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Abrasion parameter of natural stone for public infrastructure and correlations with other properties

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Abstract: The abrasion resistance is one of the crucial parameters to consider when evaluating natural stone for use in public infrastructure with light traffic. The assessment and evaluation of abrasion parameters can be carried out according to the EN 14157 standard, using two typical natural stones from different sources in order to compare the necessary parameters. The parameters will be analysed in correlation with other factors in order to find optimizations. The results showed a significant correlation coefficient between the dry sample and water saturation tests. This suggests that the abrasion resistance of natural stone when dry is closely related to its resistance when saturated with water. This information is valuable in selecting appropriate natural stone materials for public infrastructure, as it provides insights into how the materials will perform under different conditions. In public squares, natural stone is often used as paving material because of its durability, resistance to weathering, aesthetics and other parameters. However, different types of natural stone have different levels of abrasion resistance, which can affect their suitability for use in public squares.

Key words: Bohme abrasion test EN 14157, natural stone, rock properties, correlations of properties

Parametar abrazije prirodnog kamena za javnu infrastrukturu i korelacije s drugim svojstvima

Sažetak: Otpornost na habanje jedan je od ključnih parametara koje treba uzeti u obzir pri procjeni prirodnog kamena za upotrebu u javnoj infrastrukturi sa slabim prometom. Procjena i ocjena parametara abrazije može se provesti prema normi EN 14157, koristeći dva tipična prirodna kamena iz različitih izvora kako bi se usporedili potrebni parametri. Parametri će se analizirati u korelaciji s drugim čimbenicima kako bi se pronašle optimizacije. Rezultati su pokazali značajan koeficijent korelacije između suhog uzorka i ispitivanja zasićenosti vodom. Ovo sugerira da je otpornost prirodnog kamena na abraziju kada je suh usko povezana s njegovom otpornošću kada je zasićen vodom. Ove su informacije vrijedne pri odabiru odgovarajućih materijala od prirodnog kamena za javnu infrastrukturu, budući da pružaju uvid u to kako će se materijali ponašati u različitim uvjetima. Na trgovima se prirodni kamen često koristi kao materijal za popločavanje zbog svoje trajnosti, otpornosti na atmosferilije, estetike i drugih parametara. Međutim, različite vrste prirodnog kamena imaju različite razine otpornosti na habanje, što može utjecati na njihovu prikladnost za korištenje na javnim trgovima.

Ključne riječi: Bohme test abrazije EN 14157, prirodni kamen, svojstva stijene, korelacije svojstava

1. INTRODUCTION

Since the dawn of civilization, natural stone as a building material has been used in the construction of buildings and public spaces of various complexity and use, from simple shelters to monumental works of the past and the present architecture. The main parameters that makes this material suitable for use in construction industry are durability and the ability of the material to resist loads and environmental conditions.

In the scope of the development and usage of natural stone in numerous buildings and elements, this study focuses on analyzing the parameters of stone and evaluating the properties necessary for natural stone applications in construction. It is important to provide material properties of the natural stone intended to be utilized in constructing the infrastructure and public squares. The use of natural stone extracted from a local quarry is mostly important to be followed with the properties, such as durability and resistance of the material, specifically for the infrastructure and public squares where the natural stone will be used. The properties need to be tested, specifically those parameters: abrasion test, slip resistance, etc, to decide the applications of natural stone. In addition to the specific tests mentioned, it is important to consider the geological characteristics of the natural stone being used. The mineral composition, grain size, and texture can all affect the strength and durability of the material. For example, dense, fine-grained granite may be more resistant to weathering and erosion than porous, coarse-grained sandstone.

The use of natural stone in construction can provide a beautiful and durable option for buildings and public spaces. However, it is important to carefully evaluate the properties of the stone and consider factors such as sustainability and installation techniques in order to ensure a successful and long-lasting application.

2. MATERIALS AND METHODS

2.1 Natural stone for paving the public spaces

Stones are naturally resistant and perform effectively in various types of urban hardscapes. Natural stone is a long-lasting material, offering a wide range of functional and aesthetical solutions when applied as a finishing cover for squares, plazas, and other open public environments. Natural stone is considered a sustainable material, as it is one of the building materials embodying the lowest levels of carbon. Different hardness and durability properties are usually considered depending on the type and intensity of traffic, whether pedestrian or biking. But when it comes to paving, it is important to apply rough finish stones rather than smooth ones as a user safety parameter for preventing slipping and falls. Natural stone in an urban setting usually requires minimum upkeep (mostly with mild soap and water). The general evaluations of the stone for applying in frequent traffic areas need to evaluate the properties in direct relations, such as abrasion test and slip resistance, which have to be considered in close relations to other stone physical and mechanical properties, [4].

2.1.1 Abrasion testing according to the EN 14157

The performance and applications of natural stones in construction are primarily determined by testing their physical and mechanical properties. European standards regulating the requirements for natural stone mention the test methods and the properties of the stone to be tested, depending on its application. If natural stone is intended for use as floor tiles (EN 1341), paving blocks (EN 1342) on outdoor road surfaces, or as floor and staircase elements

(EN 12057, EN 12058), it is important to test their abrasion resistance. Abrasion of stone materials used in construction results from their everyday usage, [1], [2], [3].

Abrasion resistance is one of the mechanical-physical properties which allow estimating the usefulness of a particular stone type in different positions and conditions. It also affects the aesthetic qualities of the stone in long-time services. Abrasion of stone is defined as damage to its top layer due to the friction and/or impact from an element interacting with the stone layer. This friction causes stone particles to separate (loss of mass, volume and stone thickness) due to scratches. Information on the abrasion of natural stone, expressed as the loss of the top layer during tests, is fundamental for estimating the life span, including wear, of a particular stone type in a particular application.

The objective of this work is to find out the abrasion resistance of three different types of stones originating from different quarries, which are considered paving materials for public spaces, [7].

2.2 Experimental work

The test procedure is focused on testing the samples of different types of stones with dimensions 71.7 x 69.6 with contact area ~50 cm^2 ~ thickness t=70 mm. All the specimens for testing are weighed to the accuracy of 0.1 gr to proceed in testing machine BOHME equipment.

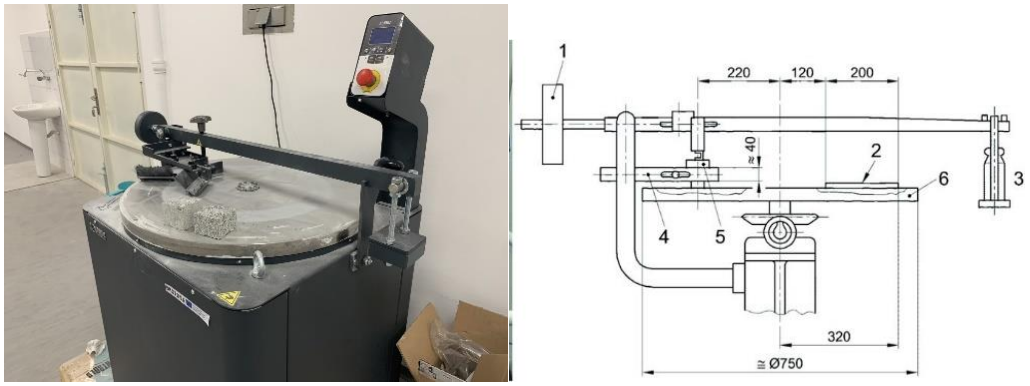

Figure 1. Bohme abrasion tester
1-counterweight, 2-test track, 3-loading weight, 4-sample holder, 5- sample; 6-rotation disc

The procedure for testing for all the samples is done per EN 14157 (Fig. 1), consisting of grinding the natural stone sample during the rotation process of the disc and calculating the loss of mass for each sample. During the testing, the steps are presented in Fig. 2, [1].

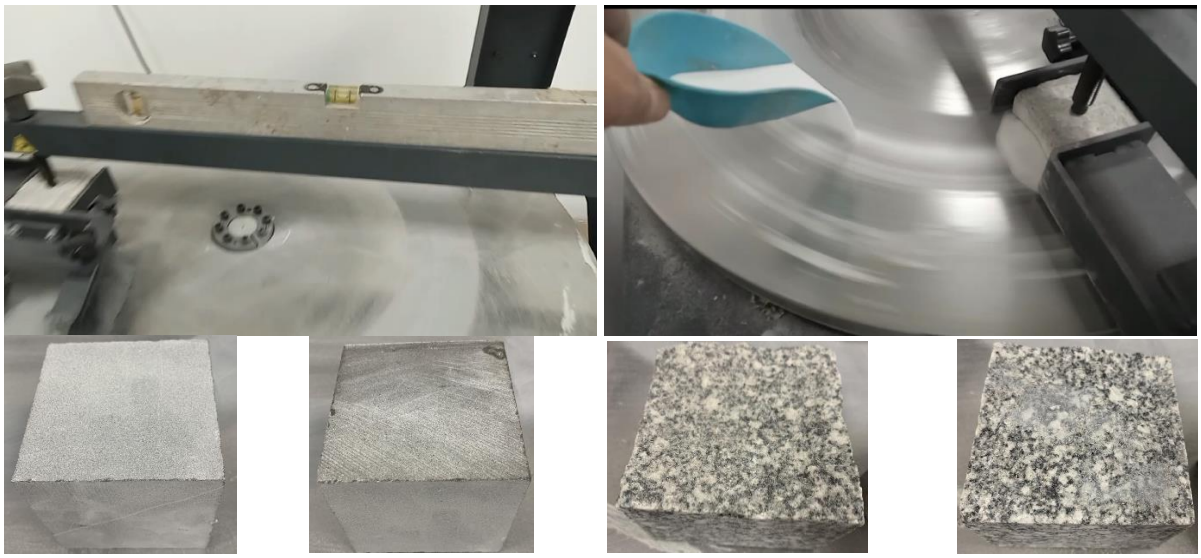

Figure 2. Testing process for different types of stone samples

The test consisted in placing the sample in a clamp and loading it with axial force. During the tests, special attention was focused on keeping the abrasive materials and rotating the sample for the next cycle. The abrasion was calculated as volume loss in the testing sample $\Delta V[cm^3]$.

$$\Delta V = \frac{\Delta m}{\rho}[cm^3] \quad (1)$$

Table 1. The results of testing the three types of natural stones

Sample	Type of stone	Density [gr/cm^3]	Water absorption [%]	Compressive strength [N/mm^2]	Flexural strength [N/mm^2]	Abrasion volume ΔV[cm^3/50 cm^2]
*	Marble-White	2.64	0.44	144.1	13.5	9.70
**	Marble-Black	2.65	0.40	150.3	14.5	9.2
***	Andesite	2.74	0.25	190.2	17.4	7.50

*Marble-white–Quarry-Stone Factory-Kosovo
**Marble-black-Quarry-Stone factory-Kosovo
***Natural stone –Natural pavement –Andesite-Paving- Quarry -Macedonia

The results will be analysed in relation to the abrasion resistance, which is one of the key parameter in determining the suitability of natural stone application in public space in paving the public spaces.

The results allow an observation that testing stones have different properties based on mineralogical and petrography properties. The correlations between the parameters are described by a probability distribution. This analysis will help to understand which properties are more indicated to abrasion resistance, which is the aim of this paper. The detailed analysis is presented in the following charts, [6], [8].

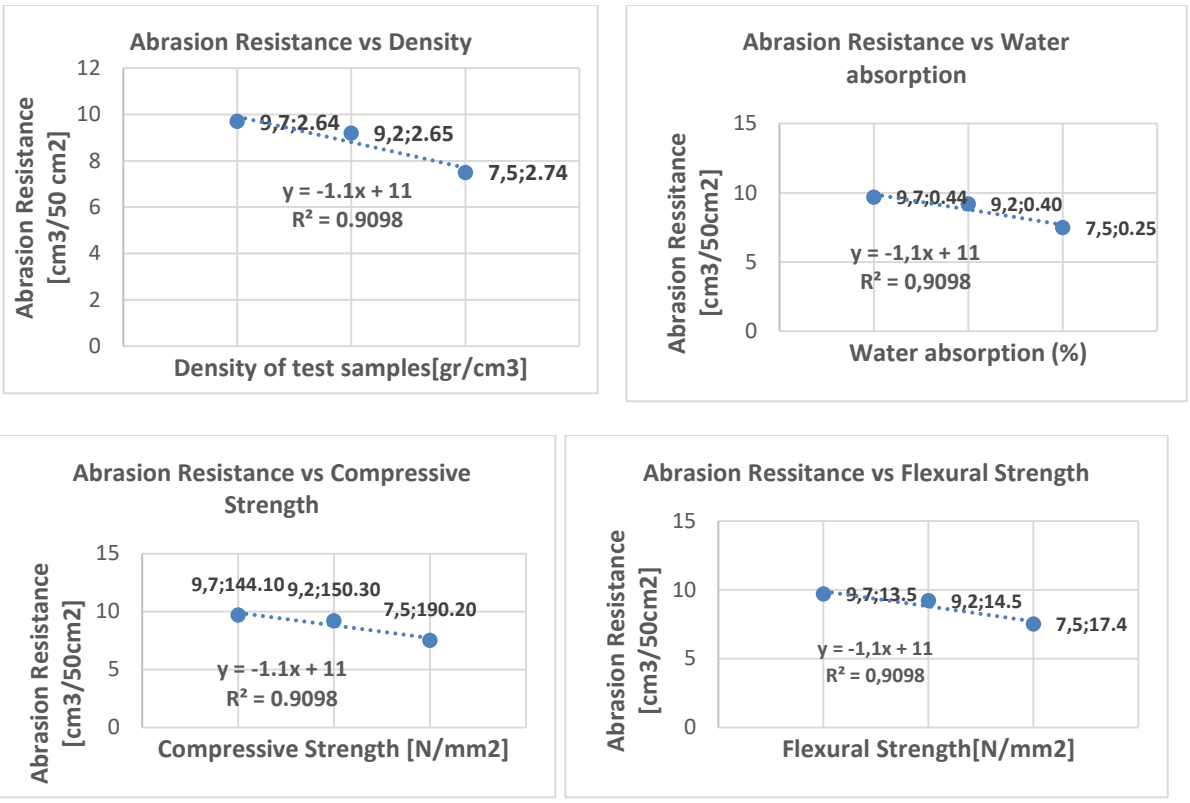

Figure 3. Chart plots of abrasion resistance vs properties of natural stones

The correlations of testing parameters presented in the charts will be analysed with equations in Table 2.

Table 2. Correlations equations concerning the abrasion resistance

Properties of testing samples	Regression equation Relations of abrasion resistance vs parameters
1	y=64.39+20.77 D
2	y=4.61+11.51 WA
3	y=16.21-0.04 CS
4	y=17.41-0.57 FS

3. CONCLUSIONS

According to the results after the testing for different types of natural stone and in correlations of properties, focused on the effect of other properties in abrasion resistance, the following conclusions are presented:

- Mineralogy of the natural stone, represented in marble stone and andesite, affected the abrasion parameter in the application process in public spaces, specifically in moderate and high traffic.
- Determination of the abrasion wear resistance characteristics of natural building stones is important for selecting the appropriate material for public spaces.

- In evaluations, the effect of low values of properties of testing sample results in the high abrasion–wear loss of the mass, with effects on the durability of public spaces.
- As key parameters in this case, all the testing parameters are highly correlated with the evaluations of the abrasion.

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