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*Full Length Research Paper*

# Correlation between "wide wheel abrasion (capon)" and "Bohme abrasion" test results for some carbonate rocks

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**The experiment standard EN 14157 (Natural stones - Determination of abrasion resistance) is applied both as certification and in the context of quality assessment for natural stones. This standard presents the application details of "wide wheel abrasion" and "Bohme abrasion" tests used for determination of abrasion resistance of natural stones used as slabs in construction sector. The standard suggests the "wide wheel abrasion (Capon)" test as the reference method. In this study, the correlation between "Bohme abrasion (BA)", which has been used for a longer time, and "wide wheel abrasion (WWA)", which is relatively a newer method, is investigated. Limestone, marble, dolomitic limestone and travertine samples were collected from 21 different locations and both BA and WWA tests carried out on each samples. Data evaluated considered both weight (%) and volume ($cm^3$) loss of Bohme abrasion test, separately. Regression analyses were performed and significant linear equations were found between WWA and BA test results.**

**Key words:** Bohme, wide wheel abrasion, limestone, marble, travertine.

## INTRODUCTION

The abrasion resistance of natural stones is extremely important especially when they are used as base slabs. Carbonate rocks present a larger reserve than other rocks and cover a wider area on earth. The abrasion resistance of rocks mainly controlled by their mineralogic, micro vs. macro textural characteristics. The most commonly used abrasion test is BA which has been known for a long time. However, WWA test, a rather new test method, is standardized and has been used nowadays. Due to the fact that BA test takes excessive time and the requirement of even more time for evaluation of the results, led to the use of WWA test which is more practical and easy. WWA test is recommended as reference abrasion test by the EN 14157 (2004) standard.

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MacGregor and Chiu (2000) revealed that there exists a logarithmic relation between abrasion and hardness; in that study they used marble and granite samples. Sahlin et al. (2000) have tested limestone and sandstone samples used as base and wall slabs and found WWA value to be 13.5 mm for fresh limestone and 20.5 mm for sandstone. On water-absorbed samples these values turned out to be 14.0 and 22 mm, respectively. Yavuz et al. (2008) have inspected the relation between BA test and the P-wave velocities, Schmidt hardness, compressive and tension strength parameters.

There are many studies in the literature regarding BA test; Budinski and Ives (2005), Ersoy et al. (2005) and Mezlini et al. (2006); whereas, few studies encountered in the literature were related with WWA test; Karaca et al. (2010) investigated the BA and WWA values of ten stone samples belonging to five different groups before and after freezing-thawing cycles. In this study, the prediction of BA abrasion values from WWA abrasion test results is investigated. The study also aims at filling the gap in


**Figure 1.** Location of sampling quarries.

literature and shed a light for future studies.

## METHODS AND MATERIALS TESTED

Carbonate originated natural stones collected from 21 different locations in Western Anatolia have been used (Figure 1). In order to make direct correlation, BA tests and WWA tests were applied on 71×71×71 mm cube-shaped and 70×70×100 mm samples respectively. Samples used in WWA tests were dried at 70°C temperature until they reach stable mass. Abrasive powder storage hopper is filled with dry powder (FEPA 42 F, 1984) and placed between sample and abrasive rotating disk (Figure 2). While the abrasive disk rotates at 75 cycles per minute, the flow of abrasive is ensured to be uninterrupted. Two surfaces of each sample is exposed to test. At the end of the test, the surface with traces of abrasion is examined under loupe and the borders of abrasion area is depicted as suggested in EN 14157 (2004) and TS EN 1341 (2004) standards. Following this step, three measurements have been obtained from each abrasion surface with 0.01 mm precision digital caliper and recorded (Figure 3).

In WWA experiment, it is important that the sample surfaces must be smooth and parallel to each other. Contrary situations would cause the abrasive surfaces to be flawed, which would cause the repetition of experiments and undesired time losses (Figures 4a and b).

Samples used in WWA experiment were also used in BA test. The 750 mm-diameter disk used for abrasion made 30 cycles per minute (Figure 5). The device is operated with a sample loaded with 294±3 N force placed on the disk. 20 grams of abrasive powder is poured on disk and this procedure is repeated 4 times by rotating each surface 90° in each step. After 16 cycles, measured weight (%) and volume ($cm^3$) were determined and losses are recorded for each sample.

Natural stone samples obtained from 21 different locations were used in experiments. The samples were dimensioned in some mining company's factories. Specific gravity and unit volume weight experiments together with water absorption by weight and volume (apparent porosity) experiments have been carried out in order to identify the physical characteristics of the samples and the results are presented in Tables 1 and 2.

## DISCUSSION

Abrasion values obtained by the tests are presented in Table 3. BA values expressed separately in terms of both percentage loss in weight and volume. The maximum measurements of WWA tests are used in calculations. Correlations were carried out and WWA prediction equations from percentage weight loss and volume loss of BA values were derived.

The relation between Bohme weight percentage loss parameter and WWA is presented in Figure 6 and the relation between WWA and volume loss parameter is presented in Figure 7. These linear relations are expressed by the following equations:

$WWA = 0.67\ BA\ (\%) + 8.37\ (r^2 = 0.86)$
$WWA = 0.45\ BA\ (cm^3) + 9.15\ (r^2 = 0.85)$

The relations between data obtained in this study and the

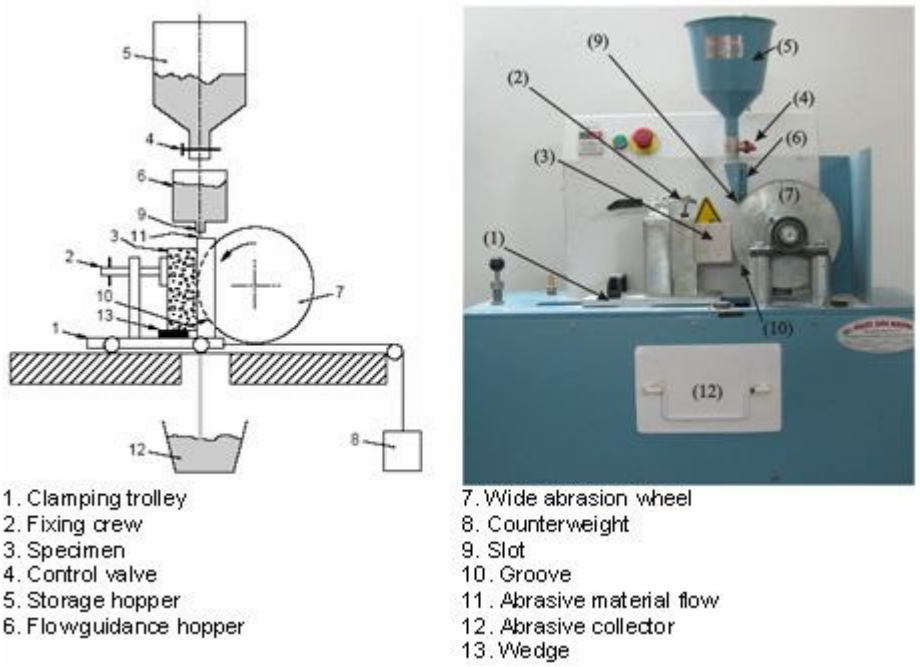


**Figure 2.** Wide wheel abrasion test device.

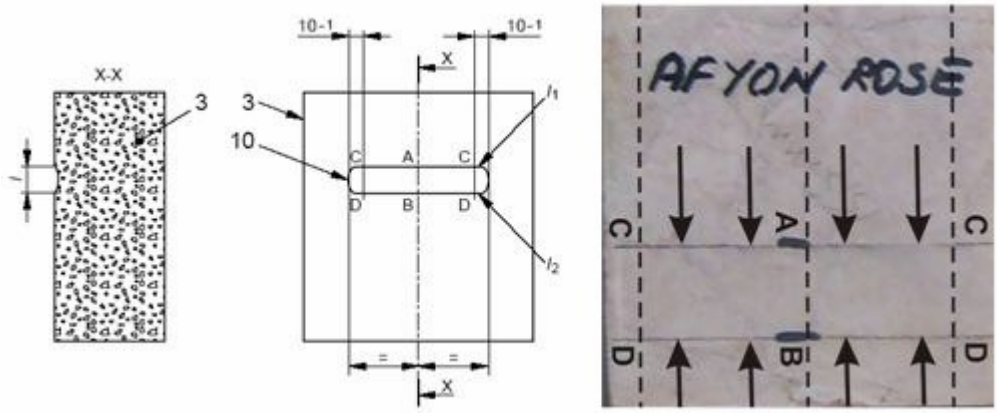


**Figure 3.** Measurement of abrasion geometry on the sample after test.

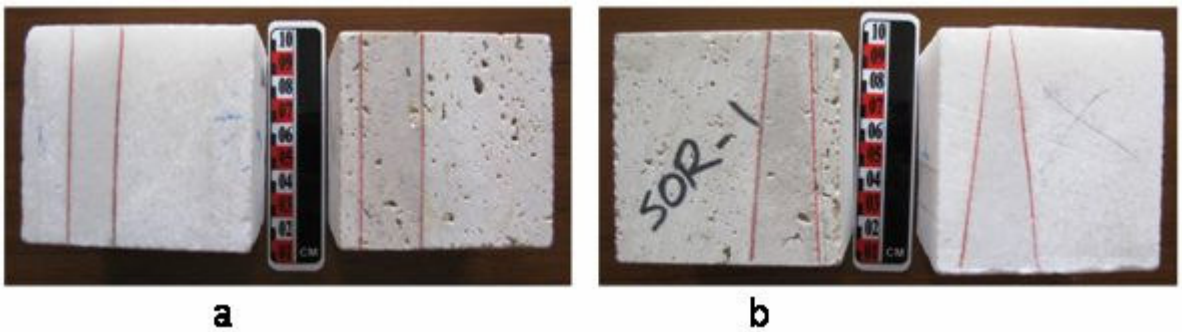


**Figure 4.** Appropriate and inappropriate abrasion surfaces in wide wheel abrasion tests. (a) Standart (appropriate) abrasion surfaces (b) Inappropriate abrasion surfaces.

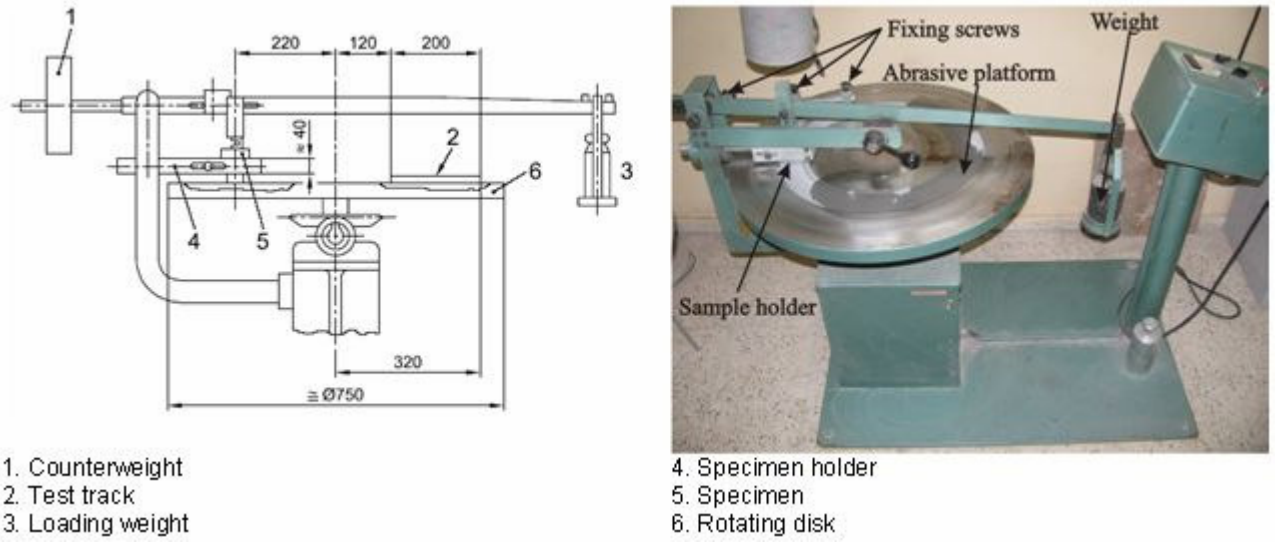


**Figure 5.** Bohme abrasion test device.

**Table 1.** Sampling location, type and commercial names of the samples.

| Sample no. | Location | Type | Commercial name |
|---|---|---|---|
| 1 | Denizli - Kaklik | Travertine | Medium travertine |
| 2 | Burdur-Tefenni | Limestone | Burdur beige |
| 3 | Denizli - Honaz | Travertine with onyx | Travertine |
| 4 | Denizli | White travertine | Ege white |
| 5 | Denizli | Travertine | Light travertine |
| 6 | Afyon | Crystallized limestone | Afyon grey |
| 7 | Afyon | Limestone | Afyon ice |
| 8 | Afyon | Pink Limestone | Afyon rose |
| 9 | Antalya - Elmali | Limestone | Elmali white |
| 10 | Denizli-Honaz | Classic Travertine | Isik Classic |
| 11 | Denizli-Bozkurt | Dolomite | Black emperador |
| 12 | Afyon | Dolomitic limestone | Emperador |
| 13 | Antalya-Korkuteli | Breccia limestone | Limestone |
| 14 | Denizli - Kaklik | Travertine | Classic travertine |
| 15 | Denizli - Kaklik | Travertine | Ece Classic |
| 16 | Denizli-Ballik (Kaklik) | Porous travertine | Travertine |
| 17 | Burdur - Yeşilova | Limestone | Burdur Beige |
| 18 | Denizli-Honaz | Noche travertine | Isik Noche |
| 19 | Burdur-Bucak | Limestone | Burdur Beige |
| 20 | Antalya-Elmali | Limestone | Apple stone |
| 21 | Denizli-Karaçay | Noche travertine | Karacay Noche |

estimated values are presented in Figure 8. WWA-BA relation constituted by a data set and carried out in Germany by EN 14157 (2004) standard is acquired as in Figure 9. In this graphic, x-axis represents the BA loss in volume ($cm^3$) and y-axis represents WWA amount (mm). The presented relation is identified by WWA = 1.712 BA + 15.32 expression. The type of supplies used in the mentioned test standard, to find out the expression, is not indicated.

## Conclusion

BA and WWA tests are experimental test methods used for determining abrasion values of natural stones. BA test is fairly older and test device exist in many research,

**Table 2.** Some physical properties of the samples.

| Sample No. | Dry unit weight (kN/m$^3$) | Saturated unit weight (kN/m$^3$) | Water absorbtion by weight (%) | Apparent porosity (%) |
|---|---|---|---|---|
| 1 | 23.24 | 23.57 | 1.39 | 3.35 |
| 2 | 26.14 | 26.16 | 0.09 | 0.24 |
| 3 | 23.88 | 25.55 | 7.00 | 15.20 |
| 4 | 23.57 | 24.05 | 2.04 | 4.95 |
| 5 | 24.09 | 24.22 | 0.56 | 1.41 |
| 6 | 26.34 | 26.36 | 0.06 | 0.16 |
| 7 | 26.33 | 26.35 | 0.08 | 0.20 |
| 8 | 26.42 | 26.44 | 0.09 | 0.24 |
| 9 | 23.58 | 24.14 | 2.37 | 5.71 |
| 10 | 22.29 | 22.76 | 2.13 | 4.98 |
| 11 | 27.27 | 27.33 | 0.20 | 0.57 |
| 12 | 26.25 | 26.26 | 0.06 | 0.15 |
| 13 | 26.13 | 26.21 | 0.31 | 0.82 |
| 14 | 25.74 | 26.27 | 2.07 | 4.86 |
| 15 | 23.62 | 23.92 | 1.23 | 3.03 |
| 16 | 20.72 | 21.37 | 3.14 | 7.03 |
| 17 | 26.08 | 26.13 | 0.21 | 0.57 |
| 18 | 23.59 | 24.05 | 1.89 | 4.65 |
| 19 | 23.24 | 24.15 | 3.90 | 9.33 |
| 20 | 21.82 | 22.93 | 5.07 | 11.47 |
| 21 | 22.92 | 23.58 | 2.89 | 6.83 |

**Table 3.** Bohme and wide wheel abrasion test results.

| Sample No. | Bohme abrasion weight loss (%) | Bohme abrasion volume loss (cm$^3$) | Wide wheel abrasion value (mm) |
|---|---|---|---|
| 1 | 11.90 | 16.60 | 15.43 |
| 2 | 7.13 | 10.50 | 15.84 |
| 3 | 12.30 | 14.00 | 16.44 |
| 4 | 17.50 | 29.20 | 21.66 |
| 5 | 12.50 | 17.20 | 16.34 |
| 6 | 11.80 | 16.20 | 14.55 |
| 7 | 10.00 | 16.80 | 14.52 |
| 8 | 12.00 | 12.40 | 16.27 |
| 9 | 16.40 | 21.50 | 18.67 |
| 10 | 13.80 | 18.60 | 16.63 |
| 11 | 8.40 | 7.20 | 13.42 |
| 12 | 8.80 | 12.10 | 14.64 |
| 13 | 2.30 | 3.60 | 8.83 |
| 14 | 6.00 | 10.30 | 14.78 |
| 15 | 11.10 | 15.30 | 15.17 |
| 16 | 11.50 | 15.10 | 15.05 |
| 17 | 13.10 | 16.70 | 16.28 |
| 18 | 4.60 | 6.50 | 12.27 |
| 19 | 6.20 | 8.70 | 13.30 |
| 20 | 10.60 | 14.80 | 14.38 |
| 21 | 18.90 | 25.80 | 24.54 |

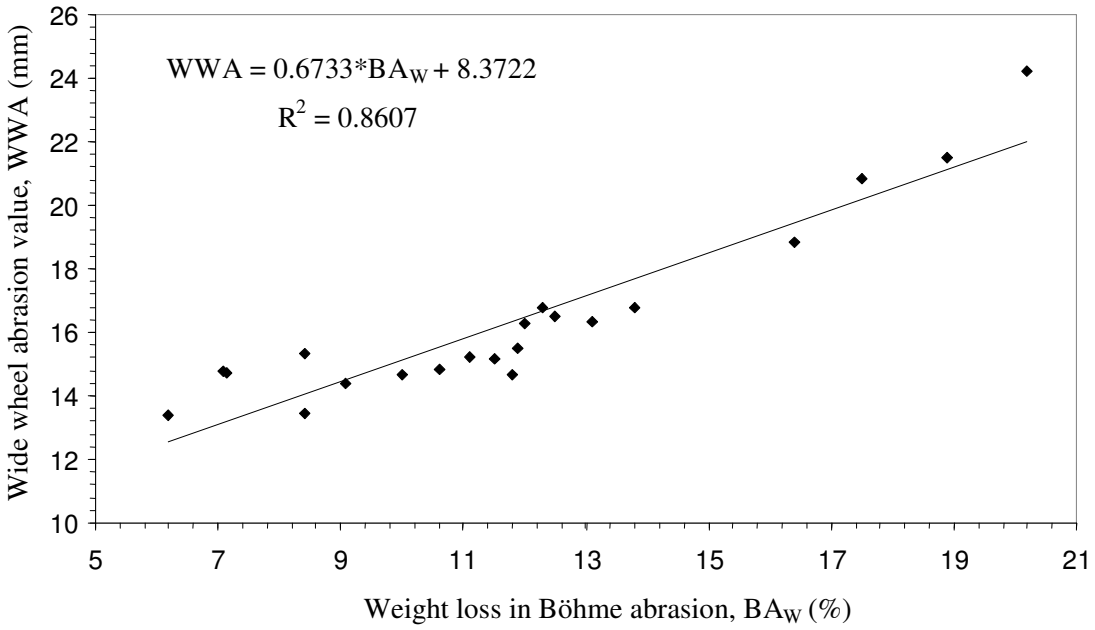


**Figure 6.** Correlation of wide wheel abrasion and bohme abrasion by weight values.

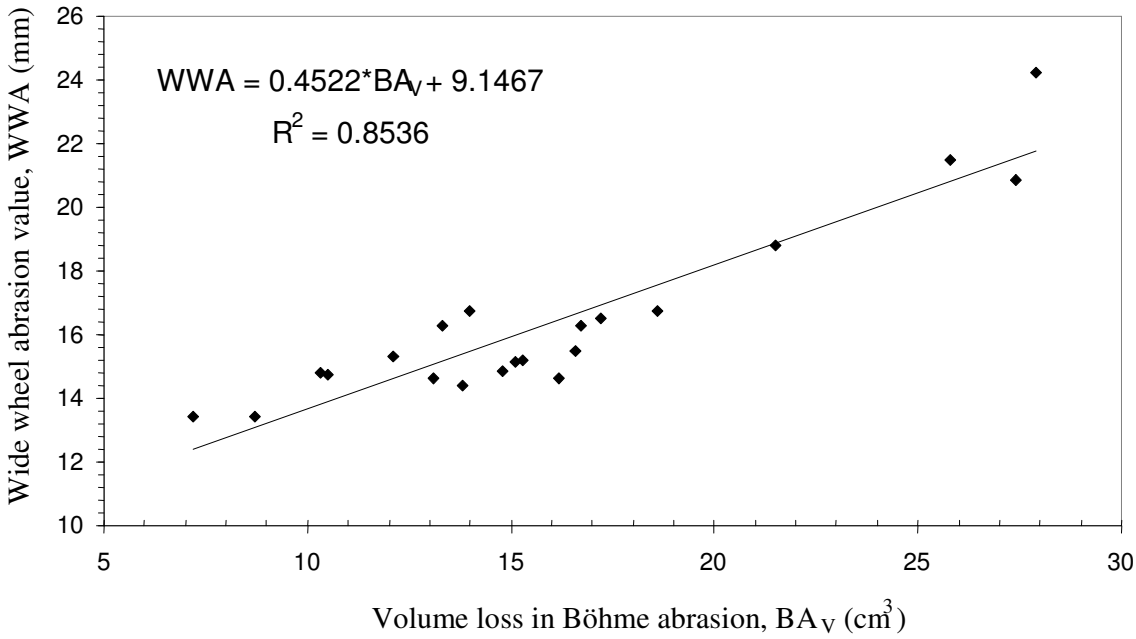


**Figure 7.** Correlation of wide wheel abrasion and bohme abrasion by volume values.

development and test laboratories. WWA test is more recent and it is still in the phase of recognition and application. This study has been carried out in order to identify relations between both BA and WWA parameters. Results reveal that WWA and BA has linear and considerably substantive relations for carbonated rocks. The relations are expressed as:

$WWA_w$ = 0.67 BA (%) + 8.37 (Bohme weight loss, %)
$WWA_v$ = 0.45 BA ($cm^3$) + 9.15 (Bohme volume loss, $cm^3$)

These expressions can be used to express one abrasion values in terms of the other one. It is essential to keep in mind that these expressions are valid only for tested sample types belonging to carbonated rock groups.

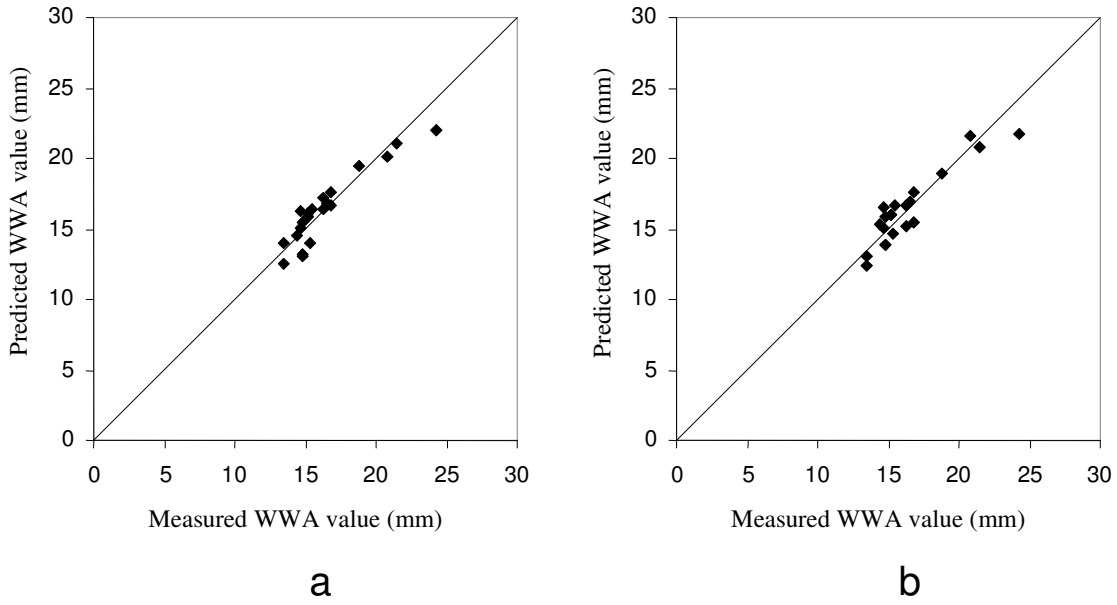


**Figure 8.** Measured and predicted values of proposed equations. (a) Bohme weight loss (%). (b) Bohme volume loss ($cm^3$).

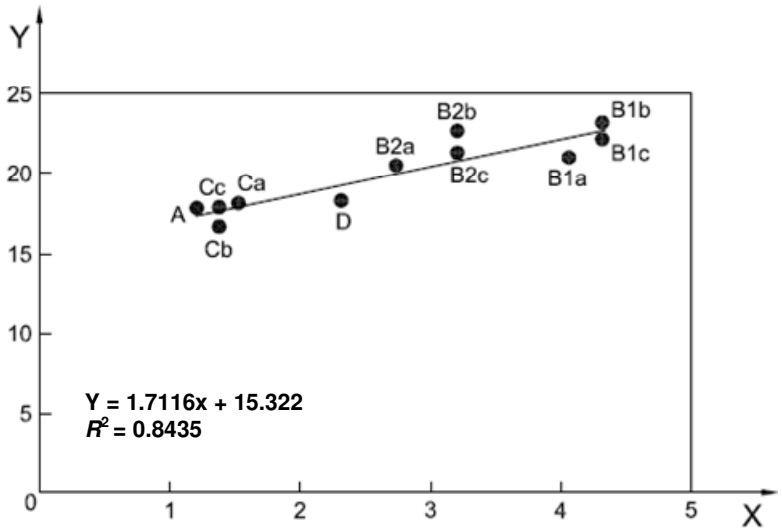


**Figure 9.** Relation between WWA and BA by volume (EN 14157, 2004).

## REFERENCES


Budinski KG, Ives LK (2005). Measuring abrasion resistance with a fixed abrasive loop. Wear, 258: 133-140.

EN 14157 (2004). Natural stones - Determination of abrasion resistance, European Standard, p. 19.

Ersoy A, Büyüksağiç S, Atici U (2005). Wear characteristics of circular diamond saws in the cutting of different hard abrasive rocks. Wear, 258: 1422-1436.

Karaca Z, Deliormanli AH, Elci H, Pamukcu C (2010). Effect of freeze-thaw process on the abrasion loss value of stones. Int. J. Rock Mech. Mining Sci. Doi: 10.1016-j.ijrmms.

MacGregor ID, Chiu KY (2000). Porosity and wear resistance in Stone flooring tiles. J. Test Eval., 28: 149-154.

Mezlini S, Kapsa P, Abry JC, Henon C, Guillemenet J (2006). Effect of indenter geometry and relationship between abrasive wear and hardness in early stage of repetitive sliding. Wear, 260: 412-421.

Sahlin T, Starzec K, Stigh J, Schouenborg B (2000). Physical Properties and Durabiity of Fresh And Impregnated Limestone And Sandstone From Central Sweden Used For Thin Stone Flooring And Cladding, 9th International Congress on Deterioration and Conservation of Stone, pp. 181-185.

TS EN 1341 (2004). Slabs of natural stone for external paving-requirements and test methods. Turkish Standard, p. 31.

Yavuz H, Uğur I, Demirdağ S (2008). Abrasion resistance of carbonate rocks used in dimension stone industry and correlations between abrasion and rock properties, Int. J. Rock Mech. Min. Sci., 45: 260-267.