QUALIFICATION OF MASS COMPOSITION CHARACTERISTICS OF ROCKS

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Abstract

Various laboratory experiments have been performed to qualify products made of stone. These studies are of a petrographic, rock-physical and technological nature. In the course of qualifying studies, rock-physical characteristics are also obtained which are only indirectly or not at all applied in qualification, such as e.g. bulk density or water absorption. It would be expedient to use these parameters and their system of correlation to make qualification more reliable. The possibilities and limits of this idea are discussed in this paper.

1. Choice of rocks for building purposes

In the course of practice a civil engineer gets into contact with rocks forming the solid crust of Earth in two ways. One of these is when he analyzes the properties of the rocks together with the extent and nature of changes to be expected in the construction and in the rock environment interacting with it. This subject is dealt with starting from a genetical basis by engineering geology or by soil mechanics and rock mechanics by using the simplified models of this interaction. The other contact developed earlier is the application of rocks as building material. Prehistoric man in the Paleolite selected from among natural stones the ones best for making tools and this nature of selection did not change practically since then. For a given building purpose we select different rock materials from the available rock supply formed by geological processes. Selection is based fundamentally on practical experience. Many thousand years of building experience of mankind could determine the application of a given rock material at a given place, for a given purpose, i.e. a decision for direct application and qualification could be provided, however, unfortunately, this way of direct qualification is not possible for several reasons. Selection based on traditions and experience depends on the knowledge and expertise of the person making the selection, therefore it has a very strong subjective character. In the course of social division of labour, the authority for collecting direct experience and making decisions for application move increasingly apart. Another contribution to this question is that at present the form of building in and its technology change very fast and the effects of damaging factors become also more predominant.

The basic properties of rocks usable as building material are determined by the properties of the continuous, elementary rock block and the form of the products (e.g. crushed stone, natural stone, tile stone, etc.). The form of products is, of course determined or restricted also by the properties of the elementary rock block but within a certain limit it can also be influenced by technological methods. For example, in the production of crushed stone, a crushing device ensuring better shape characteristics dimensioned for the particular rock material could be used, and thereby instead of NZ*, a product of the qualification KZ* could be produced.

2. Standardized prescriptions

For the qualification and classification of rock products, the standard system of building rock materials prescribes different studies for the various forms of products. The common feature of these studies is that the investigations needed for the designation and classification of rock products are of three types:

- petrographic
- rock-physical and
- technological.

Petrographic studies provide a regular *petrographic name* for the designation of the product, but simultaneously, in the knowledge of petrographic characteristics, an approximate estimation can be made for rock-physical properties not directly investigated.

The rock-physical parameters required are mainly *strength* and *durability*, but may be complemented by other functionally important parameters, too.

The technological requirements are strongly *dependent on the product*, they include e.g. particle size distribution, shape of particles, purity, size, surface processing, etc.

Based on requirements of product standards and laboratory experiments the product is given a standard designation and quality classification. In the application of the product, minimum requirements for material quality are regulated by technical directions or other demands.

Qualification and classification of products occur on the basis of some parameters only and thus ensure similar quality only in the case of identical rock names. In the case of different rock names, or sites of occurrence, even an identical rock-physical classification allows for significant differences in the non-measured properties.

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* Product classes for crushed stone in Hungary.

Product qualification is a generally very simple, fast method of evaluation. Rock evaluation is, however, a quite different, more difficult task. The first step in solving this task is to determine the stresses, the properties important from the viewpoint of stresses and complementary auxiliary characteristics in the knowledge of the mode, objective and conditions of application. After that, the studies have to be planned. This plan has to contain the minimum number of specimens, the mass of test aggregates, thus also the basic data for sampling. Based on the results of studies, the rock material is evaluated in an expert's opinion. Evaluation may basically be of two types. Qualification is made more often for determining what product and in which class can be produced from the rock body characterized by the sample. Less frequent is the study, where building objectives and requirements are satisfied by a product of a given form and given rock material.

Qualification requirements

Product qualification — Rock evaluation

Determination of the indicators and auxiliary characteristics
needed for qualification (projection)

According to prescriptions of product standards — Characteristics based on stresses to be expected

Sampling (by checking approximate petrographic studies)
Analytical petrographic studies

Rock designation (state of decay) — literature survey of properties to be expected

Production of specimens, aggregates
Adjustment of basic state for the studies
Auxiliary characteristics, determination without damage
Formation of partial sample groups
Statistical distribution, studies of correlations

Determination of indicator properties in the basic state

Averaging — Comparison with the properties to be expected

Operation of durability model effects
Determination of auxiliary characteristics
Determination of the indicator property after the operation of the model effect

Averaging
Determination of variation factors — Causal analysis of the changes in indicator and auxiliary properties.

Qualification

Comparison with requirements of the product class — Comparison of reqirements of utilization and the changes in the characteristics

Documentation of qualification

Qualification pass — Expert opinion on rock evaluation

Fig. 1. The general system of petrographic-rock-physical studies

Figure 1 shows the general correlations of the petrographic and rock-physical activities. It is seen from the Figure that product qualification is a simple routine operation, the basic and complementary parameters prescribed in product standards have to be determined only and the product should be qualified on their basis. Qualifying measurements can be usually made from the products.

In the case of rock evaluations, the circle of measurements to be carried out is significantly wider and eventually non-standard methods of investigation and evaluation have also to be applied.

Another way of determining the rock quality is the so-called rock-physical qualification. In its course all rock parameters available are taken into consideration, and the relation of the rock to an avarage rock quality characterized by the designation of the rock is determined within the rock group to which the given sample belongs.

3. Rock properties used for qualification

According to MSZ 18 282/4 (MSZ = Hungarian Standard), regular specimens of the same size and shape belonging to the same test group should be divided into equivalent partial specimen groups. This equivalence is ensured either only by bulk density determined only (ϱ_0) for the specimens, or by the simultaneous measurement of bulk density and the propagation velocity of longitudinal ultrasonic sound waves (c_0). It is of importance that the property averages of the partial groups should not deviate from those of the specimen group having also a similar standard deviation.

This quasi-equivalence of partial specimen groups is necessary for the comparability of their averages when studying their strengths in different rock-physical states, and thus they can be used for the calculation of the variation factor (λ) with sufficient reliability. The variation factor is a nearly as important qualification characteristic as compression strength, in the qualification system of the standard (class n, f or ff within the strength group).

3.1 *General correlations between properties*

The indirect role of bulk density and propagation velocity is based on the experience that the higher the bulk density of a rock, the greater its strength. This empirical fact is illustrated in Fig. 2 which has been constructed from the data of the Table on p. 196—197 in the book "Geology" by Papp and Kertész. The high standard deviation and stochastic character is obvious, as it represents the relationship between two properties of different rocks.

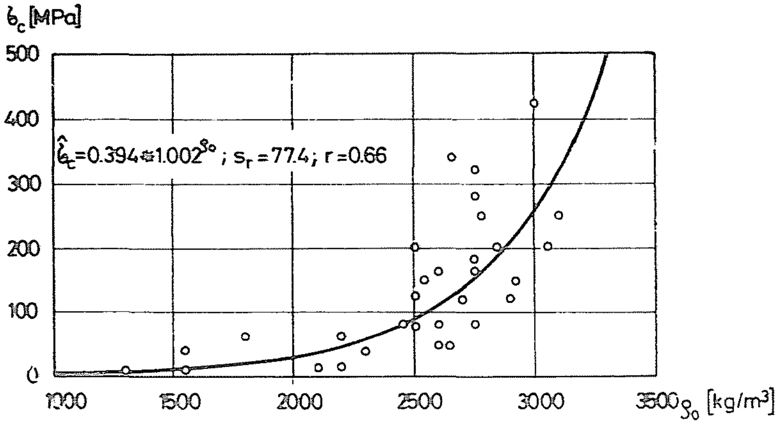

Fig. 2. Correlation between bulk density and compression strength (ϱ vs. σ_c) of different rocks on the basis of data in "Geology" by Papp and Kertész

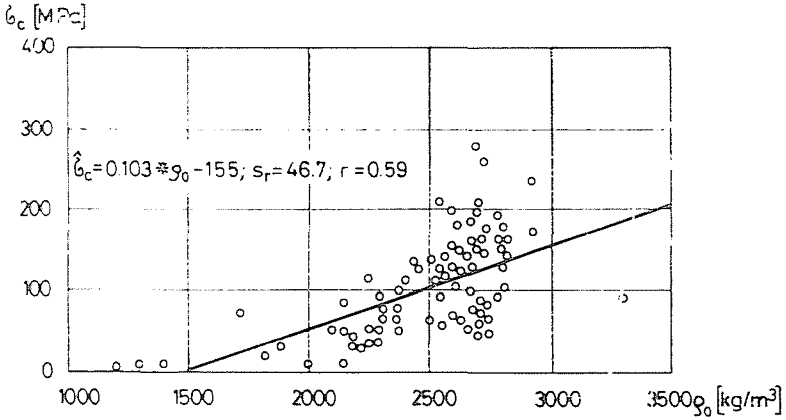

Fig. 3. Correlation between bulk density and compression strength of limestones on the basis of "Mechanical properties of rocks" by Lama and Vutukuri

The correlation can be made better (with a smaller residual standard deviation) if it is sought within one group of rocks (Fig. 3). As is seen, there is no essential improvement, since the identical designation of rocks may cover different textures and different degrees of weathering for the minerals, even for monomineralic rocks.

The stone material belonging to a sample group of a certain location may be a rock body with identical genesis, continuous, having similar macroscopic characteristics, from which the rock block characteristics for the whole rock body and samples are chosen by considering also the cross relations according to these macroscopic characteristics. Sample groups are formed by specimen of identical shape of this sample. Within these groups, the above correlation is even better and also its linearity evolves. This correlation is used in the standard for the formation of partial sample groups. There are no restrictions in the standard as to the production of these partial groups, though it is obvious that in the case of a too small deviation in the bulk density the use of the function has no sense, whereas in the case of too large deviations or multimodal distribution it is not at all sure whether we have to do with the same rock variant or not.

Mass composition properties and their measurement is prescribed in standards MSZ 18 284/1—3. These are of two types. One of them is the group of density characteristics (specific and bulk density), porosity and compactness which can be calculated from them. Hydrotechnical properties belong to the other group (basic water content, water absorption, apparent porosity), which indicate the differences in bulk density determined in a regular rock-physical state.

3.2 *Qualifying character of bulk density*

According to test plans for qualification, air-dry bulk density should be determined for all regularly shaped specimens, together with the water absorption for all regular specimens of no-dry fracture. Hence they are the two rock-physical data series most often available for the experts performing qualification product standards, however, do not use them for qualification purposes.

According to the engineering geological model, the system of properties of rock blocks constituting rock bodies depends on the constituent minerals, their quality, quantity, state of decay, the amount, size and connection of pores and on the nature and state of the bondings between the rock-forming components. The decay state of near-surface rock blocks depends naturally also on their discontinuity, as with decreasing structural distances the internal surface of effects causing this weathering process increases. In the course of weathering the porosity of the rock usually increases, and simultaneously, the bonding between constituents and that on their cleavage surface are weakened. Thus, if the decrease in bulk density and that of water absorption indicate an increase in the porosity, their interrelation with strength characteristics is obvious, hence they can be used for an indirect estimation of strength and for the formation of equivalent partial sample groups.

A basic requirement for this is that the differences in bulk densities should be large enough, perceptible. Its sensitivity threshold depends on the accuracy of the measurements readings, the deviation of readings at a given probability level. On assuming average laboratory conditons, rock materials of average bulk density and specimens for standardized uniaxial compression strength the expected value of the deviation of readings (s_s) is:

$$s_s = 1.91 \text{ kg/m}^3$$

If the deviation experienced for bulk densities on a group of samples does not exceed the three-fold of the above value, there is no sense in using it for forming partial sample groups.

3.3 *The qualifying character of the velocity of ultrasonic sound waves*

A possibly applicable property for the formation of partial sample groups may be also the propagation velocity of longitudinal ultrasonic sound waves. The value of this property depends theoretically on the solid rock constituents, their state of weathering, the nature of bondings between them, the extent of their loosening, and on the amount, situation and filling of pores. When determining it, we measure the length of the specimen and the propagation time of the first arriving wave. The parameter is the ratio of the two results which expresses the projective mean velocity of the wave. On assuming average conditions, the expected deviation of readings is:

$$s_c = 0.014 \text{ km/s}$$

Hence the resolution of the measurement is about 0.042 km/s, and at even smaller deviations, no qualitative differences can be reliably estimated. Though it is not included in the standard, a better correlation than 0.5 of these two properties should be required together with its being positive for the formation of statistically equivalent partial sample groups. If, namely, the correlation for these two values is worse than that, the probability that they show individually better correlations with the static properties with significantly larger deviation is very small.

4. Correlations of the andesite body at Sárospatak

In 1986, on the Szemince Hill at Sárospatak, core drillings have been made to ensure the stone supply of the quarry, and the stone has been qualified on the basis of the study of the core material by the Department of Minerology and Geology. Further correlations will be shown by using these results.

Eleven core drillings have been performed on the area studied; the macroscopic study of their core materials has shown that a length of 361.7 m is usable for quarrying. These core materials have been classified into 19 sample groups on the basis of approximate petrographic studies and the number of drillings, but in the present study they are considered a uniform assembly of data, since our objective is not the spatial stint of the rock bodies of different quality, but the evaluation of a studying-qualifying system.

4.1 *Petrographic properties*

Andesites cross cut in drillings are uniform concerning their chemistry. It is possible that they are formed in more than one cycle, but the composition of the originating rock has not changed during these cycles.

For andesites in general porphyritic, hyalopilitic porphyritic and pilotaxitic textures are characteristic, a cumuloporphyritic nature is frequently observed too.

Among porphyritic components, plagioclase is predominant with a labradorite nature composition, usually fresh, twin-layered, zonal. Weathering, decay is rare, if any, it starts at fissures and sericite, a clay mineral is formed.

In all the samples studied, pyroxene is the only dark coloured component. Rhombic and monoclinic pyroxenes are simultaneously present in all samples. The rhombic pyroxene is, according to its refraction index and slight pleochroism hyperstene, whereas the monoclinic variant is augite. They are usually fresh, sometimes a slight alteration can be observed (opacitization, bastitization) along the fissures. Coloured components are very rarely weathered to a higher extents.

Porphyritic components have an average size of 0.7—2.5 mm, their amount varies in the range of 40—65%.

The groundmass always contains smaller or larger amounts of rock glass. Its contribution is often as high as 20—25%, it is often fresh, but also characterized by subsequent silicification, to a small extent, seritization also occurs.

Besides rock glass, a dense plagioclase microlite network is also observable in the groundmass, sometimes with a trachitic character. Its amount varies between 15 and 30%, its size is on the average 0.003—0.04 mm. In the groundmass of the rock small pyroxene crystals also appear, but their amount is not significant.

The porosity of the andesites studied is 1—3% on the average. On the walls of the pores hydrothermal minerals can be observed.

The andesite samples can be classified into 4 groups by their porosity, state of weathering and glass content.

Type 1 : glassy pyroxene andesite (Fig. 4)

For this type it is characteristic that in their groundmass 20—25—30% of rock glass is present. These rocks are usually fresh without recrystallization.

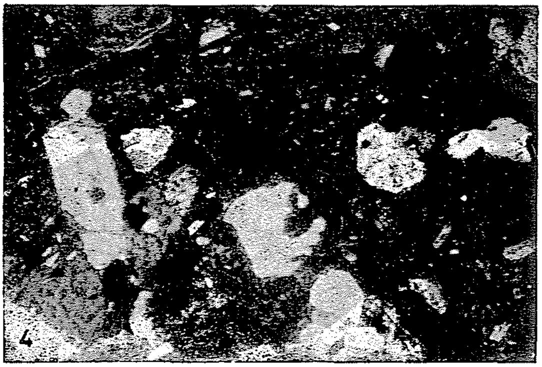

Fig. 4. Micrograph of the glassy pyroxene andesite of Szemince Hill at Sárospatak (type 1)

Fig. 5. Less glassy pyroxene andesite of the Szemince Hill at Sárospatak (type 2)

The amount of plagioclase microlites is smaller, 15—20%. Their size is also smaller than the average. Porphyritic components occur in 45—50%. Plagioclases are fresh, in pyroxenes opacitization and bastitization start along fissures. The porosity in rocks belonging to this group is usually 1.5—2.5%.

Type 2 : less glassy pyroxene andesite (Fig. 5)

This type is very frequent and characteristic among the samples. The difference from type 1 is in the glass content. In this type it never exceeds 15%, but it is often below 10%. Hence the texture of these samples is of a porphyritic-hyalopilitic or porphyritic pilotaxitic nature. The constituents of the rock are fresh, among porphyritic components the pyroxenes are slightly weathered at their edges or along fissures. The oriented intergrowth of hypersthene and augite is frequent. This pheomenon is presumably the consequence of crystallization preferences. Plagioclases are fresh, twin-layered, zonal.

Fig. 6. Porous, glassy pyroxene andesite of Szemince Hill at Sárospatak (type 3)

Fig. 7. Wheathered, silicified pyroxene andesite of Szemince Hill at Sárospatak (type 4a)

The plagioclase microlite network in the groundmass is very dense, trachitic character is frequent, sometimes flow nature is observable. Small pyroxene crystals are also present. The average porosity of the samples is 2.0—2.5%.

Type 3: porous, glassy pyroxene andesite (Fig. 6)

The most characteristic feature of this type is the relatively large porosity (usually 5—10, maximum 15%). The pore distribution is uniform, unoriented, gas bubbles in the basic material are characteristic as well as the crumbling of the weathered porphyritic material in the middle. The size of pores is 0.3—2.0 mm. They are round or irregular in shape. There is no appreciable mineral segregation on their walls. The relatively high rock glass content is also characteristic for this type (15—25%), thus the texture of samples is exclusively porphyritic-hyalopilitic. Concerning its composition, the rock is identical with type 1. In samples belonging to this group, endogenous inclusions (diorite) also occur.

Type 4: weathered pyroxene andesite

The representatives of this group are of less importance with respect to their occurrence frequency. The basic characteristic of these rocks is the partial or total transformation of the originally high rock glass content. Hydrothermal zones are found mainly along grain boundaries. The transformation is mostly silicification, clay mineralization is rare.

Fig. 8. Clay mineralized pyroxene andesite of Szemince Hill at Sárospatak (type 4b)

In the silicificated type (Fig. 7), potassium feldspar also occurs as a result of recrystallization. The porphyritic components of the samples are here relatively fresh, their state of weathering is only slightly stronger than that of fresh types and weathering is restricted mostly to the surroundings of fissures.

The type tending to clay mineralization (Fig. 8) is the most weathered, alteration is observed here, in addition to the groundmass, also for the porphyritic components, mainly pyroxenes, which transform into bastite, opacite, limonite. Plagioclases are less weathered, transformation here is to sericite.

4.2 *Distributions and correlations*

The frequency histograms of bulk densities measured for air-dry, regular-shaped specimens are shown in Fig. 9. This distribution is unimodal and of an asymmetric type. The frequency histogram of the propagation velocity for ultrasonic sound is of a similar nature (Fig. 10), with the difference that it is bimodal, though with only an insignificant displacement of the peaks.

4.2.1 *Correlation between bulk density and ultrasonic sound velocity*

The correlation of the two values is positive, but the correlation factor does not reach the value 0.5. Below a definite correlation, scattered points

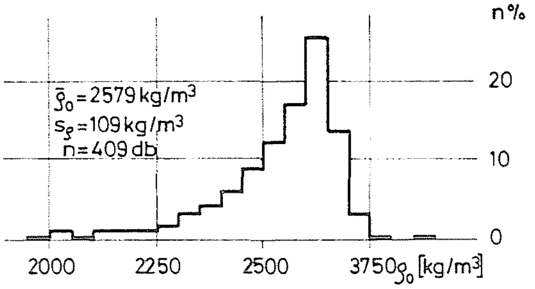

Fig. 9. Frequency histograms of bulk densities. Szemince Hill, Sárospatak (ϱ_0)

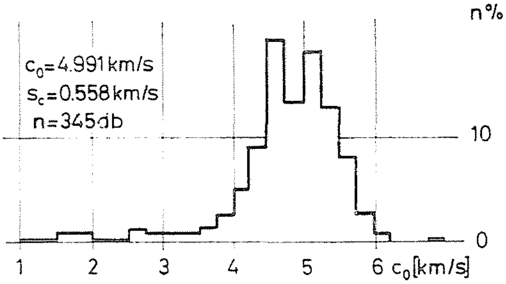

Fig. 10. Frequency histograms of measured ultrasonic sound velocities Szemince Hill, Sárospatak (c_0)

appear, especially for higher bulk densities. On studying the ultrasonic sound velocity of specimens saturated with water as a function of air-dry bulk density this scatter disappears in part, and the correlation factor becomes 0.65. The reason for this may be that in the bulk density of more weathered specimens (clay mineralization, type 4) the decomposition is hardly detectable as the products of alteration processes remain in the structure, whereas the acoustic properties of the rock change considerably.

4.2.2 *Correlation between bulk density and basic water content*

Relatively few measurements have been performed on regularly shaped specimens for the determination of their basic water content. The results of measurements on specimens with irregular shape show a similar pattern as shown in Fig. 11. The global correlation for the points is given by the full line:

$$v_0 = -0.678\varrho_0 + 3.669(\mathrm{V}\%); \quad r = 0.14; \quad s_r = 0.62$$

If we disregard the obviously erroneous average line, at least three different straight lines can be fitted to the points (a, b, c), moreover, the fit of points

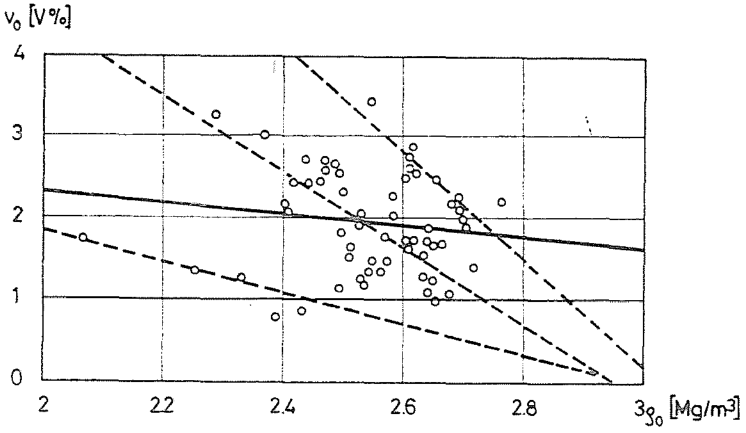

Fig. 11. Correlation between bulk density (ϱ_0) and basic water content (v_0), Szemince Hill Sárospatak

belonging to straight line "b" can be characterized better by two parallel lines. The equations of the lines are:

$$v_{0a} = -1.88\varrho_0 + 5.57; \quad r = 0.83; \quad s_r = 0.18$$

$$v_{0b} = -4.68\varrho_0 + 13.71; \quad r = 0.77; \quad s_r = 0.37$$

$$v_{0c} = -6.52\varrho_0 + 19.74; \quad r = 0.93; \quad s_r = 0.19$$

This distribution is due to petrographic-genetic reasons. In igneous volcanic rocks, the high basic water content point to the presence of either rock glass or clay minerals and other weathering products. Bulk density measured in an air-dry state depends on the mineral composition and on porosity. Porosity may here be primary or secondary, and the pores may be filled with weathering products or be empty. According to petrographic identification — as analytical petrographic studies cannot be performed for all specimens — the straight line with the smallest slope (a) corresponds to a fresh rock variant containing a low amount of rock glass or to a silicificated variant. The straight line with the largest slope (c) probably characterizes the strongly clay mineralized version in which the pores are completely filled with the products of weathering processes.

4.2.3 *Correlation between bulk density and water absorption*

Water absorption as a parameter means the amount of water expressed in vol.% taken up by the air-dry specimen when immersed into water. In the case of a nearly identical mineral composition, there is a negative correlation between bulk density and water absorption, as both depend on the porosity. This

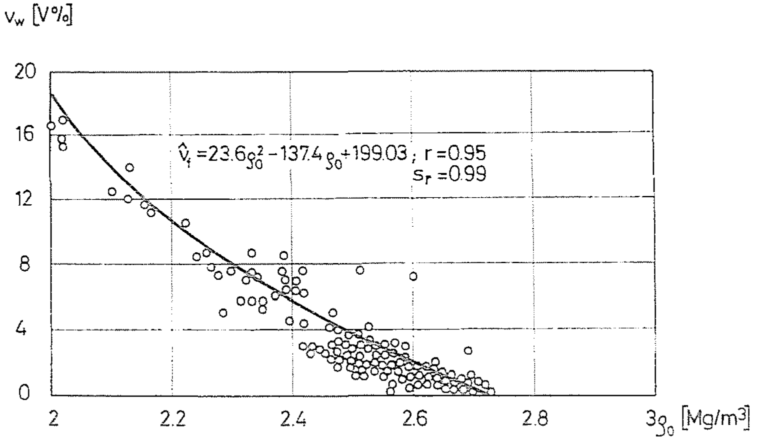

Fig. 12. Correlation between bulk density (ϱ_0) and equilibrium water absorption (v_w) of specimens, Szemince Hill, Sárospatak

corralation is shown in Fig. 12. The quadratic parabola showing a very good correlation indicates that at low bulk densities this function is steeper. Petrographic considerations do not make such a correlation probable, however, it fits very well the points measured. Within the same sample group, (identical petrographic characteristics) the correlation becomes unambiguously linear and a deviation is caused only by measurement errors.

4.2.4 *Changes in water absorption*

It is interesting to study the changes in water absorption during freezing experiments. Water absorption is determined by measuring masses, thus a combined effect of water absorption and freezing loss is detected. The first equilibrium established in an 18 °C water environment is called mass constancy, and the specific water volume calculated from the mass increment belonging to it is the so-called water absorption. During the durability tests of specimen against freezing— when we follow the mass changes—water absorption can be obtained again. The value of water absorption on freezing can be larger than the equilibrium one, as freezing can open up pores for water that have been closed till then, but in rock materials of inferior quality it usually decreases. This correlation, after 25 freezing cycles, is shown in Fig. 13. It is seen that the water absorption of specimens with a low equilibrium water absorption has not changed significantly. With samples of a higher water absorption it is increasingly frequent that the water absorption decreases on freezing to one half or one third indicating the high loss of solid material of test pieces. The low resistance against freezing becomes more and more predominant with increasing porosity.

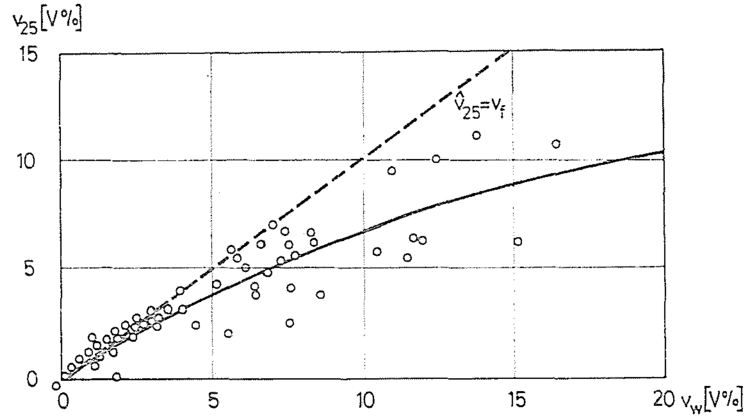

Fig. 13. Change in the water absorption after 25 freezing cycles, Szemince Hill, Sárospatak

4.2.5 *Correlation between bulk density and strength of the crushed rock (aggregate)*

In product qualification studies, the strength qualification of (aggregate) products (e.g. crushed rock) occurs on the basis of the Los Angeles crushing. In the case of core drilling, we first prepare test pieces of regular shape from the core section in question which is considered a sample group, then from the residue of the core the crushed material is gained (Z 5/8). The Los Angeles and crystallization studies necessary for the rock-physical qualification are then carried out on this fraction of the crushed rock relatively characteristic for the sample group.

Correlation for the results of the Los Angeles crushing with the average bulk density is shown in Fig. 14. The straight line shows a stone material of an about average degree of weathering.

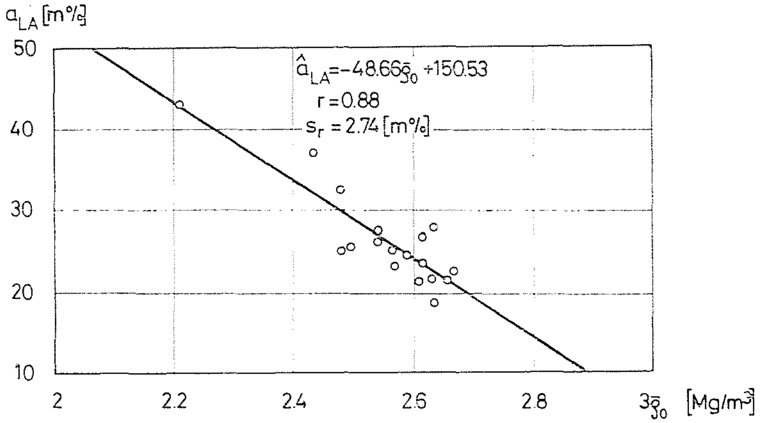

Fig. 14. Correlation between the bulk density of the rock (ϱ_0) and its Los Angeles crushing loss (a_{LA})

4.2.6 *Correlation between bulk density and compressive strength*

The classification of the majority of crushed products from the viewpoint of strength occurs on the basis of compressive strength. The first' characters of the strength class mean the minimum average compressive strength in MPa. The correlation of bulk density and compressive strength is shown in Fig. 15. For identical approximate petrographic characteristics — the same sample group — the curve is nearly linear. This empirical fact is the basis for the formation of sample groups. The correlation illustrated in Fig. 15 shows an exponential increase up to the upper limit of bulk density for both compressive strength and its deviation.

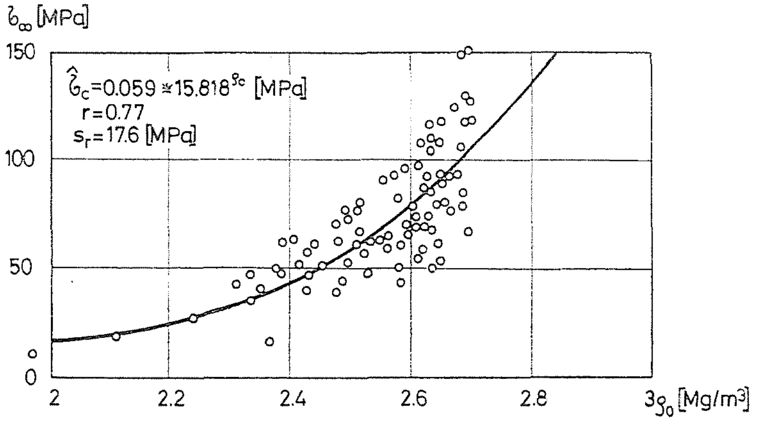

Fig. 15. Correlation between bulk density (ϱ_0) and compression strength (σ_{c0}), Szemince Hill, Sárospatak

The increasing residual deviation seems to be obvious, as for test pieces with identical size and mineral composition, compressive strength depends on the number and distribution of strength faults. The greater the number of (primary or secondary) pores within the test piece the higher the probability that faults are situated at the strength maxima formed inside the test piece and thus serve as starting points for fissures.

With increasing bulk density the probability for this spatial correspondence decreases, however, the considerably higher strength contrast may cause a significant decrease in strength. As a result of these factors, deviation increases appreciably. In rock evaluation or in core drillings the other important factor of uniaxial compression studies, the modulus of elasticity as well as the results of combined (Brasil) tensile strength measurements are also taken into account, as prescribed by standard plans.

4.2.7 *Correlations of the modulus of elasticity*

The rock-physical modulus of elasticity (Young modulus) and compressive strength correlate as shown in Fig. 16. The function is linear, and the correlation factor is high. The deviation of points from the straight line is random, it depends on the appearance of starting points for fissures in the surrounding of strength maxima. Thus the consideration of this value may decrease the qualifying effect of the deviation in compression strength.

Correlation between bulk density and modulus of elasticity is shown in Fig. 17. The shape of the curve is naturally similar to that of compressive strength, but it seems that its confidence interval is smaller and smoother, the points show smaller deviation around the straight line.

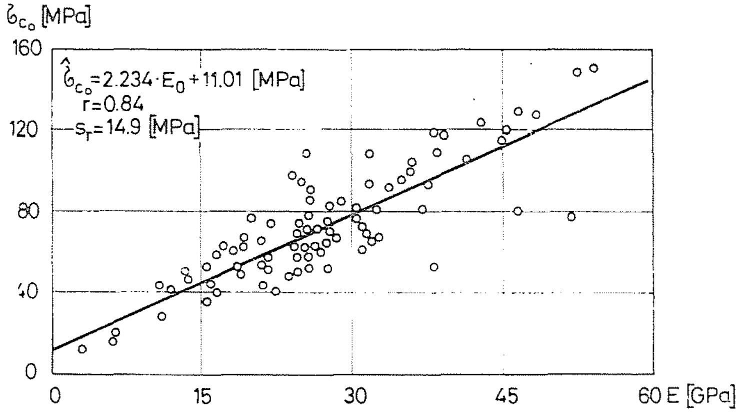

Fig. 16. Correlation between the rock-physical modulus of elasticity (E_0) and compression strength (σ_{c0}), Szemince Hill, Sárospatak

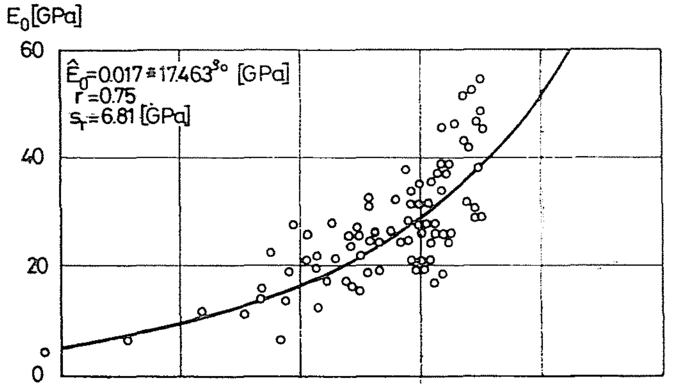

Fig. 17. Correlation between bulk density (ϱ_0) and the modulus of elasticity (E_0), Szemince Hill, Sárospatak

4.2.8 *Correlation between bulk density and tensile strength*

This function is illustrated in Fig. 18. Its shape and the situation of points are similar to those for compressive strength, but the deviation and confidence interval are higher. This may be explained geometrically by the relatively smaller volume of the strength maximum, thus the probability for the occurrence of faults in this volume is smaller. As the number of faults in unit volume is characteristic for the sample group, it is expedient to include this parameter in the qualifying procedure.

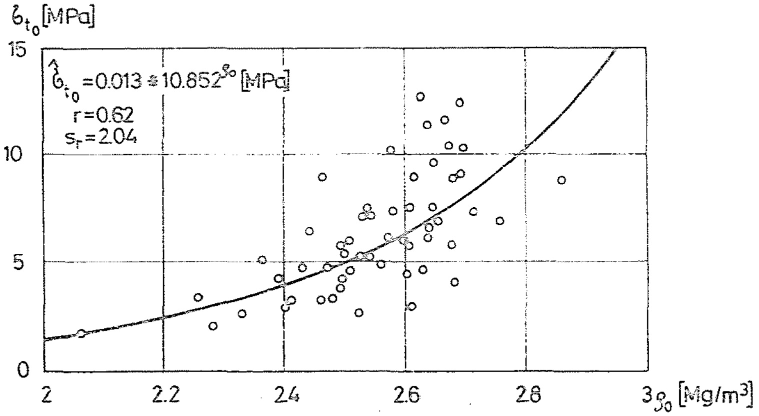

Fig. 18. Correlation between bulk density (ϱ_0) and tensile strength ($\sigma_{c\,0}$), Szemince Hill Sárospatak

5. Parameters indicating the durability of rocks

Durability properties are characterized in product standards by the variation factor of compressive strength, and this is the basis for classification *(n, f* or *ff)*. The variation factor is the ratio of the average compressive strength of test pieces having suffered a durability model effect to the air-dry average of a certain size. Its value is suitable if it is greater than the value prescribed for the group (usually 0.8). The durability model effect may be saturation with water, 25 and/or 50 freezing cycles. For qualifying the ff class, the study of 4 equivalent sample groups is required.

The uniaxial compression strength of the useful core material from the Sárospatak region has been studied on 48 partial sample groups, and the average empirical variation coefficient has been found to be 29%. From this it follows that the standard deviation of the variation factor which can be calculated from the average values of compressive strength to be expected in the surrounding of $\lambda = 0.8$ is 0.33 at a probability level of about 95%.

This large standard deviation causes a differentiation between groups questionable. The empirical finding that for really frost-resistant rocks the smallest equilibrium compressive strength is obtained in a rock-physical state saturated with water and that the average compressive strengths measured after 25 and/or 50 freezing cycles are often even larger than in the air-dry state, does not help much either. Therefore, it would be expedient to include more parameters or variation factors in product qualification. The most obvious for this purpose is to extend the studies to the other parameter of uniaxial compression investigations, the variation of the modulus of elasticity.

6. Utilizability of mass composition characteristics

Another, apparently direct possibility, which is otherwise also necessary for the standardization of rock-physical states, is the measurement of masses and mass composition parameters derivable from them.

Correlation with strength characteristics is obvious, but the disadvantage of its use is that it cannot be applied mechanically. The limiting values for qualification can be determined only by expert opinion, on a petrographic-genetic basis.

The situation is more favourable if an expert opinion is available on the rock variants of the given location. This provides the mineral composition and the primary and secondary genetic processes. The local correlations between mass composition and strength can then be drawn. From their coefficients the mass composition limits can be determined, which represent a conform assembly of parameters with the limiting value of strength. A comparison with this assembly of parameters ensures a much higher reliability of qualification, since in a later product qualification e.g. the bulk density measurements are repeated more often than the uniaxial compression strength is determined in a certain rock-physical state. This possibility of utilization unfortunately basically contradicts the expectation that the studies for classification of a product should be carried out on the material of the product if possible.

From among mass composition properties, water content, water absorption and apparent porosity are of different nature. Among them water absorption is measurable on the same specimen between freezing cycles. The extent of its variation can be used directly also in product qualification. For example, in durability classes f and ff it is required that the solid material loss should not exceed a certain limiting value.

The utilization of bulk density is expedient in the first line in engineering-geological studies of rock masses. Continuous changes in the quality can be better followed by bulk density values measurable in several points. The role of effective strength studies varies in the reliable determination of local empirical correlations.

7. Conclusions, suggestions

Due to the above reasons, the requirement system of product standards should be modified so that for crushed products it include the modulus of elasticity and its variation factor, as well as the variation factor of water absorption in qualifications. Thus durability can be expressed in a more reliable way and the selection of rock materials for building purposes can take place with a considerably larger safety.

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