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Research Article

Investigation of Fresh Concrete and Mechanical Properties of Self-Compacting Concrete with Obsidian Powder Admixture

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Abstract

Self-compacting concrete (SCC) is a special type of concrete with high workability. This type of concrete is preferred and used as innovative concrete because it does not require vibration, has high fluidity, can be applied quickly and requires minimum workmanship. The high workability of self-compacting concrete depends on the type and amount of various chemical and mineral admixtures in its content. In this study, self-compacting concrete groups were produced by using obsidian powder, which is a rock of volcanic origin, at 15, 20 and 25% ratios instead of cement. In these groups; flow-table, V-Funnel flow, L-box, U-box fresh concrete tests and compressive strength tests were carried out after 7 and 28-days of standard water curing. When the test results are examined; it was determined that obsidian powder improved the self-compacting fresh concrete properties. In addition, it has been determined that the concrete mixtures produced using obsidian can have high compressive strength.

Keywords: self-compacting concrete, obsidian, compressive strength, fresh concrete properties

Obsidiyen Tozu Katkılı Kendiliğinden Yerleşen Betonun Taze Beton ve Mekanik Özelliklerinin İncelenmesi

Öz

Kendiliğinden yerleşen beton (KYB), işlenebilirliği yüksek özel bir beton türüdür. Bu tip betonlar vibrasyon gerektirmemesi, yüksek akıcılığa sahip olması, hızlı uygulanabilmesi ve minimum işçiliğe ihtiyaç duyması gibi nedenlerle yenilikçi bir beton olarak tercih edilip kullanılmaktadır. Kendiliğinden yerleşen betonların yüksek işlenebilirliğe sahip olması, içeriğindeki çeşitli kimyasal ve mineral katkıların türü ve miktarına bağlıdır. Bu çalışmada volkanik kökenli bir kayaç olan obsidiyen tozu, çimento yerine %15, 20 ve 25 oranlarında kullanılarak kendiliğinden yerleşen beton grupları üretilmiştir. Bu gruplar üzerinde; yayılma, V-kutusu, L-kutusu, U-kutusu taze beton deneylerine ek olarak sertleşmiş beton numuneleri üzerinde 7 ve 28 gün standart kür sonunda basınç dayanımı deneyi yapılmıştır. Deney sonuçları incelendiğinde; obsidiyen tozunun kendiliğinden yerleşen taze beton özelliklerini iyileştirdiği belirlenmiştir. Ayrıca obsidiyen kullanılarak üretilen betonların yüksek basınç dayanımına sahip olabileceği belirlenmiştir.

Anahtar Kelimeler: kendiliğinden yerleşen beton, obsidiyen, basınç dayanımı, taze beton özellikleri

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1. Introduction

The concept of self-compactibility in concrete was first introduced in 1986 at the University of Tokyo by Prof. Dr. Posted Hajime Okamura. SCC started to appear on the market as a prototype in 1988 [1]. Concretes with high fluidity, which can easily settle on tightly reinforced elements without the need for compaction with their weight, and which do not undergo segregation while providing these properties, are called self-compacting concrete [2]. Despite their low water/cement ratio, SCC has superior fluidity and high strength [3]. Thanks to these usage advantages in the concrete industry, SSC has been preferred more recently.

High workability and sufficient strength are important criteria in the design of SCC. Achieving these criteria depends on the addition of various chemical and mineral additives to the concrete. While highly water-reducing hyper plasticizer additives are used as chemical admixtures, various mineral additives are preferred for high workability and sufficient strength [4-7].

There are many studies on SCCs produced using these mineral admixtures;

When the capillarity and compressive strength of self-compacting concretes formed by using fly ash and blast furnace slag in place of 20%, 40% and 60% cement are examined, fly ash substitution does not have a significant effect on the capillarity coefficient, while the increase in the blast furnace slag replacement ratio significantly reduces the capillarity coefficients of self-compacting concrete. The highest compressive strength was obtained with 20% blast furnace slag substitution [8]. When the effect of mixing time on self-compacting concrete (SCC) mixtures containing different ratios of F-type fly ash was examined, it was concluded that even if the mixing ratios were adjusted very well, when the mixing time was more than 3 minutes/45 liters, there was decomposition in fresh concrete [9]. The highest compressive strength value in SCCs produced by using 5%, 10% and 15% silica fume and 25%, 40% and 55% F-type fly ash by weight instead of cement as a mineral additive, is obtained from the concretes produced using 15% silica fume with a value of 88 MPa [10], on the other hand, it was determined that the best fluidity and compressive strength were at 40% F-type fly ash replacement rate in SCCs obtained by substituting 40%, 50% and 60% rates F-type fly ash instead of cement [11]. In SCCs produced by using fly ash and silica fume in different proportions, the highest compressive strengths has been observed as 30% fly ash replacement rate, 15% silica fume replacement rate and 10% fly ash + 10% silica fume replacement rate for using fly ash alone, silica fume alone and hybrid groups, respectively. [12].

The obsidian mineral is a natural pozzolan and has a high silica content. The mainly obsidian reserves in the world are available in many countries such as Mexico, USA, Italy, Scotland, Greece, Armenia, Turkey and its production rate is around 5.850.000 tons per year in Turkey [13].

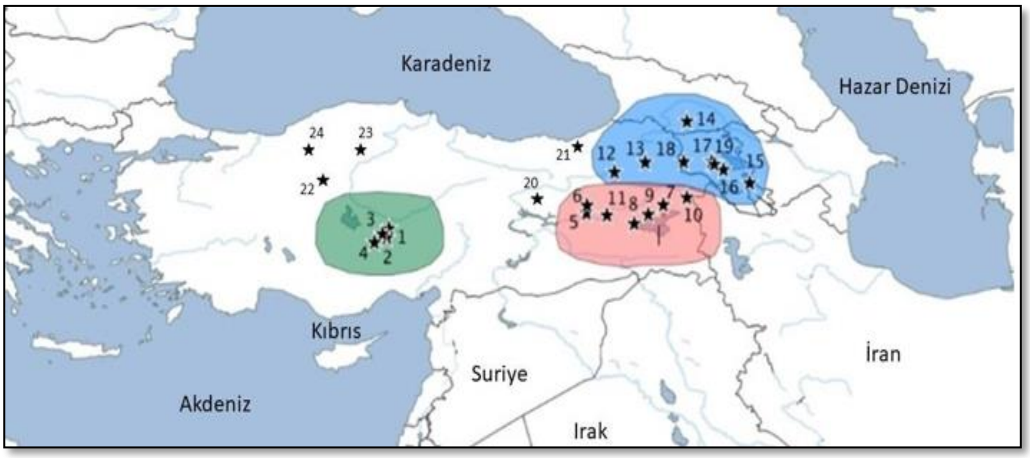

Figure 1. Reserve map of obsidian mineral in Turkey [14]

Studies in which the obsidian mineral is used in normal concrete are very limited, and there is not yet a study in which it is used in SCC design.

Obsidian from the Rize-İkizdere region can show pozzolanic activity and has a 7-day pozzolanic activity index of 77.48% and a 28-day pozzolanic activity index of 90.41% [15]. When used instead of 40% cement, it leads to higher strength than mortars with fly ash at the same rate [16]. It was determined that the obsidian belonging to Erzurum-Pasinler region could show pozzolanic activity and the 7-day pozzolanic activity index was 81% and the 28-day pozzolanic activity index was 83% [17].

Fresh concrete and strength properties of self-compacting concretes produced by using obsidian mineral with high silica content as a mineral admixture instead of cement will contribute to the concrete literature. The fact that SCC produced using obsidian has not yet been found in the literature makes the study unique.

2. Materials and Methods

2.1. Materials

In this study, CEM I 42.5 R type cement and obsidian from Erzurum-Pasinler region in Turkey were used. The Blaine fineness of the cement used in the study is 3690 cm^2/g. The chemical analysis results of the cement type and obsidian used are given in Table 1. Basalt aggregates in 4 different sizes (0-2, 2-4, 4-8, 8-16) were used in the study. The physical properties of aggregates are given in Table 2.

Table 1. Chemical Analysis of Cement and Obsidian

Components	Cement (%)	Obsidian (%)
SiO_2	18.10	77.3
Al_2O_3	4.48	12.9
Fe_2O_3	3.09	1.08
CaO	63.65	0.32
MgO	2.58	0.04
SO_3	2.84	-
Loss on Ignition	3.9	-
Na_2O	0.21	3.94
K_2O	0.62	4.30
$Na_2O+0.66K_2O$	0.62	-
Cl	0.015	-
Immeasurable	0.52	-
Total	100	-
Free CaO	0.44	-
Insoluble Residue	0.55	-

Table 2. Physical Properties of Aggregate

Aggregate Size (mm)	Specific Gravity (gr/cm^3)	Water Absorption (%)	Surface Moisture (%)
0-2	2.61	2.98	2.59
2-4	2.61	2.95	2.39
4-8	2.63	1.40	1.49
8-16	2.63	1.47	1.17

Reserves of the obsidian mineral exist in many parts of the world. The reserves of this rock of volcanic origin are predominantly found in the eastern Anatolia region of Turkey (Figure 2).

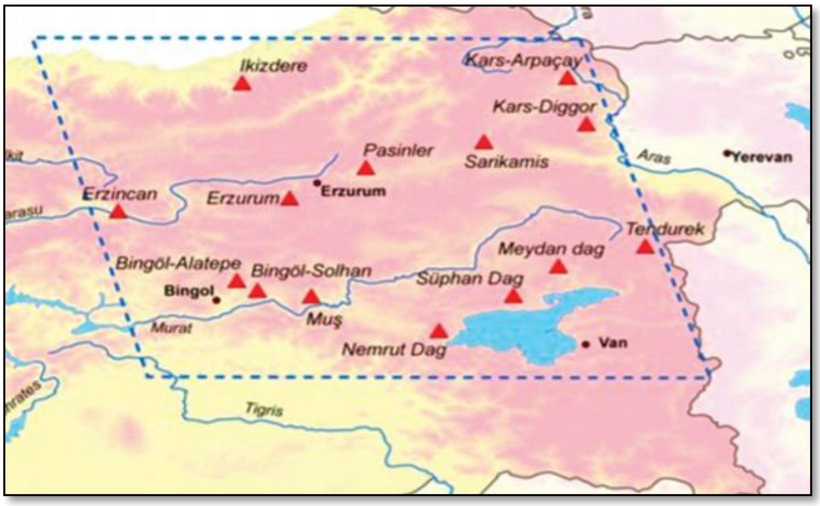

Figure 2. Obsidian reserves in eastern Turkey [18]

Figure 3. Obsidian from Erzurum-Pasinler region

The specific gravity of Pasinler obsidian is 2.46 g/cm^3 and the percentages passing through 63-micron and 75-micron sieves were given in Table 3.

Table 3. Fineness of Obsidian

Sieve Diameter	Passing the Sieve (%)
75 Micron	85
63 Micron	60

SCC Mixture Groups

The mixing ratios of SCC groups obtained by using obsidian powder were given in Table 4. Polycarboxylic ether-based 2nd generation superplasticizer ratio was used as 2.63% of the binder weight in the produced SCC groups. Many preliminary trials have been carried out for the suitability and amount of the superplasticizer additive. SCC groups were formed by using obsidian powder at the rate of 15%, 20% and 25% instead of cement.

Table 4. SCC Mixing Groups

SCC Groups	Material Quantity (kg/m^3)								
	CE	O	Aggregate (mm)				W	W/B	S
			0-2	2-4	4-8	8-16			
C	578	-	568	353	308	307	208	0.36	15.2
O15	491	87	568	353	308	307	208	0.36	15.2
O20	462	116	568	353	308	307	208	0.36	15.2
O25	433	145	568	353	308	307	208	0.36	15.2

C: Control SCC Group, **O:** Obsidian**, CE:** Cement, **W:** Water, **W/B:** Water/Binder ratio, **S:** Superplasticizer

2.2. Methods

Fresh Concrete Tests

Flow-Table

It includes observing the strain rate of the fresh SCC and measuring the diameter that the sample will form by spreading with its own weight. The test (Figure 4) was carried out according to the TS EN 12350-8 [19] standard.

Figure 4. Flow-Table Test

V-Funnel Flow

It evaluates the spread per unit time by measuring the discharge time of the SCC from the narrow mouth of a specially designed funnel with its own weight. The test (Figure 5) was carried out according to the TS EN 12350-9 [20] standard.

Figure 5. V-Funnel Flow Test

L-box

It includes observing the filling ability, passing ability and segregation resistance of the SCC in an L-shaped box. The test (Figure 6) was carried out according to the TS EN 12350-10 [21] standard.

Figure 6. L-box Test

U-box

It is a test method (Figure 7) in which the ability of SCC to pass through the reinforcement bars under the influence of its own weight is observed.

Figure 7. U-box Test

Hardened Concrete Test

Compressive Strength

The strength development in concrete was determined by compressive strength tests performed on 7 and 28-days samples. The compressive strength test was carried out on cube samples of 150×150×150 mm in accordance with the TS EN 12390-3 [22] standard, and the loading rate was taken as 0.4 MPa/sec. during the test (Figure 8).

Figure 8. Compressive Strength Test

3. Results and Discussion

Fresh Concrete Tests Results

The results of the experiments carried out to determine the fresh concrete properties of SCCs produced with different substitution rates of the obsidian admixture are given in Table 5.

Table 5. Fresh Concrete Tests Results

SCC Fresh Concrete Properties	SCC Mixed Groups				
	Units	**C**	**O15**	**O20**	**O25**
Flow Diameter	cm	90	85	89	97
T-50 Time	sec	2.25	2.24	1.9	0.98
V-Funnel Flow Time	sec	5.36	14.9	10.8	4.84
L-Box Height Ratio (h1/h2)	-	1.13	1.08	1.08	1.13
U-Box Height Difference (h1-h2)	cm	1	0.4	0.3	0.5

C: Control, **O**: Obsidian

In the EFNARC [23] standard, it is stated that the flow diameter of SCCs should be between 65-80 cm. When the flow diameters of the concrete groups are examined in Table 5, it is seen that all obsidian groups meet the standard and have sufficient fluidity. It was determined that the flow diameter obtained in the O25 group was the highest and exceeded the flow diameter of the control group. In addition, when the T-50 time and the V-funnel flow time were examined, the best results in terms of SCC were again obtained in the O25 group. It has been determined that regardless of the replacement level, the use of obsidian reduces the T-50 time.

It is known that the L-box height ratio and the U-box height difference are low, which is the desired situation in SCCs [10]. It was determined that the L-box height ratios and U-box height differences of the obsidian SCC groups were equal or lower than the control group. This shows that SCCs produced using obsidian have good inter-reinforcement transition ability.

Hardened Concrete Test

Compressive Strength

The compressive strength results of the control and obsidian powder substituted SCC groups are given in Figure 9.

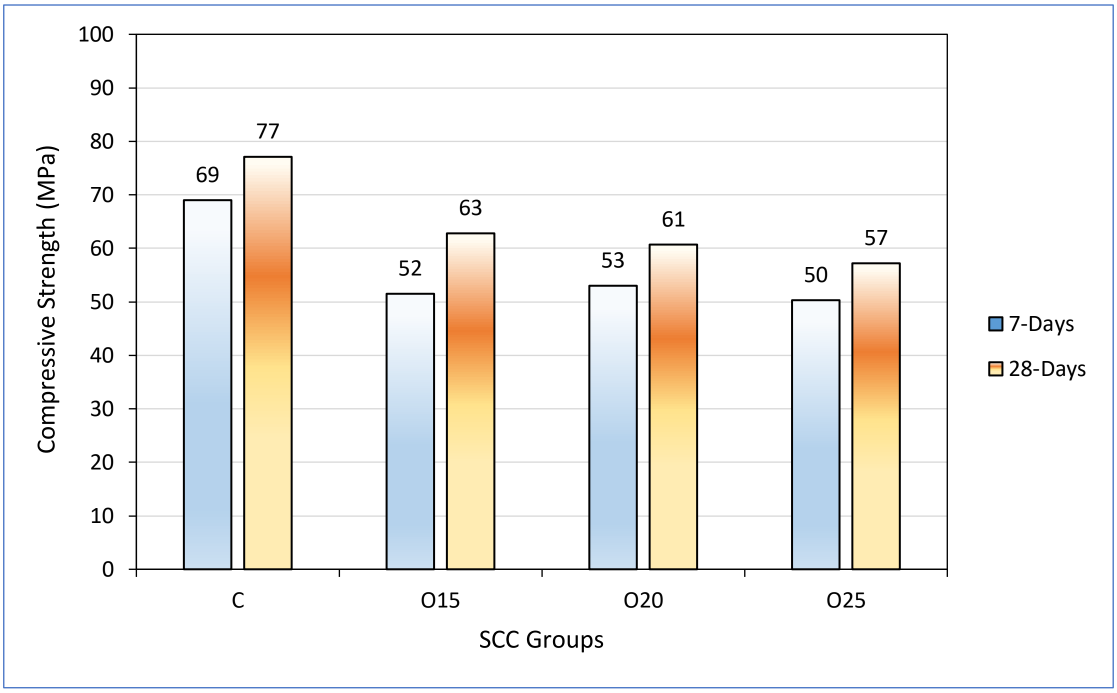

Figure 9. Compressive Strength Test Results

The changes of average compressive strength compared to control groups for 7 and 28 days of SCC groups are given in Table 6.

Table 6. The Changes of Average Compressive Strength Compared to Control Groups

SCC Groups	Change of Average Compressive Strength Compared to Control Groups (%)	
	7-Days	28-Days
C	-	-
O15	-25	-19
O20	-23	-21
O25	-27	-26

C: Control, **O**: Obsidian powder substituted concrete groups

When Table 6 and Figure 9 are examined, it is seen that the compressive strength of the obsidian SCC groups is lower than the compressive strength of the control group. The highest strength was obtained in the O15 group with a value of 63 MPa and the lowest strength was obtained in the O25 group with a value of 57 MPa at the end of 28 days of curing in SCCs produced with obsidian ratios. The strength of both groups is in the class of high strength concrete. Although there was a 67% increase in obsidian in the O25 group compared to the O15 group, both decrease in strength was limited to 8.9% and the gain was obtained from cement need in SCC since obsidian powder was used as a substitute for cement. For this reason, although the use of 15% obsidian admixture provides higher strength, the use of 25% obsidian admixture will not cause a great loss in strength.

4. Conclusions and Recommendations

In this study, obsidian mineral was pulverized and used as an admixture in SCC production. A special type of concrete, SCC, was produced using obsidian, and the fact that this study is the first in the literature of SCC concrete with obsidian material also reveals its originality. If the results obtained in the study are summarized in general;

- ✓ Obsidian mineral in pulverized form can be used in SCC production considering fresh properties and compressive strength levels.
- ✓ It has been determined that obsidian can improve the fresh concrete properties in SCC and show the best fresh concrete properties in the O25 group, where 25% replacement is applied.
- ✓ It has been determined that SCCs produced with obsidian can produce concrete with a compressive strength of at least 57 MPa after 28-days of curing.
- ✓ By determining the usability of obsidian as a substitute for cement, the most expensive material of concrete, cement will be reduced and the cost of the concrete to be produced will decrease.

Suggestions for further studies;

- ➢ Various durability and other mechanical properties of SCCs produced using obsidian can be determined.
- ➢ The other special concrete types can be produced using obsidian and their properties can be examined.

- Compressive strength of obsidian powder substituted concretes under longer curing, such as 56 and 90-days, can be studied in SCC production.

Ethics in Publishing

There are no ethical issues regarding the publication of this study.

Author Contributions

All authors have an equal contribution rate and the authors reviewed and approved the article.

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