp} = \frac{S_p}{PZ_{pr} - S_p \cdot PZ_{pr}}$$

The coefficient of resistance to re-granulation K_{opp} is characteristic for the tested varieties of stone. The values are as follows: 0.33 for dolomite from the Jarče Polje quarry; 0.72 for andesite from the Fužinski Benkovac quarry; and 0.81 for spilite-diabase from the Hruškovec quarry. Higher values of K_{opp} indicate aggregates which are more resistant to the recrushing action. This way of recrushing estimation is more favorable for aggregate from the Fužinski Benkovac quarry. This method of quality evaluation places andesite for only 11.11% behind diabase which is much more favorable with respect to the standardized way of estimation when the difference is 32.21% on average in favour of diabase.

Finally, it should be noted that the foregoing expressions are valid only for the samples of aggregate having the grain surface larger than 0.15 m²/100 cm³ before testing. This is due to the fact that the samples with smaller grain surface before crushing (PZ_{pr}) cause the values to deviate from the coefficient of resistance to recrushing (K_{opp}) calculated in this way. In fact that the grain surface (PZ) calculated in this way for the coarse-grained samples (PZ_{pr} < 0.15 $m^2/100\ cm^3$) is not in accordance with the actual grain surface. Namely, in this computation the grain surface is approximated by the sphere, which is not amenable in the case of coarse-grained samples because the shape of the grain effect its surface too strongly.

This study has demonstrated that, apart from mineralogical and petrographical characteristics, the reasons for increased recrushing of andesite should be pursued mostly in activity of post-genetic processes, particularly micro-tectonic stress which is one of the primary causes for the formation of intercrystal and fracture porosity. That, in turn, affect recrushing and reduction of the compression strength in the freezing/dry and water/dry conditions.

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