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Investigation of the Use of Marble Powder in Production of High Strength Concretes

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Abstract - The first of the aims of this study is to determine the amount of marble powder to be used in the optimum amount for high strength concrete (YDB). The second is to contribute to reducing the use of natural resources by using marble powder from waste materials in the production of YDB. For this purpose, marble powder was used by replacing it with fine aggregate at 0-8-16-24% by weight. In order to increase the pozzolanic activity in concrete mixtures and to ensure maximum use of marble powder, silica fume has been used by replacing it with cement at 10% by weight. The slump test was applied to the obtained mixtures. Then f_c-7., f_c-28. and f_c-90. days, it was kept in the curing pool to be subjected to the compressive strength test. According to the results obtained from the compressive strength test, the optimum amount of marble powder was determined by taking into account the high strength value. In addition, it is thought that the use of marble powder contributes positively to the compressive strength of concrete, consumption of natural resources and reduction of environmental pollution.

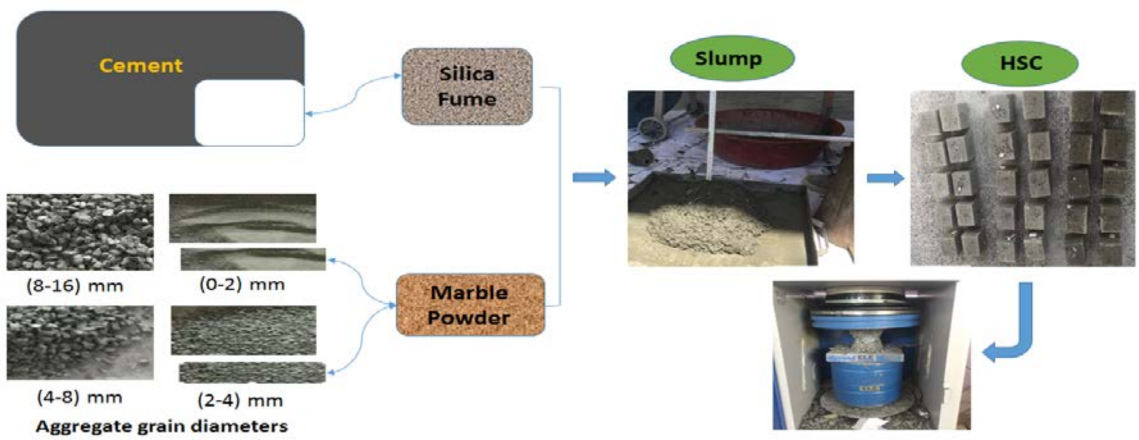
Keywords: High strength concrete, marble powder, compressive strength, silica fume

Yüksek Dayanımlı Beton Üretiminde Mermer Tozu Kullanımının Araştırılması

Öz - Bu çalışmanın amaçlarından birincisi, yüksek dayanımlı betonlar (YDB) için optimum miktarda kullanılacak mermer tozu miktarının belirlenmesidir. İkincisi, YDB üretiminde atık malzemelerden mermer tozu kullanarak doğal kaynakların kullanımının azaltılmasına katkı sağlamaktır. Bunun için ince agrega mermer tozu ile ağılıkça %0, %8, %16 ve %24 oranlarında yer değiştirilerek kullanılmıştır. Beton karışımlarda puzolanik aktiviteyi arttırmak ve mermer tozunun maksimum kullanımını sağlamak için çimentonun ağırlıkça %10'u kadar silis dumanı ilave edilmiştir. Elde edilen karışımlara slump deneyi uygulanmıştır. Daha sonra f_c-7., f_c-28. ve f_c-90. günlerde basınç dayanımı testine tabi tutulmak üzere kür havuzunda bekletilmiştir. Basınç dayanımı testinden alınan sonuçlara göre optimum mermer tozu miktarı, yüksek dayanım değeri dikkate alınarak belirlenmiştir. Ayrıca mermer tozu kullanımının, beton basınç dayanımına, doğal kaynak tüketimine ve çevre kirliliğinin azaltılmasına olumlu yönde katkı sağladığı düşünülmüştür.

Anahtar kelimeler: Yüksek dayanımlı beton, mermer tozu, basınç dayanımı, silis dumanı

Graphical Abstract



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1. Introduction

Concrete produced with traditional materials leads to the reduction of available natural materials. In recent studies, approaches have been developed to include waste materials as an alternative to traditional methods in concrete production [1]. With the use of these waste materials, the negative effects on the environment are reduced, environmental efficiency is increased and solutions are found for the storage problems of wastes. Marble powder and silica fume are widely used in sustainable concrete mixes [2].

Aggregates constitute approximately 70% of the concrete volume [3]. These aggregates are obtained from natural sources such as quarries or seabeds [4]. The increase in concrete production day by day causes the consumption of these natural resources and the emergence of environmental problems. In order to eliminate this problem, it is used in concrete production by replacing waste materials with aggregate [5]. One of these waste materials is marble powder.

Marble powder comes out during the cutting process of marble stones and blocks. It does not have a pozzolanic feature, but by creating a filling effect in concrete mixtures, it provides more void-free concrete [6]. Thus, it affects the compressive strength of concrete positively. On the other hand, due to the small specific surface area of the marble powder, the concrete increases the water requirement. Therefore, the use of more than the optimum amount in concrete mixtures reduces the compressive strength [7]. Environmental benefits are also obtained by using marble powder in concrete mixtures [8]. The use of waste in concrete production provides many advantages. Because the accumulation of industrial wastes such as marble powder, silica fume, fly ash, slag also creates ecological problems, which creates environmental concerns with the occupation of lands [9]. The storage of these wastes, which are formed in large volumes, causes a lot of damage to the environment and living things in these areas [10]. Therefore, the safe use of these wastes is also of great importance for sustainability [11]. Also, by replacing these additives with cement or aggregate in certain proportions, the amount of cement and aggregates is reduced and enables more environmentally friendly concrete production [12]. In current studies, cement and silica fume have been replaced by cement between 5% and 20% on average. In the experimental studies, it has been observed that the use of silica fume above these rates causes a decrease in the compressive strength of the concrete. marble powder was replaced with fine aggregate.

In this study, it was aimed to determine the amount of marble powder to be used in the optimum amount for high strength concrete (YDB). In the literature, the optimum ratio of marble powder to be used in the YDB is not specified. Therefore, in this study, it is anticipated to contribute to the literature by determining this rate. In addition, it is thought that the use of marble powder in the production of YDB will contribute to the reduction of natural resource consumption, as well as gains in terms of works that require great labor and cost such as obtaining fine aggregate and transportation (Figure 1). For this purpose, fine aggregate was used by replacing marble powder at the rates of 0%, 8%, 16% and 24% by weight. In order to increase the pozzolanic activity in concrete mixes and to ensure the maximum use of marble dust, silica fume was added up to 10% by weight of the cement. The slump test was applied to the obtained mixtures. Then fc-7., fc-28. and fc-90. days, it was kept in the curing pool to be subjected to the compressive strength test. According to the results obtained from the compressive strength test, the optimum amount of marble dust was determined by taking into account the high strength value.

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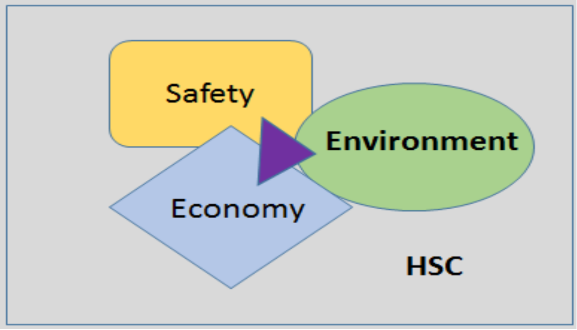

Figure 1. The key elements of the HSC

2. Materials and Methods

2.1. Materials

In this study, CEM I 42.5 R portland cement type produced in accordance with TS EN 197-1 standard was used [13]. Marble powder was used by replacing 0%, 8%, 16% and 24% fine aggregate. In order to increase the pozzolanic activity and to ensure the maximum use of marble powder, 10% by weight of silica fume was added to the cement. The physical and chemical properties of these materials are given in Table 1.

Table 1. Chemical and physical properties (%) of materials used in HSC

Chemical Properties	Cement (C)	Silica Fume (SF)	Marble Powder (MP)
CaO	63.19	0.40	40.45
SiO_2	19.07	94.10	28.35
Fe_2O_3	3.72	1.50	9.70
Al_2O_3	4.82	0.90	0.17
SiO_3	2.94	94.10	0.02
Na_2O	0.39	0.40	0.05
K_2O	0.62	0.90	0.01
MgO	1.83	0.10	16.25
Cl	0.0101	-	-
Insoluble residue	0.56	-	-
Loss of ignition	3.43	-	4.84
Physical Properties			
Specific surface cm^2/g	3838		3920
Specific gravity g/cm^3	3.13	2.20	2.71
Initial setting time (min)	135	-	-
Final setting time(min)	215	-	-
Total volume exp. (mm)	1	-	-

In the study, andesite aggregate, which has a high compactness, was used. This type of aggregate is dark colored, non-absorbent, non-dispersible and highly compact. At the same time, andesite aggregate contains 52-63% quartz [10,11]. The maximum aggregate grain diameter (Dmax) used in experimental studies is 16 mm. Aggregates are divided into 4 different groups as 0-2, 2-4, 4-8, 8-16 mm. Aggregates separated by sieve classes are given in Figure 2. The grain density values of the aggregate and usage rates in the mixture are presented in Table 2.

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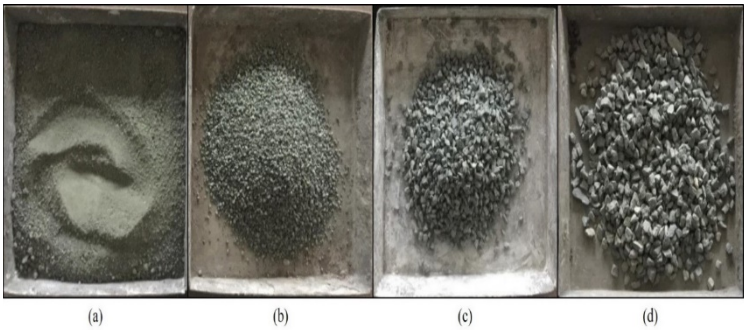


Figure 2. Aggregate grain diameters a) (0-2) mm, b) (2-4) mm, c) (4-8) mm, d) (8-16) mm

Table 3. The grain density values of the aggregate and usage rates in the mixture

Aggregate Group	Specific Gravity (gr/cm^3)	Mixture Rate (%)
0-2 mm	2.74	30
2-4 mm	2.71	20
4-8 mm	2.69	20
8-16 mm	2.69	30

2.2. Preparation of Samples

In the experiments, 4 series of concrete mixtures with different mixing ratios were prepared. Cement dosage was taken as 500 kg/m3 and water/binder ratio was 0.30 in the mixtures. Marble powder was used by replacing 0%, 8%, 16% and 24% fine aggregate. Silica fume was used as a mineral additive by replacing 10% by weight with cement. Due to the high water absorption properties of the materials used, Optima 280 SC3 chemical additive was used at the rate of 1.4% by weight of the cement to provide a fluid consistency in the concrete. The density value of this additive material is 1.08 gr/cm^3 and its ph value is 6. The coding and ratios of these samples are presented in Table 3.

Table 3. Proportions of the concrete mixtures (kg/m^3)

Mix Code	Cement	Water	Silica Fume	(0-2) mm	(2-4) mm	(4-8) mm	(8-16) mm	Chemical Additive
S500-1	475	150	35.1	545	359	358	535	6.65
S500-2	475	150	35.1	523	345	358	535	6.65
S500-3	475	150	35.1	501	330	358	535	6.65
S500-4	475	150	35.1	480	316	358	535	6.65

The slump test, which is one of the fresh concrete tests, was applied to the concrete mixtures in the first stage. Afterwards, the prepared concrete mixture was placed in molds of 100x100x100 mm. The samples, which were cured by waiting in the laboratory environment for 24 hours, were removed from the molds and left in the curing pool. In order to determine the hardened concrete properties, the samples were subjected to standard compressive strength tests on the 7th, 28th and 90th days.

3. Conclusions and Evaluation

3.1.Fresh concrete properties

Slump values of 4 series mixtures produced in the experimental study were determined. The numerical results of these slump values are compared by showing them as graphics (Figure 3).

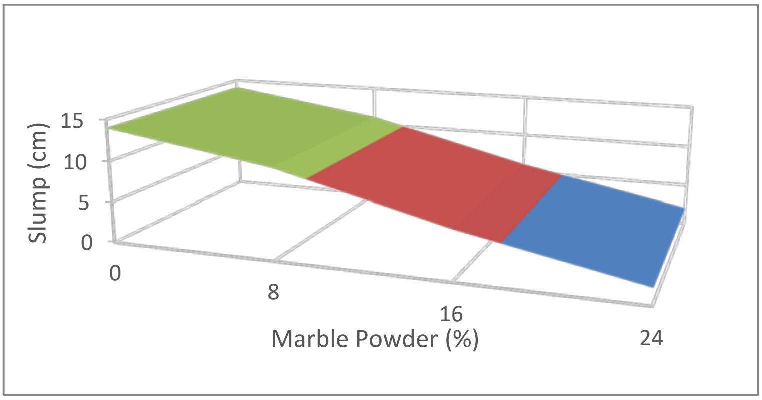
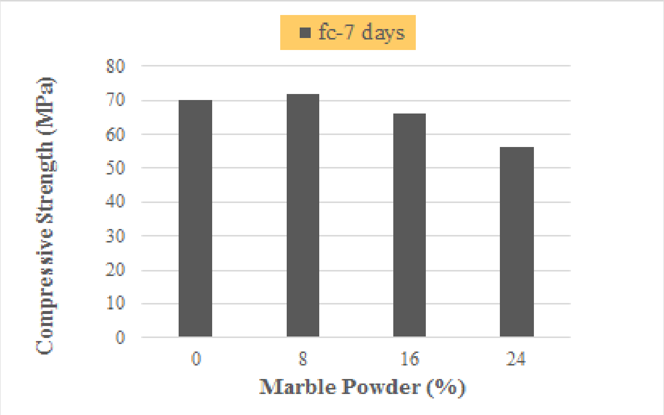


Figure 2. Comparison of slump values of the series

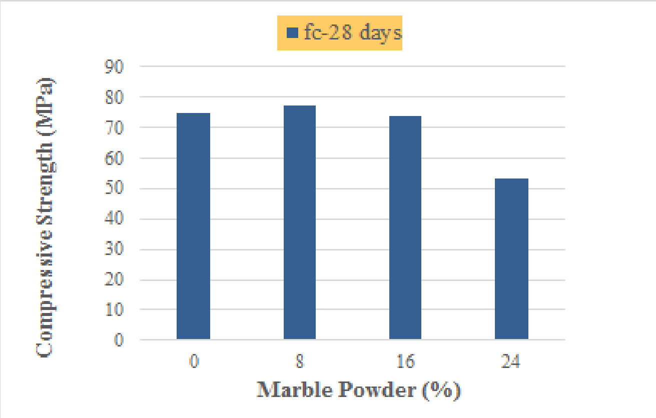
When Figure 3 is examined, it is observed that the slump value decreases with the increase in the amount of marble powder. As stated in the literature, marble powder, which creates a filling effect in concrete mixtures, also increases the water requirement of the concrete mixture due to its thinness.

3.2.Compressive Strength

In this study, it is aimed to determine the amount of marble powder to be used in the optimum amount for HSC based on the compressive strength. For this, 4 series of concrete mixes were prepared and f_c-7., f_c-28. and f_c-90. Compressive strength test was applied. The numerical results of the S500 dosed sample groups are shown in Figure 3 as graphics.



(a)



(b)

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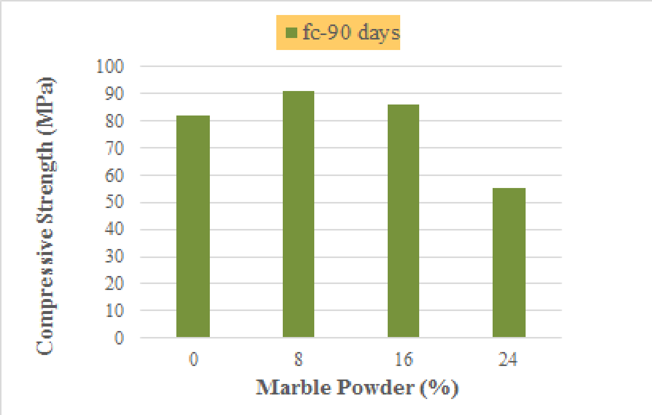

(c)

Figure 3. (a) f_c-7 days compressive strength values (b) f_c-28 days compressive strength values (c) f_c-90 days compressive strength values

When Figure 3 is examined in terms of compressive strength, the compressive strength value was found to be high in the series in which 8% of marble powder was used in general. Due to the filling effect of the marble powder, the compressive strength value in the 1st series, in which marble powder is not used, was lower than in the 2nd series. On the other hand, due to the low machinability of the 3rd and 4th series in which marble powder is used at 16% and 24%, it is thought that the compressive strength of the materials used in the mixture cannot be homogeneously mixed and lumped and placed in the molds well [16]. Therefore, as a result of the data obtained from the experiments, it was seen that the optimum amount of marble powder for HSC was 8%.

The use of more than optimum amount of marble powder complicates the mixing, placing and compaction of concrete due to the increasing water demand. This adversely affects the compressive strength [17]. On the other hand, it is thought that the use of marble powder in HSC mixtures will contribute to the environment and economy.

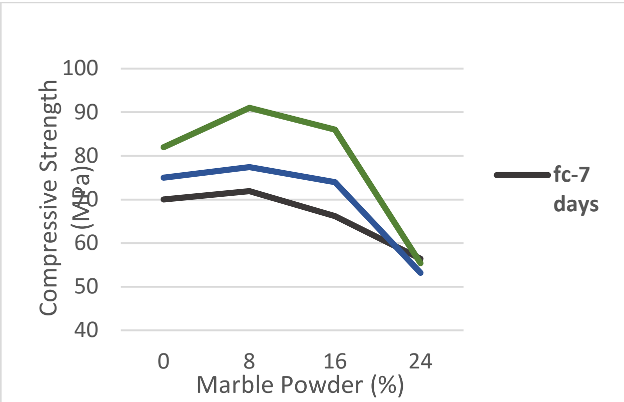

Figure 4. Comparison of f_c-7, f_c-28, and f_c-90 days compressive strength values

Figure 4 shows the comparison of f_c-7, f_c-28, and f_c-90 daily compressive strength values of all series. When the graph is examined, when the increase in compressive strength of f_c-7 and f_c-28 days is compared with the increase in compressive strength of fc-28 and fc-90; The increase after f_c-28 days was greater. The reason for this increase is the addition of silica fume with high pozzolanic activity to the mixture [18]. In parallel with the literature, it is seen that silica fume in concrete mixtures shows a great increase in strength at advanced age and final age values [19]. Likewise, it is clearly seen that the highest value in the compressive strengths of marble powder on the 7th, 28th and 90th days is 8%.

4. Conclusions

In this study, the amount of marble powder that can be used at the optimum rate in HSCs was determined and its effect on the performance of concrete was compared. For the study, 4 series of concrete mixes were prepared. Series slump experiments with f_c-7, f_c-28 and f_c-90. Compressive strength tests were carried out. The data obtained and the variation of the marble powder ratio were compared. The general results of the study are given below:

• Since proper workability could not be achieved in concrete mixtures with high marble powder content, a decrease in the compressive strength value was observed.

• It has been determined that high strength is obtained with the use of optimum marble powder and silica fume.

• From the data obtained as a result of the experiments, it was observed that the pozzolanic activity of the silica fume continued for a long time.

As a result of the experiments, the optimum marble powder ratio was determined. In future studies, it is planned to make trial mixtures for HSC at different dosage values at intervals where the marble powder is 8% +/-2%. As a result of the study, it is aimed to produce more environmentally friendly concrete.

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Author contributions: Concept – T.D., K.E.A.; Data Collection &/or Processing - T.D., K.E.A; Literature Search - T.D.; Writing - T.D.

Conflict of Interest: This paper has been presented at the ICENTE'21 (International Conference on Engineering Technologies) held in Konya (Turkey), November 18-20, 2021.)

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