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EFFECTS OF BASALT AGGREGATES ON CONCRETE PROPERTIES

ABSTRACT

Concrete is one of the most important building materials of engineering structures and especially construction applications. Since compressive strength is the most effective parameter for determining the strength of concrete, it is one of the most important mechanical properties to be determined in concrete. Aggregate grain strength, aggregate granulometry, cement strength, water/cement ratio, and concrete fill rate are the most important factors affecting the compressive strength of concrete. The quality of concrete is directly related to the aggregate that is volumetrically found most in the concrete. It is suggested that high strength, hard, easy to obtain and easy to access basalt aggregates are preferred to obtain high-performance concrete. The present study aims to investigate the fresh and hardened concrete properties of the concrete produced by the basalt aggregates extracted in the Elazig region. For this purpose, concrete mixtures containing cement dosages of 300, 350 and 400 kg/m^3 and containing different sizes of basalt aggregates were prepared. The concrete compressive strengths were tested for cubic samples of 150x150x150mm and 100x100x100mm, while the tensile splitting strengths were tested for cubic samples of 150x150x150mm. As a result of the tests performed, as the cement dosage increased, the slump values of the concrete mixtures and the strength of the concrete increased. The micro-structural structure of existing aggregates was investigated, and strong molecular bonds were observed with SEM analysis conducted within the scope of this study. In addition, a comparison was made with reference to the concrete samples prepared with different types of aggregates used in previous studies. It was seen that the compressive strength of the concrete containing the basalt aggregate was generally higher. In this experimental study, it was concluded that the concretes produced with basalt aggregates might have better mechanical properties and be environmentally friendly and economical.

Keywords: Basalt Aggregate, Concrete, Mechanical Properties, Fresh and Hardened Concrete Properties, Sem Analyses

1. INTRODUCTION

A high compressive strength, as well as high resistance to physical and chemical effects, are the most important properties sought in concrete. Strength is used as a parameter that determines more or less all the other properties of concrete. Therefore, concrete types are classified in the standards based on their compressive strengths. An important feature of the concrete strength is that the tensile strength is very smaller than the compressive strength. Besides pressure, concrete is exposed to tensile and bending stresses in roads, bridges, dams and many other structures. Therefore, the tensile and bending strengths of the concrete used in these structures should be as high as possible (Yalçın, 2006). Aggregates constitute approximately 70% of the total

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volume of the concrete. It is a known fact that a suitable aggregate should be used to obtain good concrete. Therefore, the chemical composition, mineralogical and petrographic structure of the aggregates need to be tested well. Aggregate properties directly affect the performance and durability of concrete (Taşdemir, 2001). The studies in the literature show that basalt aggregates have been used by many researchers from the earliest times to the present due to their high strength, hardness, and easy accessibility. Özturan ve Çeçen (1997) investigated the effect of aggregate type on compressive strength in concrete mixtures containing basalt and limestone aggregates. The highest compressive strengths were determined in concrete samples containing basalt aggregates. Ajdukiewicz and Kliszczewicz (2002) investigated the effects of recycled granite and basalt aggregates on the mechanical properties of high strength concrete. The compressive strengths of the concrete samples with basalt aggregates and different mixing ratios vary between 58.6MPa and 95.9MPa. Korkanç and Tuğrul (2003) investigated the usability of basalts with different properties and extracted from Niğde region as concrete aggregates. Şengül, et al., (2003) compared the 28-day compressive and bending strengths of concrete mixtures containing basalt, sandstone and limestone aggregates.

The lowest compressive strength (19.6MPa) was seen in concrete samples containing sandstone, while the highest compressive strength (27 MPa) was seen in those containing basalt. Al-Baijat (2008) investigated the effect of basalt aggregate utilization rate in concrete mixtures. For this purpose, the concrete mixtures containing 25%, 50%, 75%, and 100% basalt and the limestone-containing reference concrete mixtures were prepared. Concrete samples produced for both mixtures were compared and it was seen that as the usage rate of basalt aggregates increased, the concrete strength was affected positively. The highest compressive strength (41.11MPa) was obtained by using 100% basalt aggregates instead of limestone aggregates. Kılıç, et al., (2008) used 5 different aggregates including gabbro, basalt, quartzite, limestone, and sandstone to produce high strength concrete containing silica fumes. When the 3-, 7-, 28-, and 90-day compressive strengths were examined, it was seen that the compressive strength values of aggregates increased as the curing period increased. According to 28-day compressive strength values, the compressive strength was the highest (121.2MPa) in concretes with basalt and lowest in concretes with sandstone (50.3MPa) as aggregate. Tasong, et al., (1998) and İbrahim, et al., (2009) conducted an experimental study to evaluate the performance of asphalt concrete mixtures containing different proportions of basalt aggregates and to find the most suitable substitution percentage of basalt and limestone aggregates. As a result of the experiments, the optimum mixture was obtained by using basalt as the coarse and limestone as the fine aggregate. Pek (2014) studied the use of basalt aggregates instead of limestone as coarse aggregates in very high strength concrete marine structures. According to the 28-day compressive strength test results, the compressive strength of the concrete containing basalt aggregates was 98 MPa, and the compressive strength of the concrete containing limestone aggregates was 91 MPa. Çelik and Şahbaz (2017) investigated whether the basalts extracted in Ilıca (Kütahya) region were in conformity with the TS 706 EN 12620+A1 da "Concrete Aggregates" standard to be used as aggregate in concrete.

Tunç (2019) carried out a review study that aimed the production of concrete, which both had high strength and was useful for the environment and economy, with the use of waste aggregates in concrete. He developed equations that could be used safely for compressive strength and splitting tensile strength. The present study aims to investigate the fresh and hardened concrete properties of the concrete produced by the basalt aggregates extracted in the Elazig region. It was aimed to produce high strength concrete with the use of basalt aggregates, which are known to be highly resistant, in concrete.

2. RESEARCH SIGNIFICANCE

The use of basalt aggregates in order to obtain better strength in concrete compared to limestone and similar aggregates frequently used in concrete production increases the importance of the present study. Because concrete production with basalt aggregate will be more economical compared to using chemical additives in places where high strength is desired. In addition, since there are too many basalt quarries in Turkey, a great contribution will be made to the environment and the national economy through the use of this aggregate in the construction industry.

3. EXPERIMENTAL PROGRAM

3.1. Materials

The basalt aggregates extracted from Elazığ province were used as aggregate in the present experimental study (Figure 1).

Figure 1. Elazığ province basalt aggregates in the quarry (Tuğrul, 2015)

The physical properties of the basalt aggregates such as saturated surface dry specific gravity, water absorption rates and standard Los Angeles value (Tunç, 2018a) are presented in Table 1. Figure 2, however, shows the granulometry curve of basalt aggregate mixtures with the largest grain diameter (31.5mm). Figure 2 shows that the amount passing through the sieve with the largest grain diameter (31.5mm) is 100%. The best compactness was achieved by the curve of the mixture falling into the A32-B32 region. According to TS 802, basalt aggregates used in the present study seem to be suitable in this respect (Figure 2).

Table 1. Physical properties of basalt aggregates

Saturated Surface Dry Specific Weights (g/cm^3)			Water Absorption Rates (%)			Standard Los Angeles Abrasion Loss(%)
(S_{dyk}^{coarse})	(S_{dyk}^{medium})	(S_{dyk}^{fine})	(S_{a}^{coarse})	(S_{a}^{medium})	(S_{a}^{fine})	LA
2.85	2.86	2.79	0.7	0.8	1.4	11.5

S_{dyk}^{coarse}=rough aggregate saturated surface dry unit volume weight
S_{dyk}^{medium} = medium aggregate saturated surface dry unit volume weight
S_{dyk}^{fine}=fine aggregate saturated surface dry unit volume weight
S_{a}^{coarse}=rough aggregate water absorption ratio
S_{a}^{medium} =medium aggregate water absorption ratio
S_{a}^{fine}=fine aggregate water absorption ratio

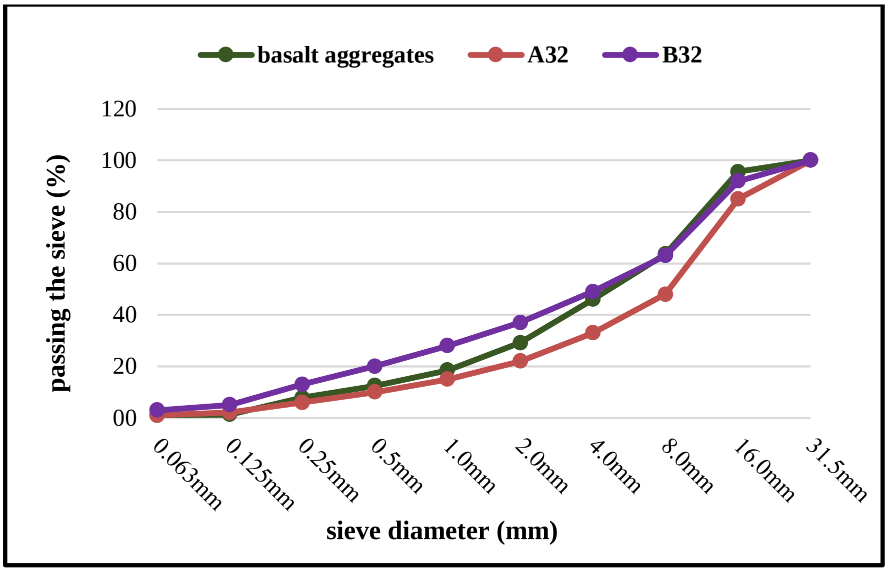

Figure 2. Granulometry curve of basalt aggregates (Tuğrul, 2015)

The CEM I 42.5N Portland cement was used in the present study. The specific gravity of the said cement was 3.1g/cm^3 and the Blaine specific surface area was 3490cm^2/g (Tuğrul, 2017). The initial setting time of the cement was 2.6h, and the final setting time was 3.5h. In addition, the 2-, 7- and 28-day compressive strengths of the cement mortar were determined as 25.8MPa, 38.1MPa, and 49.1MPa, respectively, in accordance with the TS EN 197-1 standard (Tunç, 2018b).

3.2. Mixture Proportioning and Preparation

In the present study, a series of concrete samples were poured for different cement dosages (300, 350, 400kg/m^3) and different cubic sample sizes (150x150x150mm and 100x100x100mm) using the basalt aggregate type. The saturated surface dry weights of the said aggregate were used when forming the concrete mixtures. Table 2 shows the aggregate, cement and water weights (for 1kg/m^3) of the concrete mixtures. The concrete mixtures were prepared by the mixture content in Table 2, using a vertical-axis mixer with a rotation speed of 1.5 rev/sec on the average (Figure 3).

Table 2. Mixture ratios (for 1kg/m^3) and slump values

Cement	Coarse Aggregate	Medium Aggregate	Fine Aggregate	Water	Slump*
300	613.0	510.0	904.0	185.9	0
350	587.5	475.7	845.1	212.2	2
400	551.0	450.5	787.3	238.4	15

*The unit of slump values is cm

Figure 3. Concrete mixer

3.3. Casting and Curing of the Specimens

The concrete mixtures formed with the mixture contents in the previous section were made ready for the determination of the fresh and hardened concrete properties. A cut slump cone was used according to the TS EN 12350-2 standard in order to determine the fresh concrete properties of the concrete samples obtained. Table 2 shows the deposition values of the respective mixtures. A total of 27 concrete samples, including 18 150x150x150mm and 9 100x100x100mm cubic samples, were poured in order to determine the hardened concrete properties of concrete samples (Figure 4a). Samples put into the curing pool with a temperature of 23±2°C were removed from the pool at the end of the 28th day (Figure 4b).

(a) (b)

Figure 4. Preparation of the concrete samples
(a) Cubic samples; (b) Curing pool

3.4. Experimental Tests

In this study, the EDX micro-analyzer was used and the Scanning Electron Microscopy (SEM) test was conducted to investigate the microstructure of the said aggregate. The magnification of the SEM image were chosen as ×10000 magnification (Figure 5). According to Figure 5, a porous microstructure is seen when the elementary structure of the basalt aggregate is examined. In addition, it is seen that the thicknesses of microcracks are low.

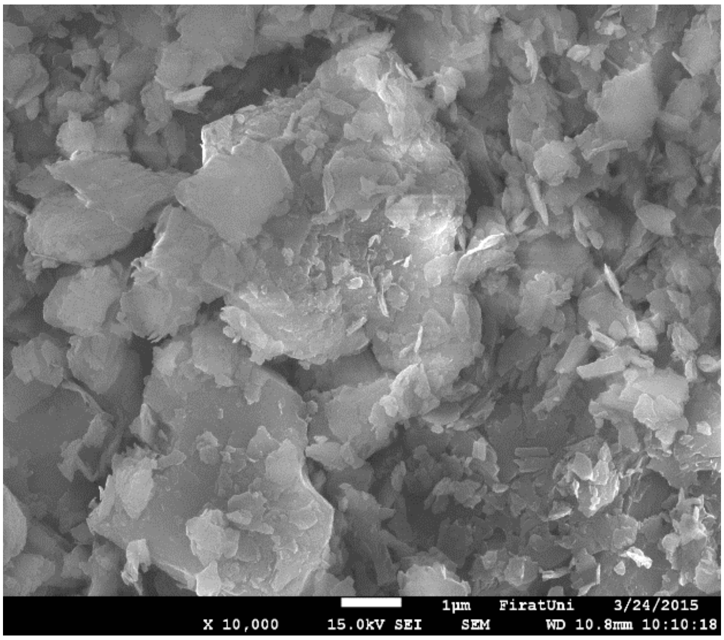

Figure 5. SEM photograph of the basalt aggregate: ×10000 magnification

In order to determine the hardened concrete properties of concrete samples, a compressive strength test was conducted on the cubic samples of the sizes 150x150x150mm and 100x100x100mm in accordance with the TS EN 12390-3 standard. A compressive strength tool with a constant loading speed was used to break the concrete samples (Figure 6a). The compressive strength is calculated by dividing the applied load by the surface area. Similarly, the splitting tensile strength tests were performed on the 28-day cubic samples of the sizes 150x150x150mm in accordance with the TS EN 12390-6 standard (Figure 6b).

(a) (b)

Figure 6. Determination of the compressive strengths of the concrete samples
(a) Compressive strength test; (b) Splitting tensile strength test

4. RESULTS AND DISCUSSION

Post-test images of concrete samples containing the basalt aggregates are presented in Figure 7. As a result of the splitting tensile strength test, the presence of basalt aggregates in the sample content can be clearly seen.

(a) (b) (c)

Figure 7. Situations of the concrete samples with different cement dosages after being subjected to strength tests
a) C=300kg/m^3, b) C=350kg/m^3, c) C=400kg/m^3

Figure 8 shows the average compressive strength values (f_c) of the samples of different sizes (100×100×100mm and 150×150×150mm) containing basalt aggregate determined for different cement dosages (300, 350 and 400kg/m^3). With the increase in cement dosage, it was seen that the compressive strength values of the concrete samples produced with these aggregates increased linearly. The highest compressive strength value (42.3MPa) was obtained for C=400kg/m^3. For both 100×100×100mm and 150×150×150mm size samples when the cement dosage increased from 300kg/m^3 to 400kg/m^3 in cubic samples, an increase was observed in the compressive strength of these samples and this value was calculated as 6%. In addition, according to Figure 8, the compressive strength of the smaller sample size was found to be higher examining the relationship between the sample size and the compressive strength values by keeping the cement dosages constant. For the cement dosages of 300-350kg/m^3, the increase of compressive strength between the cubic samples of 100×100×100mm and 150×150×150mm was determined to be approximately 7%, and this value was 6% for the cement dosage of 400kg/m^3. According to the results obtained, it can be said that the increase rates are approximately the same.

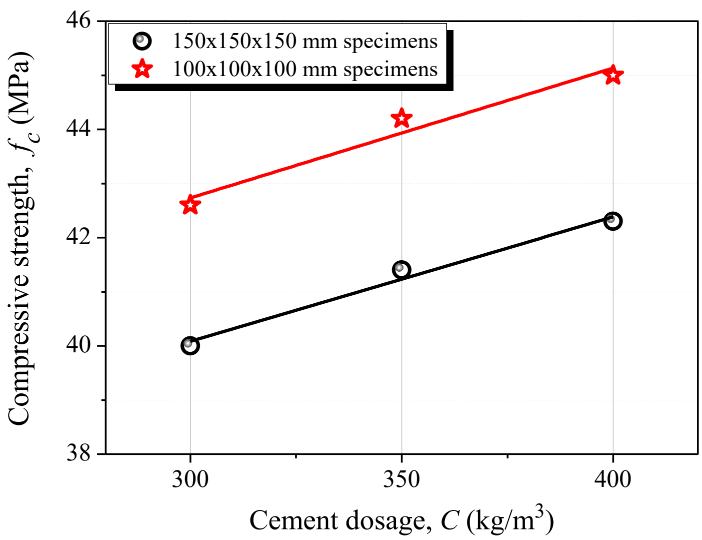

Figure 8. Investigation of the change of compressive strengths of 100×100×100mm and 150×150×150mm concrete samples with the change in cement dosage

Figure 9 shows the splitting tensile strength values (f_t) of the 150×150×150mm samples containing basalt aggregates for the cement dosages of 300, 350 and 400kg/m^3. Similar to Figure 8, it was seen that the tensile strength values of concrete samples produced with these aggregates increased linearly with the increase in the cement dosage. The increase in splitting tensile strengths of these samples was determined to be 0.5% with the increase in the cement dosage from 300kg/m^3 to 350kg/m^3 and to be 0.3% with the increase in the cement dosage from 350kg/m^3 to 400kg/m^3. According to the obtained values, the increase in the splitting tensile strength when the cement dosage increased from 300kg/m^3 to 350kg/m^3 for the samples of 150×150×150mm was approximately 2 times higher than the increase in the splitting tensile strength when the cement dosage increased from 350kg/m^3 to 400kg/m^3 approximately 2 times the rate.

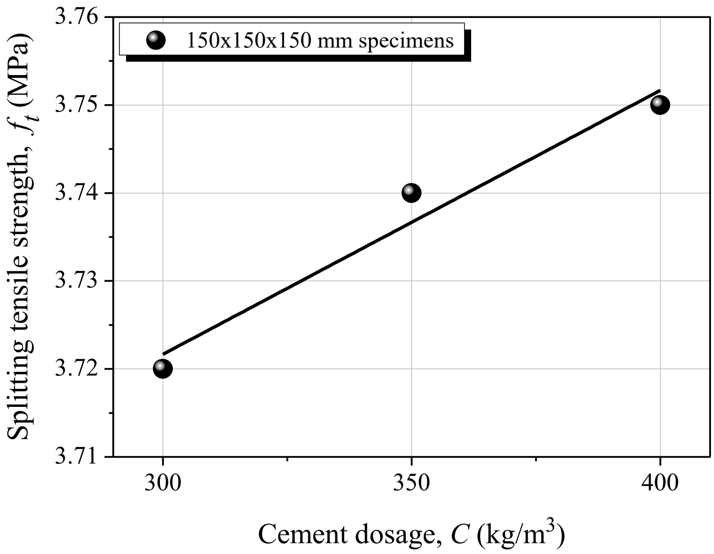

Figure 9. Investigation of the splitting tensile strengths of 150×150×150mm concrete samples for different cement dosages

Figure 10 shows the relationship between the compressive and the splitting tensile strengths for different cement dosages using standard cubic samples (150×150×150mm). With the increase in cement dosage, it was seen that both the splitting tensile strength and compressive strength of the concrete samples increased, and this curve was linear. The compressive strength and the splitting tensile strength values were higher for the cement dosage of 400kg/m^3 compared to other dosages. When the 300kg/m^3 and 350kg/m^3 cement dosage samples were compared, there was an increase of 3.5% in the compressive strength in response for an increase of 0.5% in the splitting tensile strength. Similarly, when the 350kg/m^3 and 400kg/m^3 cement dosage samples were examined, this rate of increase was calculated as 0.3% for the splitting tensile strength and as 2.2% for the compressive strength. In addition, a very good correlation was found between the compressive and the splitting tensile strengths of the standard cubic samples, and the correlation coefficient was determined as R^2=0.9957.

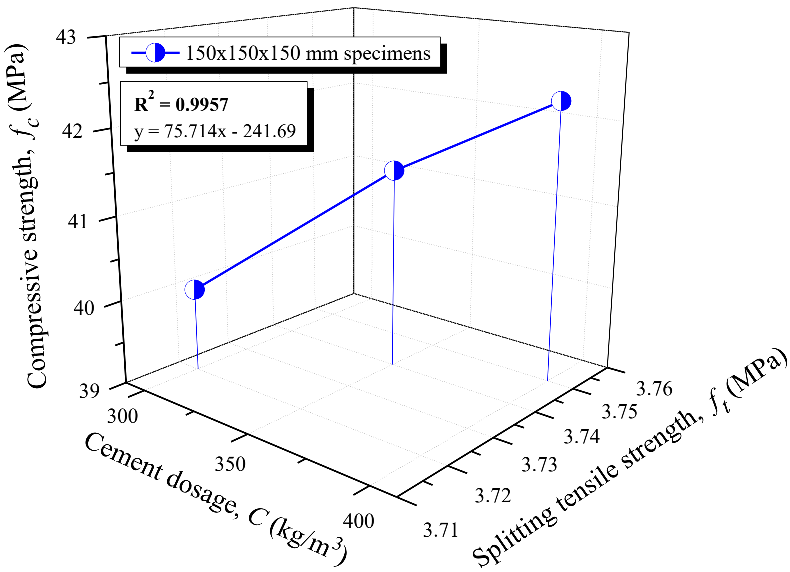

Figure 10. Correlation between the compressive and splitting tensile strengths of 150×150×150mm of cubic samples for different cement dosages

5. COMPARISON WITH PREVIOUS STUDIES

The compressive strengths of the concrete samples produced with basalt aggregates used in the present study and the compressive strengths of the concrete samples in similar studies in the literature were compared in this section. In the experimental studies, the cement dosage (C=400kg/m^3) water/cement ratio (w/c=0.6) and curing period (28 days) were kept constant and the effects of different aggregate types (marble-limestone-calcerous-basalt) on the compressive strength of concrete were investigated. According to Figure 11, the lowest compressive strength was in the study by Acikgenc, et al., (2012) which was 32MPa, and the highest compressive strength value was 47.2MPa in the study by Alyamac and Tugrul (2014). Acikgenc, et al., (2012), Tugrul (2017) and Ulaş, et al., (2018) studied the effects of calcerous aggregates on the compressive strength of concrete. The average compressive strength value obtained was 37.3MPa, and the use of this aggregate type in concrete was recommended. In Turkey, the compressive strength of the concrete obtained by using the cherry marble aggregates of Elazığ province was determined as 33MPa (Tunc, 2018b). The compressive strength value (42.3MPa) obtained in the present study was found to be quite higher compared to the results obtained in other studies in the literature. When the effects of basalt, calcerous and cherry marble aggregates of Elazığ province on concrete compressive strength were compared, the compressive strength value of the concrete sample containing the basalt aggregate was 28.2% higher than the compressive strength of the concrete containing marble aggregates used in the study by Tunç (2018b), and 12.5% higher than the compressive strength of the concrete sample containing the calcerous aggregates used in the study by of Tuğrul (2017) (Figure 11).

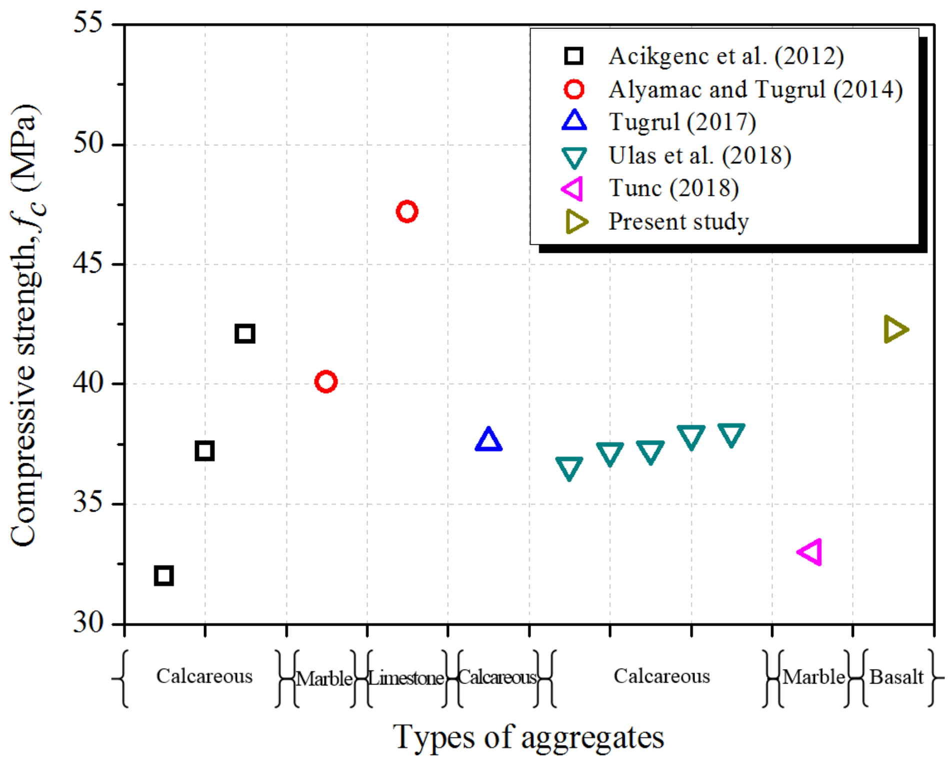

Figure 11. The correlation between the aggregate types used in the present study and previous studies and the compressive strength of concrete

6. CONCLUSIONS

In this study, the effects of the basalt aggregates extracted in Elazig province on the concrete properties were investigated experimentally to examine the effects of aggregate type on the compressive strength of concrete. The results obtained are as follows:

- In the present study, the usability of the aggregate, which is unique to Elazığ region, in concrete was investigated. This is thought to be an original and important study in this respect.
- As the cement dosage increased, the compressive strength values of the concrete containing the basalt aggregate also increased.
- It was seen that the splitting tensile strength values of concrete samples produced with basalt aggregates increased linearly with the cement dosage.
- Low thickness micro cracks were seen in the inner structure of the aggregate when the SEM analysis performed within the scope of this study was examined.
- The relationship between compressive strength and tensile strength of the concrete containing basalt aggregates was investigated and a good fit was obtained.
- The relationship between the compressive and splitting tensile strengths of the concrete containing basalt aggregates was investigated and a quite good consistency was obtained between them.
- The compressive strength value for C=400kg/m^3 was found to be above the average when compared to the results obtained from other studies in the literature.
- As a result of the experiments in the present study and the literature reviews, it is seen that basalt aggregates can be used safely in concrete.

- It is thought that an economical, high quality and performance concrete type will be obtained with the use of these aggregates in concrete.

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