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A PRELIMINARY EXPERIMENTAL STUDY ON THE COMPARISON OF CONCRETE STRENGTH TESTS AND BOHME ABRASION TEST FOR BASALT AGGREGATE CONCRETE

Esra TUGRUL TUNC [1]

[1] *Fırat University, Civil Engineering Department, Elazığ, Türkiye, esratugrul@firat.edu.tr*

ABSTRACT

It is very important to determine whether the strength of concrete structures, especially under the effect of earthquakes, is sufficient to prevent loss of property and life. In this context; the tests required for the concrete to be used in the structure should determine the most suitable concrete properties for the intended use of the structures. With the present study, by utilizing basalt aggregate in concrete production, both concrete strengths will be increased and economic contribution will be provided since its reserves are abundant. In addition to the concrete compressive strength and concrete splitting tensile strength tests performed on structural concrete for the building of earthquake-resistant structures, alternative strength tests should also be tested to determine the mechanical properties of concrete with the developments in concrete production and application technologies. One of them is the Bohme abrasion strength test, which is performed to determine the resistance to abrasion. In the present study, concrete compressive strength, concrete splitting tensile strength, and Bohme abrasion strength tests were performed experimentally for a series of conventional concrete specimens produced using basalt aggregate. Relatively high concrete strength values were obtained for the tested concrete specimens. It was observed that the concrete compressive strength value and concrete splitting tensile strength value increased in direct proportion to each other, while the Bohme abrasion loss value decreased with a high determination coefficient. Thus, it indicates that the concrete strength increases with decreasing Bohme abrasion loss value.

Keywords: Bohme abrasion strength, Compressive strength, Splitting tensile strength, Basalt aggregate, Earthquake.

1 INTRODUCTION

Since Türkiye is located in a geography surrounded by the Eurasian, African, and Arabian active fault plates that can produce earthquakes, it has been exposed to many destructive earthquakes throughout history and is still at earthquake risk [1]. When the earthquakes that occurred in Türkiye in the last century are analyzed; it is seen that 16 destructive earthquakes above magnitude 7.0 occurred (Figure 1). Especially after the earthquakes in recent years, it has been determined that there have been many losses of life and property, and many structures were severely damaged [2], [3].

As a result of the investigations made as a result of the earthquakes experienced; it was concluded that the damaged or collapsed structures were mostly produced from poor-quality concrete [4], [5]. Thus, there is a need for more research on the production of concrete, which has a great impact on the durability of structures. In addition, it has become essential to design sustainable and economical concrete production by performing concrete strength tests more meticulously and ensuring that the mix content and mix ratios are optimum for the purpose. For this reason, it is of great importance to investigate the effect of aggregates, which constitute a large part of the content of concrete, on concrete strength. In this context; in order to increase the strength of concrete produced with traditional aggregates, there is a lack of literature and practice in literature and practice on the production of concrete that can be produced with higher strength aggregates with Türkiye's own resources. It is known that the existing building stocks worldwide generally consist of reinforced concrete structures and Türkiye has a high ratio of concrete production. In the present study, basalt aggregates, which are known to have higher strength than other aggregates, were tested for a series of basalt concrete specimens produced. Since it is known that basalt aggregate reserves in our country are quite high, it is thought that it will be economical to use it in concrete production [6].

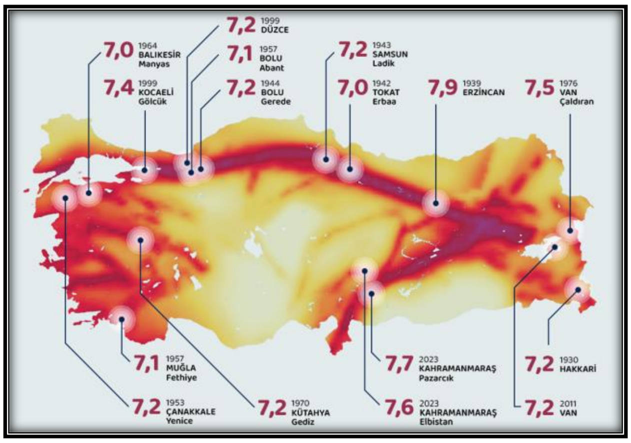

Figure 1. Türkiye earthquake map [7].

Concrete is the most common building material required for the construction of reinforced concrete structures, which is formed by combining aggregate materials such as gravel and sand with a binder material such as cement. The annual consumption of concrete in the world is estimated to be quite high, at around 6 billion m3 [8]. Concrete aggregate is defined as the unbroken or crushed grains of natural or artificial material that are mixed with the binding material consisting of cement and water mixture in concrete production. The diameter of concrete aggregate used in construction concrete is generally less than 63 mm [9].

Concrete aggregate has the largest volume and mass among concrete components. Aggregates are very important for the properties of concrete, as they usually account for about 60-80% of the total volume of concrete. Aggregate is not only an economical filling material for concrete but also an important component that increases the durability, abrasion resistance, and bearing capacity of concrete. In addition, it is possible to say that the physical and mechanical properties of concrete are largely influenced by the aggregate properties used. In this context, the physical and mechanical properties of the tested concrete aggregate directly determine the quality of the concrete [10].

Concrete producers should definitely evaluate the quality and economic conditions when choosing aggregate. Necessary tests of the aggregate to be used in concrete production should be carried out and especially 7-28 day compressive strengths of hardened concrete specimens containing the tested aggregate should be measured. In general, concrete aggregate should be hard, durable, void-free, and resistant to abrasion [11]. Experiments such as sieve analysis, specific gravity, and water absorption should be performed on concrete aggregates to have an idea about aggregate quality. In our country, concrete aggregates are required to comply with the TS 706 EN 12620 +A1 standard [12].

It is known that limestone aggregate is widely used in traditional concrete. However, basalt aggregate can also be preferred for more durable concrete production. Because basalt is a hard, dense volcanic rock that can be found in many regions of the world. Previously used only in architectural applications and pavements, basalt has recently been used in concrete production as crushed basalt aggregate. Basalt aggregate concrete, which is generally ideal for highway and airport pavements, is also known to have high abrasion resistance and high compressive strength. It has been determined that the specific gravity of basalt aggregate is higher than that of limestone aggregate used in traditional concrete production, while its abrasion loss and water absorption value are lower [13], [14].

Concrete used as pavement in road superstructure is subject to abrasion due to friction in bridge abutments and dams exposed to water flow. The abrasion resistance of concrete varies depending on the strength characteristics of the concrete, the internal structure of the concrete, the construction of the concrete surface, and the test method used. It is known that the most common test to determine the abrasion resistance of concrete is the Bohme (Dorry Device) Test [15], [16], [17].

For the Bohme abrasion test, firstly, concrete specimens with standard dimensions and a certain water-to-cement ratio are manufactured and left to cure for a certain period of time. After the weights of the cured specimens are measured with a precision balance, they are abraded in the Bohme abrasion device at the specified time and speed. After the abrasion process, the weights of the specimens are measured again. Based on the weight loss and the change in the dimensions of the specimen, the volume change is calculated. Using the data obtained, the abrasion resistance of the concrete is determined. The values obtained as a result of the Bohme abrasion test are an important parameter showing the resistance of concrete against abrasion. These values are used for the comparison of different concrete mixtures, material selection, and quality control. The bohme abrasion test is performed according to national and international standards such as TS 699. These standards contain detailed information on the conduct of the test, the equipment used, specimen preparation, and evaluation of the results. In conclusion; the Bohme abrasion test is an important method used to determine the resistance of building materials such as concrete against abrasion. Thanks to this test, structures are ensured to be longer lasting and safer [18], [19].

In a study [20] investigating the abrasion resistance of natural building blocks under different loads between 100 N and 500 N, the widely used Bohme abrasion tester was used to determine the abrasion properties. It was concluded that abrasion loss was an important factor depending on the load on the tested natural building blocks. In another study [21], the wide wheel abrasion test and Bohme abrasion test were performed to determine the abrasion loss of 21 different building stones from the Denizli province of Türkiye and it was determined that the findings obtained from these test methods were very close to each other. In another study [22], it was stated that the effect of aggregate properties on mechanical properties such as wear and strength is very important depending on the intended use.

Concrete's abrasion resistance primarily depends on the aggregate it contains, as aggregates typically comprise a larger portion of the material than cement [23]. The aggregate's properties, including specific gravity, hardness, and void ratio, influence its abrasion resistance.

Certain aggregates, like glass, schist, marly limestone, and coarse mineralized stones, are susceptible to abrasion. To enhance concrete's abrasion resistance, using hard, abrasion-resistant aggregates is crucial. The availability and mechanical properties of aggregates are key factors to consider in concrete production. Abrasion resistance is a significant parameter in evaluating aggregate suitability for concrete applications [24].

Various tests have been employed in the literature to assess the abrasion resistance of concrete aggregates [23, 25]. In a previous study [26], marble powder and sand were partially replaced with different proportions (10-90% by volume) and subjected to the Bohme surface abrasion test on 28-day specimens. The results indicated a correlation between abrasion resistance and compressive and splitting tensile strengths, key indicators of concrete strength. The optimal mixture contained 40% marble dust. Another study [27] applied the Bohme abrasion test to tile mosaic floor coverings reinforced with steel fiber. Abrasion resistance was evaluated using volume and average surface abrasion values, with results of 9.3±0.3 cm^3/cm^2.

In the present study; primarily the aim is to test concrete strength experimentally. In this context; concrete compressive strength, concrete splitting tensile strength, and concrete Bohme abrasion value of a series of concrete specimens containing basalt aggregate produced in the present laboratory were measured experimentally. It is known that the basic tests determining concrete quality are compressive strength and splitting tensile strength tests [28], [29]. With this study, the relationship between the Bohme abrasion value of concrete and concrete strength is revealed and it is determined that the Bohme abrasion value is a test that can be evaluated in determining concrete properties and quality [30], [31]. Thus, the studies to be carried out on the subject, it is aimed to evaluate and disseminate the Bohme abrasion test, which is seen to be a great deficiency in the literature, together with the existing destructive strength tests.

Since a large amount of concrete is used in the construction of buildings, the durability of the structure against a possible earthquake is directly related to the durability of concrete. Concrete strength is directly related to the aggregate properties. In the present study, concrete compressive strength, concrete splitting tensile strength and Bohme abrasion tests were performed experimentally on a series of basalt aggregate concrete specimens. The aim of the present study is to compare the related strength and abrasion tests for basalt aggregate concrete and to determine the relationship between them. For this purpose, within the scope of the present study, the relationship between the change in Bohme abrasion loss and concrete strength was experimentally investigated.

2 MATERIAL AND METHOD

2.1 Experimental Materials

Basalt aggregate from ready-mixed concrete companies in Elazığ province of Türkiye was used in the present study (Figure 2). Specific gravity, unit weight, and water absorption rate values of aggregate mixtures with the largest grain diameter of 31.5 mm are presented in Table 1 [32].

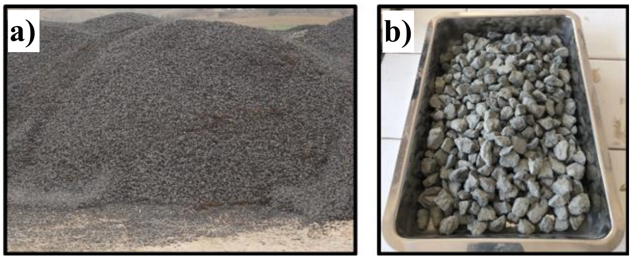

Figure 2. View of tested basalt aggregate in the present study: a) view from the aggregate quarry, b) view from the laboratory.

Table 1. Specific gravity, unit weight, and water absorption ratio values of tested basalt aggregate.

G_{coarse}	G_{fine}	W_{coarse}	W_{fine}	A_{coarse}	A_{fine}
2.87	2.83	1.87	1.85	0.7	1.4

In Table 1; G_{coarse}: coarse basalt aggregate specific gravity, G_{fine}: fine basalt aggregate specific gravity, W_{coarse}: coarse basalt aggregate unit weight, W_{fine}: fine basalt aggregate unit weight, A_{coarse}: coarse basalt aggregate water absorption rate and A_{fine}: fine basalt aggregate water absorption rate.

The granulometry curve of the aggregate mixture to be used in the concrete mix design calculation according to TS 802 is given in Figure 3. The best compactness was achieved with the curve graph of the mixture falling into the A-B region (except 16.0 mm and 0.125 mm).

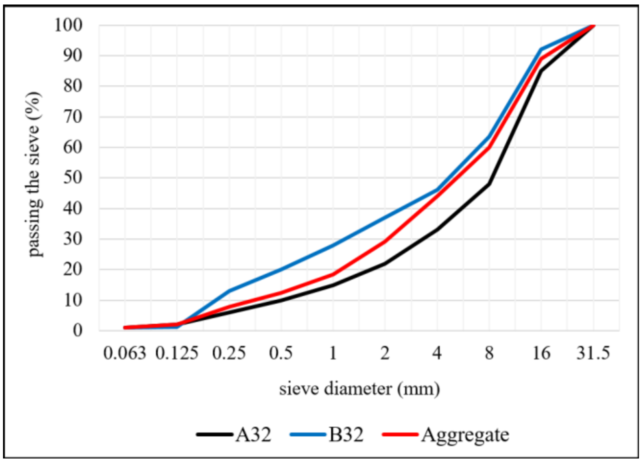

Figure 3. Granulometry of the mixture basalt aggregate prepared according to TS 802.

The cement used in the present experimental studies is CEM I 42.5 N Portland cement produced in Elazığ Cement Factory. The physical and chemical properties of this cement type are presented in detail in Table 2.

Table 2. Physical and chemical properties of the cement used in the present study.

physical properties	**test results**
specific gravity (gr/cm^3)	3.03
setting start (min.)	155
setting end (min.)	210
finesse (cm^2/gr)	3490
chemical composition	mass percent
SiO_2 (%)	21.12
Al_2O_3 (%)	5.62
Fe_2O_3 (%)	3.24
CaO (%)	62.94
Cl^-	0.0044
insoluble residue	0.64
glow loss	3.52

2.2 Concrete Compressive Strength Test

The compressive strength test was carried out in accordance with TS EN 12390-3 standard [33] and concrete cube specimens with dimensions of 150×150×150 mm were tested to determine the strength. At the end of the 28-day curing period, the related concrete cube specimens removed from the curing pool were subjected to uniaxial compression test in the laboratory environment and their compressive strength was determined. A compressive press with a capacity of 2000 kN was used for the said test and at the end of the test, the compressive strength value was taken on the computer screen (Figure 4a). The specimens placed in the device were loaded at a constant speed of 6.8 MPa/sec, the fracture loads were determined and the compressive strengths were calculated by Equation (1).

$$f_c = \frac{P}{A} \tag{1}$$

In Eq. (1); f_c= represents the compressive strength value (MPa), P= represents the maximum load (N) that causes the specimen to fracture and A= represents the cross-sectional area (mm^2) of the specimen perpendicular to the direction of load application.

2.3 Concrete Splitting Tensile Strength Test

Similar to the compressive strength test, at the end of the 28-day curing period, tensile strength at splitting test was performed on the tested concrete cube specimens with dimensions of 150×150×150×150 mm in accordance with TS EN 12390-6 standard [34] (Figure 4b). The specimens placed in the device were loaded at a constant speed of 1.05 MPa/sec, the fracture loads were determined and the splitting tensile strength was calculated by Eq. (2). For each series, 3 control specimens were tested and the strength results were evaluated as the arithmetic average of these three specimens.

$$f_t = \frac{2\,P}{\pi\,D^2} \tag{2}$$

In Eq. (3); f_t= represents the splitting tensile strength value (MPa), P= represents the compressive load (N) causing fracture and D= represents the size of the cube specimen (mm).

2.4 Bohme Abrasion Test

Surface abrasion tests of basalt aggregate concrete specimens were determined on 71×71×71 mm cube specimens cured in water for 28 days in accordance with TS 699 and TS EN 14157 standards [35], [36]. In order to determine the unit volume weights of the specimens, the specimens were weighed in air and water-saturated state and dried in an oven at 105±5 °C for 24 hours. The oven-dried samples were placed on the abrasive disc, the abrasive surface was coated with 20 g ± 0.5 g corundum powder, and a load of 294±3 N was applied to the sample (Figure 4c). The surface of the disk, which was rotated 22 turns, was carefully cleaned at the end of the process and the same process was repeated by rotating the sample 90° on the same surface. This process was repeated 16 times for 3 specimens from each series. At the end of the experiment, the volumetric wear loss of the specimens was calculated by Eq. (3).

$$\Delta V = \frac{\Delta m}{\rho_r} \tag{3}$$

In Eq. (3); ΔV: represents the volume loss after 16 cycles (cm^3), Δm: represents the mass loss after 16 cycles (g), and ρ_r = sample unit volume weight (g/cm^3).

With the help of the above calculations, the total volume loss occurring in the sample is calculated. In addition, the volume loss can be calculated with the help of the total shortening that occurs in the thickness of the specimen. Since the base area of the specimen is approximately 50 cm^2 (71×71 mm), all results should be based on this base area [32]. Tested water-to-cement ratios and tested aggregate-to-cement ratios of the series of concrete specimens produced are presented in Table 3.

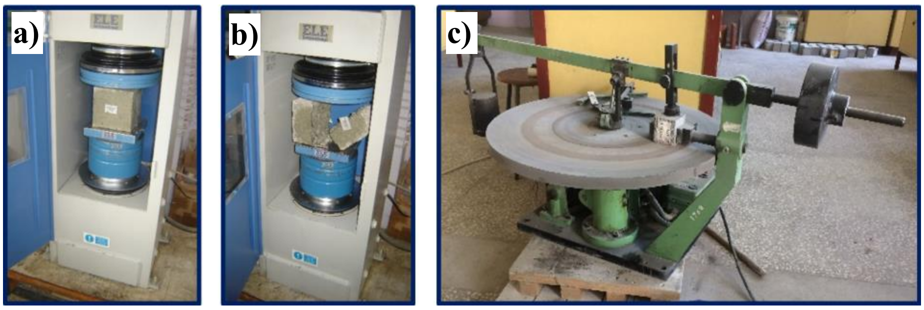

Figure 4. a) compressive strength test, b) splitting tensile strength test, c) Bohme abrasion strength test.

Table 3. Ranges of parameters for tested basalt aggregate concrete specimens.

W/C	A/C
0.20-0.25-0.30-0.35-0.40	2.0-2.1-2.2-2.3-2.4-2.5

3 RESULTS AND DISCUSSION

In the present study, a series of strength tests were carried out on a total of 30 concrete mix series by evaluating different water-to-cement ratios (*W/C*= 0.20, 0.25, 0.30, 0.35 and 0.40) and different basalt aggregate to cement ratios (*A/C*= 2.0, 2.1, 2.2, 2.3, 2.4 and 2.5) on a series of concrete specimens with basalt aggregate tested. The experimental strength tests performed on these specimens are the concrete compressive strength test, also known as destructive concrete strength tests, the tensile strength test in splitting, and Bohme abrasion test. Figure 5 shows the variation of concrete compressive strength values (f_c), concrete splitting tensile strength values (f_t), and Bohme abrasion strength values (*BA*) of the tested specimens with water to cement ratio (*W/C*). Accordingly, it was observed that the tested f_c values varied between

23.6 MPa and 46.2 MPa, f_t values varied between 2.3 MPa and 5.2 MPa, and *BA* values varied between 6.8 $cm^3/50cm^2$ and 24.1 $cm^3/50cm^2$. Table 4 presents the concrete compressive strength (f_c), concrete splitting tensile strength (f_t), and Bohme abrasion (*BA*) values of the concrete for the tested water-to-cement ratio (*W*/*C*) and aggregate-to-cement ratio (*A*/*C*) separately.

Table 4. Experimental test parameters and the strength results of tested concrete specimens.

W/C	A/C	f_c	f_t	BA
0.20	2.0	46.2	5.0	12.2
0.20	2.1	47.9	5.2	10.8
0.20	2.2	48.5	5.3	9.2
0.20	2.3	50.1	5.5	8.0
0.20	2.4	51.2	5.6	7.2
0.20	2.5	52.3	5.8	6.8
0.25	2.0	40.9	4.5	15.1
0.25	2.1	41.6	4.6	14.5
0.25	2.2	42.8	4.7	13.8
0.25	2.3	44.1	4.9	12.9
0.25	2.4	45.2	5.0	12.4
0.25	2.5	46.7	5.1	11.9
0.30	2.0	36.8	3.8	17.5
0.30	2.1	37.5	4.0	16.6
0.30	2.2	39.1	4.2	16.0
0.30	2.3	39.9	4.3	15.3
0.30	2.4	40.8	4.5	14.8
0.30	2.5	42.3	4.7	13.9
0.35	2.0	30.9	3.2	20.6
0.35	2.1	31.6	3.3	20.0
0.35	2.2	32.9	3.4	19.1
0.35	2.3	34.1	3.6	18.4
0.35	2.4	35.6	3.7	17.8
0.35	2.5	37.2	3.9	16.9
0.40	2.0	23.6	2.3	24.1
0.40	2.1	25.1	2.5	23.5
0.40	2.2	27.2	2.7	22.6
0.40	2.3	28.0	2.8	22.0
0.40	2.4	28.8	2.9	21.5
0.40	2.5	29.6	3.1	20.9

3.1 Variation of Concrete Strength Values with Water to Cement Ratio for Tested Specimens

Figure 5 shows the variation of concrete compressive strength values (f_c), concrete splitting tensile strength values (f_t), and Bohme abrasion values (*BA*) of tested basalt aggregate concrete specimens with water-to-cement ratio (*W*/*C*). The lowest f_c value (f_c= 23.6 MPa) and the lowest f_t value (f_t= 2.3 MPa) were measured for the highest water-to-cement ratio (*W*/*C*= 0.40) and the lowest aggregate-to-cement ratio (*A*/*C*=2.0) tested. The highest f_c value (f_c= 46.2 MPa) and the highest f_t value (f_t= 5.2 MPa) were measured for the lowest water-to-cement ratio (*W*/*C*= 0.20) and the highest aggregate-to-cement ratio (*A*/*C*= 2.5) tested. The lowest *BA* value (*BA*= 6.8 $cm^3/50cm^2$) was measured for the highest tested water-to-cement ratio (*W*/*C*= 0.40) and the lowest aggregate-to-cement ratio (*A*/*C*= 2.0).

The highest *BA* value (*BA*= 24.1 $cm^3/50cm^2$) was measured for the lowest tested water-to-cement ratio (*W*/*C*= 0.20) and the highest aggregate-to-cement ratio (*A*/*C*= 2.5). With the increase in water-to-cement ratio from *W*/*C*= 0.20 to *W*/*C*= 0.40; an average decrease of approximately 42% in f_c values, an average decrease of approximately 47% in f_t values, and an average increase of approximately 2.4 times in *BA* values were calculated. The coefficient of determination of the equation developed for the variation of f_c values with *W*/*C* was calculated as R^2≈0.93. The coefficient of determination of the equation developed for the variation of f_t values with *W*/*C* was calculated as R^2≈0.91. The coefficient of determination of the equation developed for the variation of *BA* values with *W*/*C* was calculated as R^2≈0.93. This indicates that the variation of the values of the relevant strength indicators (f_c, f_t, and *BA*) with *W*/*C* was formulated with a near-perfect fit.

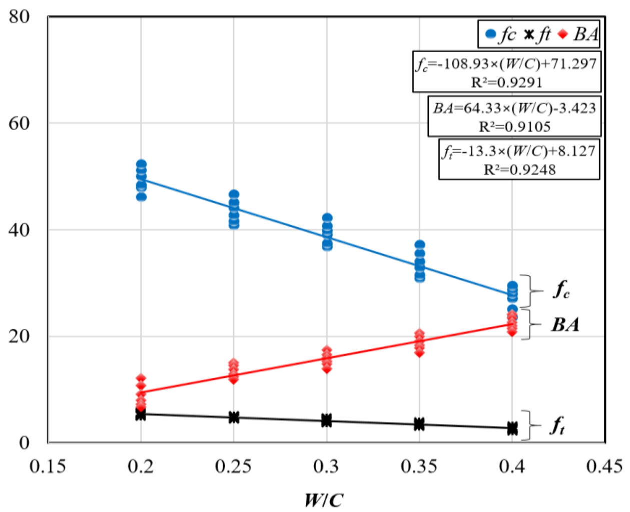

Figure 5. Variation of concrete strength values and Bohme abrasion strength values of the tested specimens with water-to-cement ratio.

3.2 Variation of Concrete Strength Values with Aggregate to Cement Ratio for Tested Specimens

Figure 6 shows the variation of concrete compressive strength values (f_c), concrete splitting tensile strength values (f_t), and Bohme abrasion values (*BA*) of tested basalt aggregate concrete specimens with aggregate-to-cement ratio (*A*/*C*). With the increase in aggregate to cement ratio from *A*/*C*= 2.0 to *A*/*C*= 2.5, an average increase in f_c values of approximately 13% for *W*/*C*= 0.20, an average increase of approximately 14% for *W*/*C*= 0.25, an average increase of approximately 15% for *W*/*C*= 0.30, an average increase of approximately 20% for *W*/*C*= 0.35 and an average increase of approximately 25% for *W*/*C*= 0.40 were calculated. Thus, it is possible to say that the percentage change of the f_c value with *A*/*C* increases as the *W*/*C* value increases. When the findings of all tested specimens were evaluated, it was calculated that there was a total average increase of approximately 17% in f_c values with the increase from *A*/*C*= 2.0 to *A*/*C*= 2.5. With the increase in aggregate to cement ratio from *A*/*C*= 2.0 to *A*/*C*= 2.5; it was calculated that there was an average increase of approximately 16% for *W*/*C*= 0.20, an average increase of approximately 13% for *W*/*C*= 0.25, an average increase of approximately 24% for *W*/*C*= 0.30, an average increase of approximately 22% for *W*/*C*= 0.35 and an average increase of approximately 35% for *W*/*C*= 0.40 in ft values. When the findings of all tested specimens were evaluated, it was calculated that there was a total average increase of approximately 22% in f_t values with an increase from *A*/*C*= 2.0 to *A*/*C*= 2.5. With the increase in aggregate to cement ratio from *A*/*C*= 2.0 to *A*/*C*= 2.5; approximately 44% decrease in *BA* values for *W*/*C*= 0.20, approximately 22% decrease for *W*/*C*= 0.25, approximately 21% decrease for *W*/*C*= 0.30, approximately 18% decrease for *W*/*C*= 0.35, approximately 13% decrease for *W*/*C*= 0.40 were calculated. Thus, it is possible to say that the percentage of change of *BA* value with *A*/*C* decreases as the *W*/*C* value increases. When the findings of all tested specimens were evaluated, it was calculated that with the increase from *A*/*C*= 2.0 to *A*/*C*= 2.5; there was a total average decrease of approximately 24% in *BA* values.

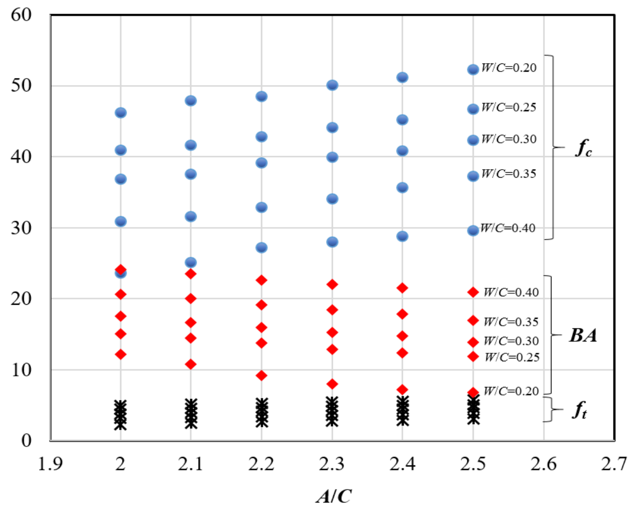

Figure 6. Variation of concrete strength values and Bohme abrasion values of the tested specimens with aggregate-to-cement ratio.

3.3 Variation of Compressive Strength Values with Splitting Tensile Strength Values for Tested Specimens

Figure 7 shows the variation of concrete compressive strength values (f_c) of the tested specimens with concrete splitting tensile strength values (f_t). Accordingly, f_c values ranged between 23.6 MPa and 52.3 MPa and f_t values ranged between 2.3 MPa and 5.8 MPa. It is observed that f_c values increase linearly with f_t. The correlation coefficient R^2= 0.9963 was calculated for the linear equation developed for the estimation of f_c depending on f_t. Accordingly, it is possible to say that the agreement is very close to perfect (Figure 7). Equation (4) was developed to calculate the concrete compressive strength value from the concrete splitting tensile strength value of the tested concrete specimens.

$$f_c = 8.157 \times f_t + 4.875 \tag{4}$$

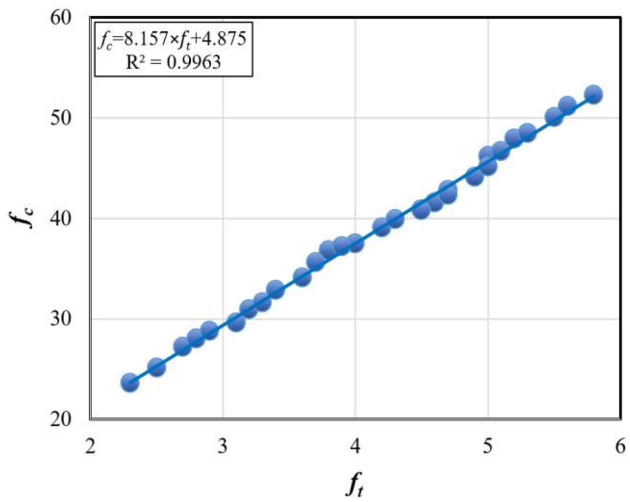

Figure 7. Variation of measured fc values with measured ft values of the tested specimens.

3.4 Variation of Bohme Abrasion Strength Values with Compressive Strength Values for Tested Specimens

Figure 8 shows the variation of concrete Bohme abrasion values (*BA*) with concrete compressive strength values (f_c) for the tested specimens. Accordingly, f_c values ranged between 23.6 MPa and 52.3 MPa, and *BA* values ranged between 6.8 $cm^3/50cm^2$ and 24.1 $cm^3/50cm^2$. It was observed that *BA* values decreased linearly with f_c values. The correlation coefficient R^2= 0.988 was calculated for the linear equation developed for the estimation of *BA* depending on f_c. Accordingly, it is possible to say that the agreement is very close to perfect (Figure 8). Equation (5) was developed to calculate the concrete Bohme abrasion value from the concrete compressive strength value of the tested concrete specimens.

$$BA = 0.59 \times f_c + 38.78 \quad (5)$$

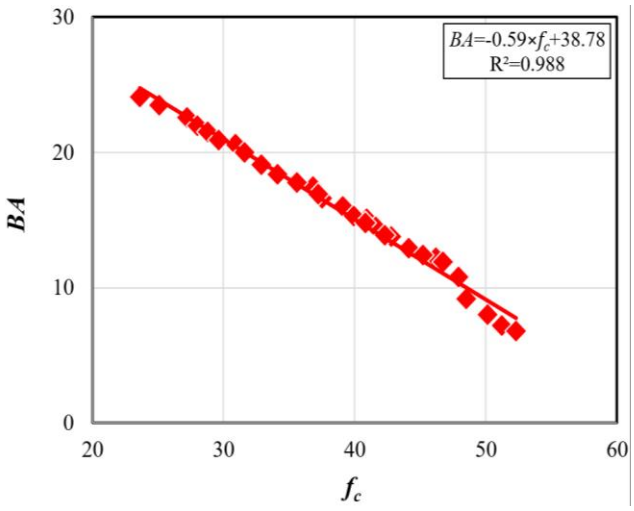

Figure 8. Variation of measured BA values with measured fc values of the tested specimens.

3.5 Variation of Bohme Abrasion Strength Values with Splitting Tensile Strength Values for Tested Specimens

Figure 9 shows the variation of concrete Bohme abrasion values (*BA*) with concrete splitting tensile strength values (f_t) for the tested specimens. Accordingly, f_t values ranged between 2.3 MPa and 5.8 MPa, and *BA* values ranged between 6.8 $cm^3/50cm^2$ and 24.1 $cm^3/50cm^2$. It was observed that *BA* values decreased linearly with f_t values. The correlation coefficient R^2= 0.9817 was calculated for the linear equation developed for the estimation of *BA* depending on ft. Accordingly, it is possible to say that the agreement is very close to perfect (Figure 9). The low Bohme abrasion loss value (*BA*) indicates that the abrasion resistance is high. Concrete with high abrasion resistance will also have high compressive strength and high splitting tensile strength. Equation (6) was developed to calculate the concrete Bohme abrasion value from the concrete splitting tensile strength value of the tested concrete specimens.

$$BA = -4.83 \times f_t + 35.86 \tag{6}$$

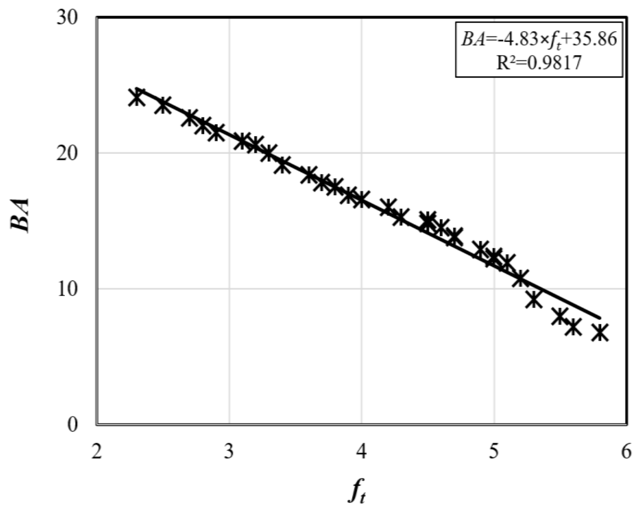

Figure 9. Variation of measured BA values with measured ft values of the tested specimens.

4 CONCLUSION AND SUGGESTIONS

The main results obtained from the present study, which experimentally investigated the relationship between concrete compressive strength, concrete splitting tensile strength, and Böhme abrasion strength, which are the test methods determining concrete strength for basalt aggregate concrete, are summarized below.

- Since reinforced concrete structures are composed of concrete, the mechanical properties of concrete should be investigated in detail for resistance against possible earthquakes.
- In the present experimental study; f_c values of the tested specimens ranged from 23.6 MPA to 46.2 MPa, f_t values ranged from 2.3 MPa to 5.2 MPa, and *BA* values ranged from 6.8 $cm^3/50cm^2$ to 24.1 $cm^3/50cm^2$.
- The lowest f_c and f_t values were measured for the highest water-to-cement ratio and the lowest aggregate-to-cement ratio tested. The highest f_c and f_t values were measured for the lowest water-to-cement ratio and the highest aggregate-to-cement ratio tested.
- The lowest *BA* value was measured for the highest water-to-cement ratio and the lowest aggregate-to-cement ratio tested. The highest *BA* value was measured for the lowest water-to-cement ratio and the highest aggregate-to-cement ratio tested.

- With the increase of the water-to-cement ratio from W/C=0.20 to W/C=0.40; approximately average 42% decrease in f_c values, approximately average 47% decrease in f_t values and approximately average 2.4 times increase in *BA* values were calculated.
- The coefficient of determination of the equation developed for the variation of f_c values with W/C was calculated as $R^2 \approx 0.93$. The coefficient of determination of the equation developed for the variation of f_t values with W/C was calculated as $R^2 \approx 0.91$. The coefficient of determination of the developed equation for the variation of *BA* values with W/C is calculated as $R^2 \approx 0.93$.
- It is concluded that the values of the concrete strength findings (f_c, f_t, and *BA*) investigated experimentally in the present study are correlated with the W/C and A/C dimensionless parameters with a near-perfect agreement.
- It is suggested that the present study be further developed by applying destructive and non-destructive strength test methods on concrete specimens produced with other aggregates and different mix contents specific to the region.

Statement of Research and Publication Ethics

The study is complied with research and publication ethics.

Artificial Intelligence (AI) Contribution Statement

This manuscript was entirely written, edited, analyzed, and prepared without the assistance of any artificial intelligence (AI) tools. All content, including text, data analysis, and figures, was solely generated by the author.

REFERENCES

[1] K. Gokkaya, "Geographic analysis of earthquake damage in Türkiye between 1900 and 2012. Geomatics," *Natural Hazards and Risk*, vol. 7, no. 6, pp. 1948-1961, April 2016. doi: 10.1080/19475705.2016.1171259

[2] W. Y. Kam, S. Pampanin, K. Elwood, "Seismic performance of reinforced concrete buildings in the 22 February Christchurch (Lyttleton) earthquake," *Bulletin of the New Zealand Society for Earthquake Engineering*, vol. 44, no. 4, pp. 239-278, December 2011.

[3] E. Sayın, B. Yon, O. Onat, M. Gor, M. E. Oncu, E. Tugrul Tunc, ... Y. Calayır Y, "24 January 2020 Sivrice-Elazığ, Türkiye earthquake: geotechnical evaluation and performance of structures," *Bulletin of Earthquake Engineering*, vol. 19, pp. 657-684, January 2021. doi: 10.1007/s10518-020-01018-4.

[4] A. Dogangun, "Performance of reinforced concrete buildings during the May 1, 2003 Bingöl Earthquake in Türkiye," *Engineering Structures*, vol. 26, no. 6, pp. 841-856, May 2004. doi: 10.1016/j.engstruct.2004.02.005.

[5] A. H. Akca, O. Sahin, K. Koc, Y. Aygörmez, "Mechanical and microstructural investigations on concrete of the collapsed buildings after Kahramanmaraş earthquakes," *Engineering Science and Technology, an International Journal*, vol. 56, no. 101784, August 2024. doi: 10.1016/j.jestch.2024.101784.

[6] E. Tugrul Tunc, "Strength and Durability of Superplasticizer Concrete Based on Different Component Parameters: An Experimental and Statistical Study," *Arabian Journal for Science and Engineering*, pp. 1-16, April 2024. doi: 10.1007/s13369-024-08985-9.

[7] https://bilimgenc.tubitak.gov.tr/turkiyede-son-yuzyilda-gerceklesen-buyuk-depremler

[8] P. K. Mehta, P. Monteiro, "Concrete: microstructure, properties, and materials" (*No Title*), 2006.

[9] http://www.agub.org.tr

[10] E. Tugrul Tunc, K. E. Alyamac, "A preliminary estimation method of Los Angeles abrasion value of concrete aggregates," *Construction and Building Materials*, vol. 222, pp. 437-446, October 2019. doi: 10.1016/j.conbuildmat.2019.06.176.

[11] M. Bustillo Revuelta, "Properties and Testing," *In The Basics of Aggregates, Cham: Springer International Publishing*, pp. 21-52, February 2024. doi: 10.1007/978-3-031-42961-3_2.

[12] "Beton agregaları," *Türk Standartları Enstitüsü*, TS 706 EN 12620+A1, 2009 (in Turkish).

[13] E. Tugrul Tunc, "Effects of basalt aggregates on concrete properties," *Qualitative Studies*, vol. 13, no. 2, pp. 68-79, April 2018. doi: 10.12739/NWSA.2018.13.2.E0043.

[14] C. Ingrao, A. L. Giudice, C. Tricase, C. Mbohwa, R. Rana, "The use of basalt aggregates in the production of concrete for the prefabrication industry: Environmental impact assessment, interpretation and improvement," *Journal of Cleaner Production*, vol. 75, pp. 195-204, July 2014. 10.1016/j.jclepro.2014.04.002

[15] C. Yalcinkaya, J. Sznajder, A. Beglarigale, O. Sancakoglu, H. Yazici, "Abrasion resistance of reactive powder concrete: The influence of water-to-cement ratio and steel micro-fibers," *Advanced Materials Letters*, vol. 5 no. 6, pp. 345-351, 2014. doi: 10.5185/amlett.2014.amwc.1021.

[16] C. Kara, S. Yazıcıoğlu, "Effects of Marble Duster Waste and Silica Fume to Carbonation of Concrete," *Bitlis Eren University Graduate Institute Journal*, vol. 5, no. 2, pp. 191-202, August 2016. doi: 10.17798/bitlisfen.282253.

[17] İ. Çobanoğlu, S. B. Çelik, "Assessments on the usability of Wide Wheel (Capon) test as reference abrasion test method for building stones," *Construction and Building Materials*, vol. 151, pp. 319-330, October 2017. doi: 10.1016/j.conbuildmat.2017.06.045.

[18] F. Bayram, "Data mining techniques for the prediction of Bohme surface abrasion rates from rock properties," *Journal of Testing and Evaluation*, vol. 48, no. 1, pp. 323-332, January 2020. doi: 10.1520/JTE20190130.

[19] L. Bodnárová, R. Hela, L. Osuská, M. Ťažký, "Effect of Type of Aggregate on Abrasion Resistance of Concrete," *In Materials Science Forum*, vol. 987, pp. 39-43, April 2020. doi: 10.4028/www.scientific.net/MSF.987.39.

[20] Z. Karaca, A. H. Deliormanli, H. Elci, C. Pamukcu, "Effect of freeze–thaw process on the abrasion loss value of Stones," *International Journal of Rock Mechanics & Mining Sciences*, vol. 47, no. 7, pp. 1207-1211, October 2010. doi: 10.1016/j.ijrmms.2010.07.003.

[21] İ. Çobanoğlu, S. Çelik, D. Alkaya, "Correlation between "wide Wheel abrasion (capon)" and "Bohme abrasion" test results for some carbonate rocks," *Scientific Research and Essays*, vol. 5, no. 22, pp. 3398-3404, November 2010.

[22] B. Ç. Sefer, "Investigation of Abrasion Resistance of Carbonate Rocks by Wide Wheel Abrasion Test," *Fırat University Journal of Engineering Science*, vol. 30, no. 1, pp. 303-310. March 2018.

[23] E. Tugrul Tunc, K. E. Alyamac, "Determination of the relationship between the Los Angeles abrasion values of aggregates and concrete strength using the Response Surface Methodology," *Construction and Building Materials*, vol. 260, no. 119850, November 2020. doi: 10.1016/j.conbuildmat.2020.119850.

[24] P. Poitevin, "Limestone aggregate concrete, usefulness and durability," *Cement and Concrete Composites*, vol. 21, no. 2, pp. 89-97, April 1999. doi: 10.1016/S0958-9465(98)00047-X.

[25] E. T. Tunç, K. E. Alyamaç, "The Effect of Aggregate Type on Los Angeles Abrasion Loss for Different Test Parameters," *Fırat University Journal of Engineering Science*, vol. 32, no. 1, pp. 1-10, March 2020. doi: 10.35234/fumbd.569198. (in Turkish).

[26] K. E. Alyamaç, A. B. Aydin, "Concrete properties containing fine aggregate marble powder," *KSCE Journal of Civil Engineering*, vol. 19, no. 7, pp. 2208-2216, February 2015. doi: 10.1007/s12205-015-0327-y.

[27] K.E. Alyamaç, R. İnce, "Çelik lifli karo mozaik döşeme kaplama plakalarının fiziksel ve mekanik özelliklerinin belirlenmesi," *BAÜ FBE Dergisi*, vol. 1, pp. 31-45, 2008. (in Turkish).

[28] A. Alyaseen, A. Poddar, N. Kumar, P. Sihag, D. Lee, T. Singh, "Assessing the compressive and splitting tensile strength of self-compacting recycled coarse aggregate concrete using machine learning and statistical techniques," *Materials Today Communications*, 38:107970, 2024. doi: 10.1016/j.mtcomm.2023.107970.

[29] F. Almohammed, M.S. Thakur, D. Lee, R. Kumar, T. Singh, "Flexural and split tensile strength of concrete with basalt fiber: An experimental and computational analysis." *Construction and Building Materials*, 414:134936, 2024. doi: 10.1016/j.conbuildmat.2024.134936.

[30] A. Teymen, "Assessment of Bohme surface abrasion resistance of natural stones by simple and nonlinear multiple regression methods." *Construction and Building Materials*, 411:134195, 2024. doi: 10.1016/j.conbuildmat.2023.134195.

[31] E. Köken, "Development of Comprehensive Predictive Models for Evaluating Böhme Abrasion Value (BAV) of Dimension Stones Using Non-Destructive Testing Methods." *Applied Sciences*, 15(1):60, 2025. doi: 10.3390/app15010060.

[32] E. Tuğrul, "The investigation of abrasion resistance of aggregates under different conditions," Firat University, Master Thesis, 2015. (in Turkish).

[33] TS EN 12390-3 (2010) Testing hardened concrete – Part 3: Compressive Strength of Test Specimens. Turkish Standards Institutions Ankara. (in Turkish).

[34] TS EN 12390-6 (2010) Testing Hardened Concrete – Part 6: Tensile Splitting Strength of Test Specimens. Turkish Standards Institutions Ankara. (in Turkish).

[35] TS 699, 2009, Nokta Yükü Dayanım İndeksi Deneyi, Türk Standartları Enstitüsü, Ankara. (in Turkish).

[36] TS EN 14157, 2005, Aşınma direncinin tayini – Böhme, Türk Standartları Enstitüsü, Ankara. (in Turkish).