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# Investigation of the Relationship between Böhme Abrasion Resistance and Strength Properties of Some Natural Stone

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**Abstract**

Natural stones are widely used in construction sector. Physico-mechanical properties of natural stones are very important for their in terms of areas of use. Abrasion Resistance of natural stones is an important phenomenon for leads to decrease in mechanical and aesthetical properties. Böhme abrasion (BA) test are the most widely used test methods for determining abrasion resistance.

In this study, 8 different natural stones were tested for their abrasion resistance, flexural strength and uniaxial compressive strength. Relationships between Böhme abrasion resistance and the strength properties were investigated on the basis of experimental results by using Minitab 18 and meaningful relationships were obtained between Böhme abrasion resistance and strength properties. Statistical equations have been determined for estimating the abrasion resistance of natural stone using uniaxial compressive strength and flexual strength.

**Keyword:** Böhme abrasion resistance, Natural stone, Flexural strength, Uniaxial compressive strength

## INTRODUCTION

Natural stones are used in exterior walls, flooring, decoration, stairways, walkways and for architectural purposes. The physical, chemical and mechanical properties of natural stone determine its use area. One of the most important of these properties is abrasion resistance.

The determination of abrasion resistance according to TS EN 14157 [1] is required for the European conformity (CE) marking on natural stones. In natural stone, the Böhme abrasion (BA) resistance test are the most widely used standard test methods for determining abrasion resistance.

The BA resistance test was developed in the 1950s and, since then, has been accepted as a standard stone abrasion test by many institutions [2]. There have been many studies on the BA resistance since this time. Kılıç and Teymen [3] studied relationship between the various mechanical properties and the BA resistance of the rocks, they found non-linear correlations.

Some researchers investigated correlations between hardnesses (Shore, Rockwell) and BA resistance for some rocks. They found statistically significant correlations [4,5].

Kılıç et all [6] examined physical, mechanical and petrographical properties of some calcium carbonate rocks. They pointed to the relationship between Bohme surface abrasion resistance and point load tests and Shore hardness in this study. Some researchers [7–8] associated abrasion resistance with mechanical strength and density.

BA test is widely used in our country but requires considerable workload and a great deal of abrasive material is necessary for this test, which makes it relatively costly. The main objective of the present study was to make an investigation into the relation between Böhme abrasion (BA) resistance, flexural strength(FS) and uniaxial compressive strength (UCS) for a wide range of natural building stones. So equations were produced to predict BA resistance.

## MATERIALS AND METHODS

Material

In this study used 8 different natural stones. This natural stones;

Denizli Travertine,
Elazığ Travertine,
Elazığ Rosso Levanto,
Kozan Limestone Marble,
Ceyhan Limestone Marble,
Silifke Limestone Marble,
Yaylak Granite,
Tokat Diabase.

Methods

In this study, Böhme abrasion resistance, uniaxial compressive strength and flexural strength of the 8 different natural stones were determined.

The uniaxial compressive strength test was conducted on an ELE (3000 kN) auto compression machine with 40×40×40 mm3 cube specimens (Figure 1).

The flexural strength test was conducted on an ELE machine with 50x100x200 mm prism specimens (Figure 2).

BA resistance test carry out according to the TS EN 14157 [1] standard. The test samples should be edge lengths of 71±1.5 mm (50 cm2 surface section). The sample surface is subjected to abrasion between a rotating metal disc and normalized 20 g of grinding powder (artificial corundum) under a load of 294 ± 3N (Figure 3)[2]. The samples are tested for 16 cycles, each consisting of 22 revolutions. The loss in sample volume after 16 cycles is expressed in cubic millimeters. The mean of six individual tests is accepted as the BA resistance value for a given rock.

**Figure 1.** Uniaxial compressive strength test machine

**Figure 2.** Flexural strength test machine

**Figure 3**.Böhme abrasion resistance test machine

RESULTS AND DISCUSSION

Regression analysis is the traditional method for estimation models of mechanical and physical properties of rocks. In order to develop simple regression and multiple regressions, the database was obtained by a series of laboratory tests on different natural stone samples. During the extensive study eight rock types were collected. The experimental program included flexural strength tests (FS) and uniaxial compressive strength (UCS) tests for determining BA resistance. Results obtained from the tests average values are given in Table 1.

Simple regression analysis

Simple regression analyzes were made and correlated for each independent variable. The rate of change in the dependent variable explained by independent variables was assessed using R2. The value of R2, which is close to 1, indicates that most of the variability was explained by the regression model.

Uniaxial compressive strength (UCS), Bending strength tests (FS) and BA resistances of natural stones were compared statistically and it was found to be a strong relationship between variables. Optimal regression model was determined as the cube type and the suitability of each model was tested.

The relationship between UCS and BA resistances is given in Fig 4. There is a strong relationship between UCS and BA resistances (R2=0.95). According to Eq.(1), which presents the relation of BA resistance with UCS, BA resistance predicted and fitting model compared actual laboratory measurements (Fig 5).

BA Resistance=67.30-1.251USC+0.008136USC2-0.000018USC3 (1)

The relationship between FS and BA resistances is given in Fig 6. There is a strong relationship between FS and BA resistances (R2=0.97).According to Eq.(2), which presents the relation of BA resistance with FS, BA resistance predicted and fitting model compared actual laboratory measurements (Fig 7).

BA Resistance=42.03-4.384FS+0.1646FS2-0.00F1956 FS3 (2)

Multiple regression analysis

Multivariable regression equation was developed for the prediction of BA resistance by using UCS and FS (Fig. 8), shown Eq. (3).

BA Resistance= 21.69-0.0714 USC-0.228 FS (3)

**Table 1.**The means of the results of the analysis of natural stone

| Name of natural stone | BA Resistance ($cm^3/50cm^2$) | UCS (MPa) | FS (MPa) |
|---|---|---|---|
| **Denizli Travertine,** | 21.6 | 54.22 | 6.67 |
| **Elazığ Travertine** | 18.17 | 57.98 | 7.06 |
| **Elazıg Rosso Levanto** | 15.3 | 62.6 | 7.93 |
| **Kozan Limestone Marble** | 13.2 | 70.01 | 9.36 |
| **Ceyhan Limestone Marble** | 11.68 | 84.60 | 11.81 |
| **Silifke Limestone Marble** | 7.32 | 90.02 | 13.52 |
| **Yaylak Granite** | 5.24 | 96.86 | 27.41 |
| **Tokat Diabase** | 3.42 | 167.48 | 40.82 |

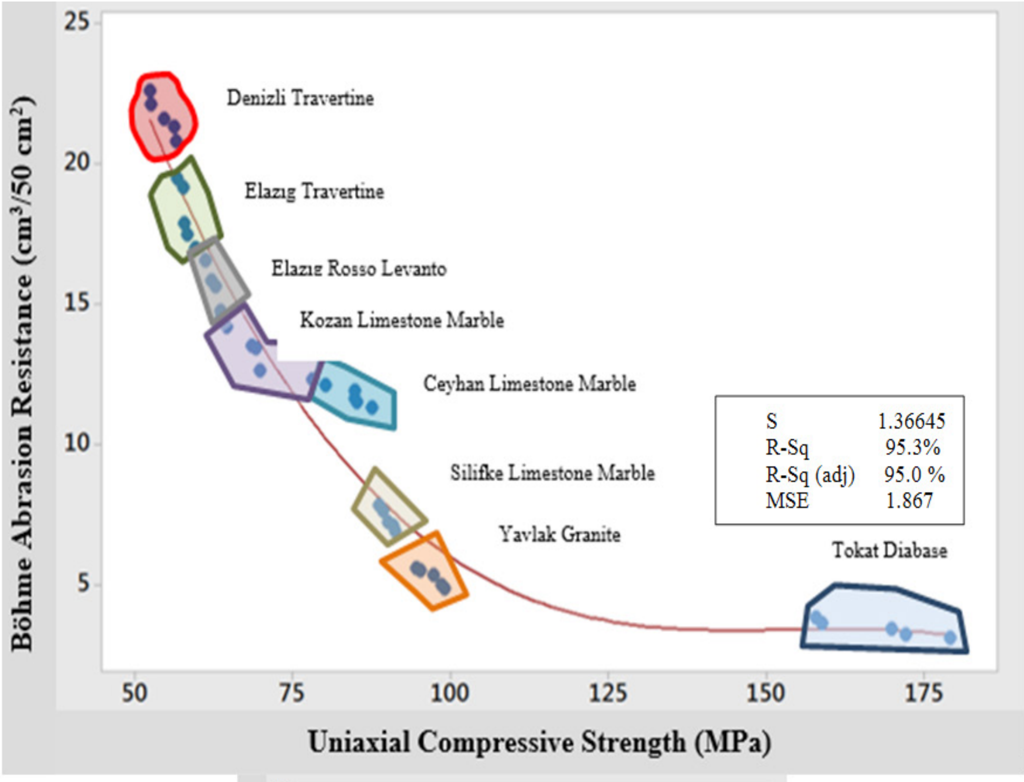


Figure 4. The relationship between BA resistance and USC for natural stones

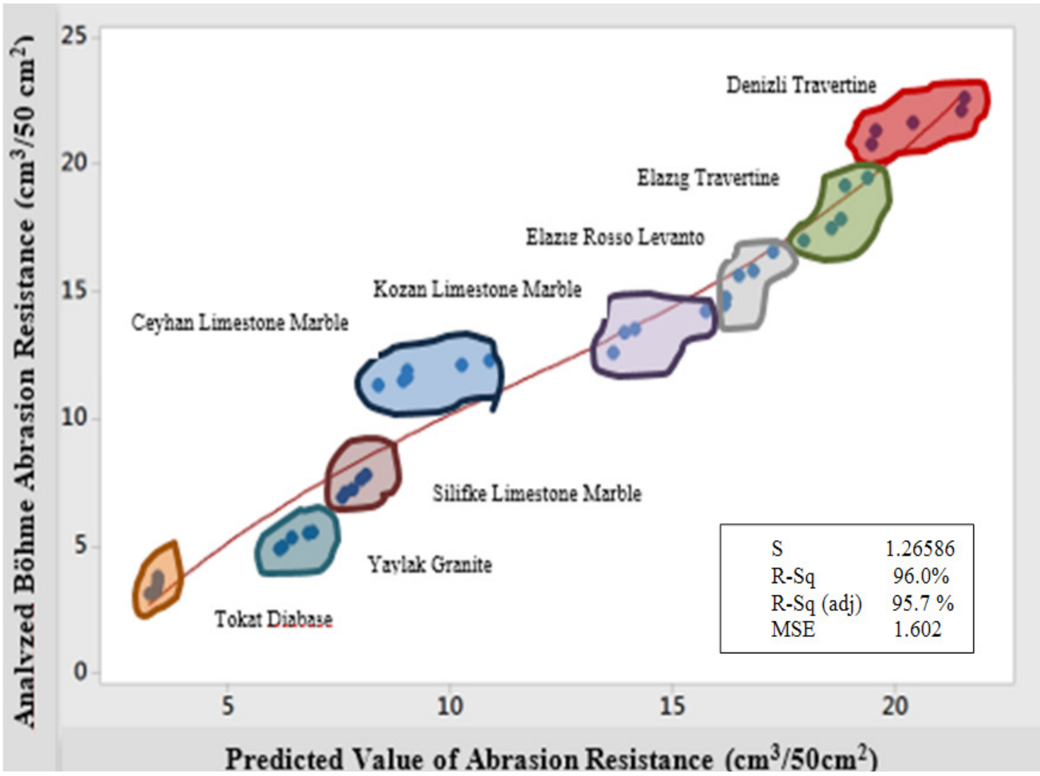


Figure 5. According to UCS the comparasion to BA resistance predicted by fitting model and laboratory measurements

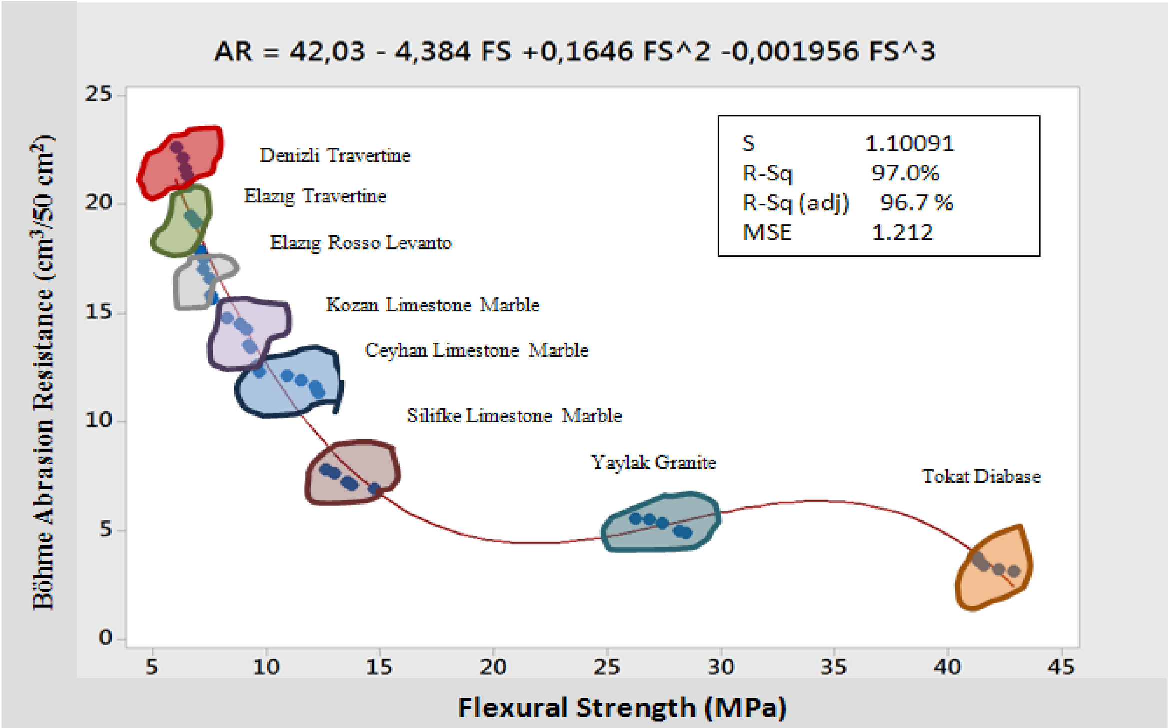


Figure 6. The relationship between BA resistance and FS for natural stones

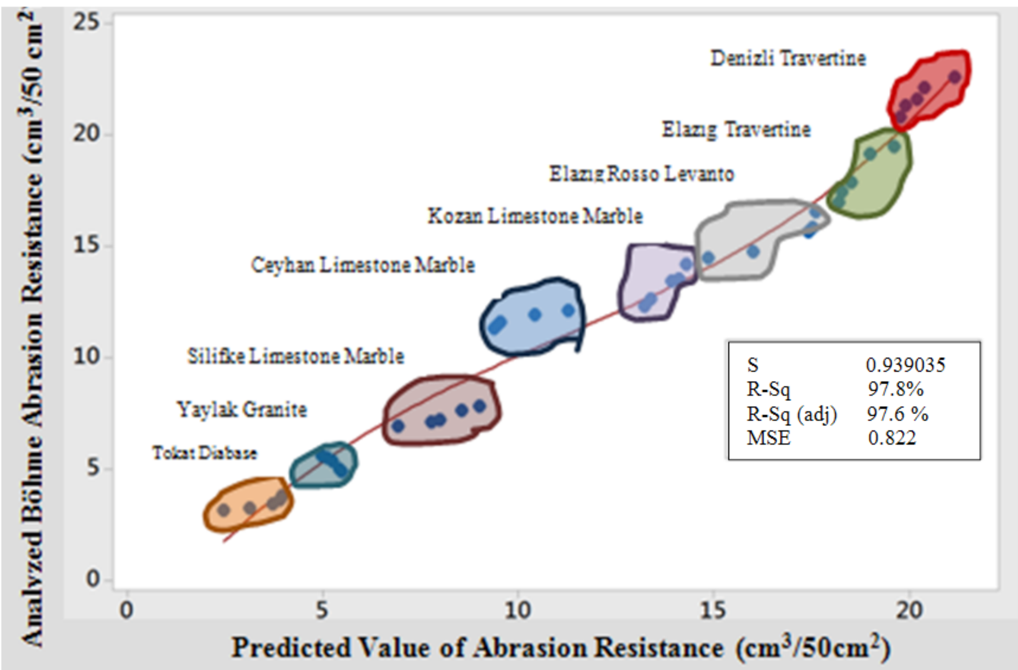


Figure 7. According to FS the comparasion to BA resistance predicted by fitting model and laboratory measurements

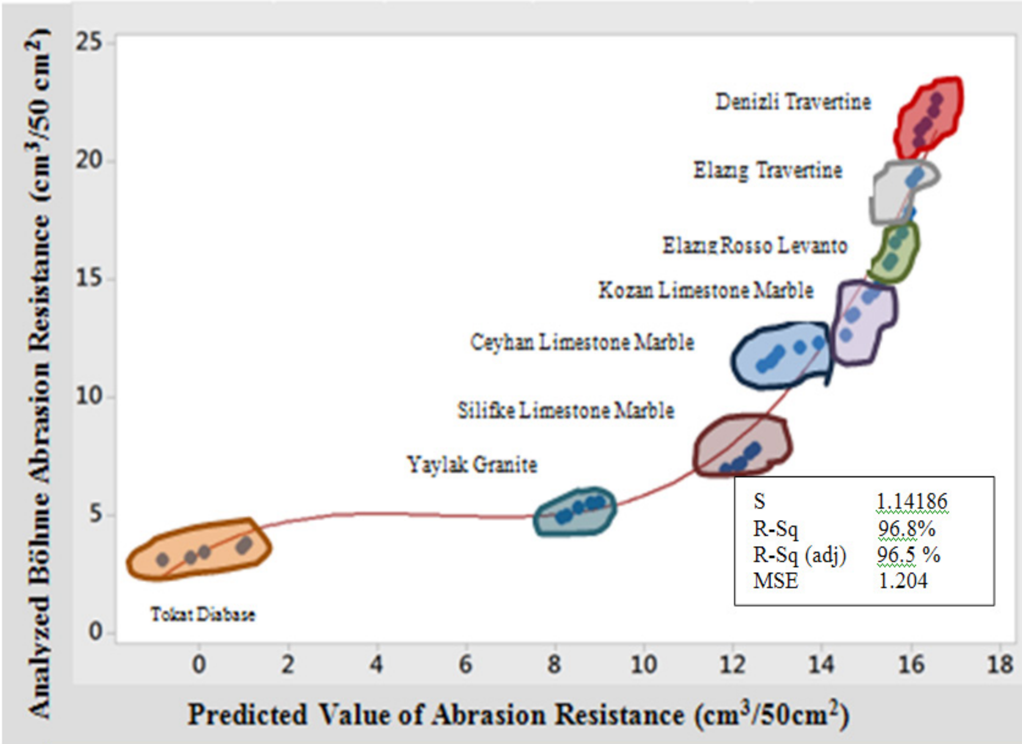


Figure8. According to UCS and FS the comparasion to BA resistance predicted by fitting model and laboratory measurements

## CONCLUDING COMMENTS

BA resistance values of natural stone depending on the UCS and FS were analyzed using the method of least squares regression. The equation of the best-fit line and the coefficient of determination (R2) were determined for each regression.

The results of simple regression analyses may suggest that the relationships between BA resistance and UCS and FS values are meaningful.

The multiple regression analysessupports relationship between BA resistance and UCS and FS.Under unsuitable laboratory conditions, it may be difficult and complicated to measure the BA resistance of natural stones. The use of empirical relationships to estimate the BA resistance of natural stones can be more practical and economical.

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