The Effect of High Temperature on Physical and Mechanical Properties of Self Compacting Lightweight Concretes

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***Abstract*—**In this study, the effects of high temperatures on physical on mechanical properties of self compacting lightweight concretes with marble powder are investigated. To this end, one control and three different types of mixes are prepared and exposed to high temperature with 300oC, 600oC, and 900oC for one hour at the end of 28 days curing. Marble powder is replaced by weight of cement by 10%, 15%, 20% and used in mixes as mineral additive. The compressive strength and ultrasonic pulse velocity values are concrete samples under high temperatures are measured and evaluated. As a result, the effect of high temperature on ultrasonic pulse velocity, compressive strength, and surface conditions cannot be ignored.

***Keywords*—** Self compacting lightweight concrete, marble powder, ultrasonic pulse velocity, compressive strength, high temperature

I. INTRODUCTION

THE use of lightweight concretes is highly popular in the construction sector. Lightweight concrete has superior characteristics compared to conventional concretes such as lightness, high temperature and sound resistance. However, lightweight concretes have low compressive strength and poor workability characteristics. Self compacting concrete (SCC) is a flowable special concrete that does not require vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and providing full compaction, even in case of congested reinforcement [1].

Today, different types of filler materials are used in self compacting concrete mix to increase durability and strength properties of plain concretes. One of these filler materials is marble powder. Marble powder is a by-product that release during the production of marble processing and the vast majority of them are less than 200 microns. These by-products release after precipitated by sedimentation method and directly into the field. Thus, using of marble powder in different industrial areas is highly useful in terms of to reduce environmental pollution [2].

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Concrete throughout its service life can be damaged by chemical and physical effect. These chemical and physical effects may lead to some negative results and decrease function and durability of concretes. One of these physical effects is the fire and high temperature. In the case of fire temperature values may rise to 1200o C. The effects of high temperature on the properties of concrete have been investigated since the middle of the 20 century [3-7]. Physical and mechanical properties can be changed when concretes exposed to high temperature [8]. Affecting of concrete in high temperatures depends on the concrete components, moisture in the beginning conditions, the cement paste, and aggregate type. It can be easily seen the color changes on the concrete surfaces as well as mechanical properties of concretes under high temperature conditions. For example, if the colour of concrete turns into pink or red, it means that the heat is possibly between 300oC and 600oC. If it is grey, the heat of concrete is between 600oC and 900oC [9-10].
In this study, the effects of high temperature on the loss of unit weight, ultrasonic pulse velocity, and compressive strength of self compacting concretes with marble powder are investigated and discussed.

II. EXPERIMENTAL PROGRAM

In all of mixes, CEM I 42.5 N Portland cement, pumice with maximum aggregate size of 8 mm, marble powder and superplasticizer are used according to Turkish Standard TS EN 197-1 [11]. The specific gravity and specific area of cement 3.09 and 3865 cm2/g, respectively. Pumices obtained from Van (Erçiş-Kocapınar) areas with the size of 0-2 mm (A1), 2-4 mm (A2), and 4-8 mm (A3) are used in concrete mixes. The specific gravities of A1, A2, and A3 aggregates is 1.72, 1.32 and 1.06, respectively. The unit weights of pumice aggregates are obtained as 636 kg/m3, 495 kg/m3, and 413 kg/m3, respectively. The marble powder is supplied from Malaylar Mermer A.Ş. that is located in Van organized industrial site. The marble powder used in all concrete mixes is dryed at 105oC in drying oven before using in concrete mixes. The specific gravity of marble powders is 2,61. Several design procedure based on scientific theories or empiritical experience have been proposed for normal SCC. In this study, all mix design of self compacting lightweight concrete have been done according to ACI 211.2-98 [12] and ACI 237R-07 [13] design codes. One control and three different mixes are

prepared and tested. Marble powder is replaced by cement of weight by 0%, 10%, 15%, and 20% ratios. The ratios of water/cement in all mixes are kept as 0.63. The concrete mix proportions are given in Table 1.

TABLE I
MIX PROPORTIONS OF SELF COMPACTING LIGHTWEIGHT CONCRETE FOR 1 M^3

Mix description	W/C (%)	Binder (kg/m^3)	Water (kg/m^3)	Cement (kg/m^3)	Marble Powder (kg/m^3)	Fine aggregate (0-2mm) (kg/m^3)	Fine aggregate (2-4mm) (kg/m^3)	Coarse aggregate (4-8mm) (kg/m^3)
Control	0.625	500	312.5	500	25	455.599	157.683	143.140
MP10	0.625	500	312.5	450	50	452.948	157.765	142.307
MP15	0.625	500	312.5	425	75	451.602	157.300	141.885
MP20	0.625	500	312.5	400	100	450.255	155.834	141.462

In order to investigate the effects of high temperatures on self compacting concretes, cube samples with the dimensions of 10x10x10 cm are produced. As seen in Fig.1, after 28 days curing conditions, cube samples are exposed to Protherm HLF 150 oven with the capacity of 1200oC for one hour at 300oC, 600oC, and 900oC. Three samples for each mixes are tested under each heating values. The oven is runned for one hour at target temperature and after automatically closed. Afterwards, the cube samples are allowed to cooling. Then, loss of unit weights, ultrasonic pulse velocity, and compressive strength of cube samples are determined. Hydraulic press with 3000 kN capacity is used to determine compressive strength of concrete samples. Compressive strength tests are performed according to Turkish Standard TS EN 12390-3 [14]. The Ultrasonic pulse velocity tester PULSONIC equipment that consist of the ultrasonic tester 58 E-48, two transducers, one transmitter and one receiver head 54 kHz type, two connecting cables, and two 1.5V alkaline D type batteries are used to measure UPV of cube concrete samples. The ultrasonic pulse velocity tests are performed according to ASTM C 597-83[15]. The setup for measuring UPV of concrete is shown in Fig.2.

Fig. 1: High temperature oven

Fig. 2: UPV device

III. TEST RESULTS

3.1 High Temperature Effects on Surface Properties of Concrete

As seen in Fig.3, some color changes happens on surface of self compacting lightweight concrete samples due to high temperature effects. As a result of these color changes, it can be easily estimated the range of temperature values. The color changes on concrete samples are much more apparent for the ones with siliceous river aggregates. The views of concrete samples exposed to high temperatures are seen in Fig.3.

Fig 3. Concrete samples exposed to high temperature

As seen in Fig.3, it can be seen that cracking, rupture, and color changes happened much more in the concrete samples exposed to 900°C than the ones with 300°C and 600°C.

3.2 High Temperature Effects on Loss of Unit Weights of Concretes

Unit weights of self compacting lightweight concrete samples are decreased due to high temperature effect. The loss of unit weights of concrete samples is given in Table 2.

TABLE II
LOSS OF UNIT WEIGHTS OF CONCRETES EXPOSED TO HIGH TEMPERATURE

Mixture code	Temperature (°C)	Loss of unit weight (%)
Control	300	1.75
Control	600	7.58
Control	900	9.60
10 MP	300	1.57
10 MP	600	7.11
10 MP	900	10.7
15 MP	300	1.52
15 MP	600	7.08
15 MP	900	10.3
20 MP	300	1.95
20 MP	600	9.2
20 MP	900	11.5

It is seen that unit weights of all concrete samples decrease after high temperature effects. Loss of unit weights of concrete samples with exposed to 300oC is between 1.52% and 1.95%, the ones with exposed to 600oC is between 7.08% and 9.02%, and the ones with exposed to 900oC is between 9.6% and 11.5%. The most decrease in compressive strength is obtained for concrete with 20% replacement of cement with marble powder at 900oC temperature.

3.3 High Temperature Effects on Ultrasonic Pulse Velocity

The effects of high temperature on the ultrasonic pulse velocity of self compacting lightweight concretes are given in Table 3. As seen in Table 3, it is observed to decrease in ultrasonic pulse velocity values when temperature effect increases.

TABLE III
ULTRASONIC PULSE VELOCITY VALUE OF CONCRETES EXPOSED TO HIGH TEMPERATURE

Mixture code	Temperature (°C)	Ultrasonic pulse velocity (km/sn)
Control	300	4.11
10 MP	300	4.20
15 MP	300	4.23
20 MP	300	3.96
Control	600	2.34
10 MP	600	2.41
15 MP	600	2.58
20 MP	600	2.20
Control	900	1.68
10 MP	900	1.72
15 MP	900	1.76
20 MP	900	1.63

3.4 High Temperature Effects on Compressive Strength

The effects of high temperature on the compressive strength of self compacting lightweight concretes are given in Table 4. As seen in Table 4, the biggest difference in ultrasonic pulse velocity values compared to control samples is for the concretes with 20% replacement of cement with marble powder at 900oC temperature.

TABLE IV
MECHANICAL PROPERTIES OF SELF COMPACTING LIGHTWEIGHT CONCRETE MIXTURES

Mixture code	Temperature (°C)	Compressive strength of concrete (MPa)	Loss of strength (%)
Control	20	27.68	-
Control	300	24.17	12.68
Control	600	19.85	28.28
Control	900	8.05	70.91
MP10	20	28.25	-
MP10	300	25.29	10.47
MP10	600	20.35	27.96
MP10	900	8.65	69.38
MP15	20	30.03	-
MP15	300	26.44	11.95
MP15	600	21.34	28.93
MP15	900	9.15	69.53
MP20	20	25.79	-
MP20	300	22.07	14.47
MP20	600	18.73	27.37
MP20	900	6.85	73.43

IV. CONCLUSION

This paper presents the results of experimental study on physical and mechanical properties of lightweight self compacting concretes. Following findings are reached as a result of this study.

- The effect of high temperature especially at 900oC on concrete samples in terms of compressive strength, ultrasonic pulse velocity, and surface changes are very significant.
- Cracking, rupture, and color changes on concrete surfaces happened much more in the concrete samples with exposed to 900oC than the ones at 300oC and 600oC.
- The biggest difference in compressive strength between control samples and concrete with 20% replacement of cement with marble powder is 73.43%.
- The increase in compressive strength and ultrasonic pulse velocity values is only valid for concrete samples with up to 15% replacement of cement with marble powder. These values are smaller for concrete samples with 20% replacement of cement with marble powder than the control ones.

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