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Using Waste Marbles in Self Compacting Lightweight Concrete

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***Abstract*—**In this study, the effects of waste marbles as aggregate material on workability and hardened concrete characteristics of self compacting lightweight concrete are investigated. For this purpose, self compacting light weight concrete are produced by waste marble aggregates are replaced with fine aggregate at 5%, 7.5%, and 10% ratios. Fresh concrete properties, slump flow, T_{50} time, V funnel, compressive strength and ultrasonic pulse velocity of self compacting lightweight concrete are determined. It is concluded from the test results that using waste marbles as aggregate material by replacement with fine aggregate slightly affects fresh and hardened concrete characteristics of self compacting lightweight concretes.

***Keywords*—**Hardened concrete characteristics, self compacting lightweight concrete, waste marble, workability.

I. Introduction

NOWADAYS, using self-compacting concrete (SCC) is becoming widespread in construction application due to its some characteristics such as good workability, absence of vibration, faster construction and easier placing [1]–[3]. The concept of self-compacting concrete was first proposed by Hajime Okamura in 1986 and the prototype was produced in 1988 in Japan [4]. SCC is used in precast elements, bridge and tunnel construction [5], [6].

Lightweight concrete is defined as having oven-dry density of less than 2000 kg/m^3 [7]. There are many advantages of lightweight concrete. For example lightweight concrete has low density, reduction of dead, faster building rate and handling costs [8]-[11].

The self compacting lightweight concrete is a new relatively development in the field of construction industry. This concrete combines all good properties of the lightweight concrete and SCC [12].

In marble industries are produced large amount wastes. These wastes are generally stored in open dumps. Storing the wastes causes unwanted environmental problems. For this reason, there have been studies to evaluate these wastes. One of the areas to evaluate these wastes is construction sector [13]-[16].

7.500.000 ton marble was produced in Turkey annually and 30% of these productions were waste marbles [17]. Two types of wastes are generated during the extraction of marble from the quarry and processing in marble plant. These wastes are dust and pieces of marble [18], [19].

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In previous researches, there have been many articles about using marble dust in concrete however using marble waste aggregates were not fully investigated. The main purpose of this research is to study the effects that waste marble have on self compacting lightweight concrete.

II. Material and Methods

A. Cement

CEM II/A-LL 42.5R type Portland cement complying with the requirements of TS EN 197-1 [20] standards was used. Specific gravity of cement is 3.04 gr/cm^3 and blaine surface area is 4414 cm^2/g. The chemical properties of cement are given in Table I. The physical properties of cement are shown in Table II.

TABLE I
Chemical properties of Cement

Component	(%)
SiO_2	17.21
Al_2O_3	4.61
Fe_2O_3	2.98
CaO	60.35
MgO	2.40
SO_3	2.92

TABLE II
Physical Properties of Cement

Property	Value
İnitial setting time (minute)	190
Final setting time (minute)	250
Specific gravity	3.04
Blaine (cm^2/gr)	4414
+ 45 µm	2.7
+ 90µm	0.0
Compressive strength	
2 days (MPa)	25.5
7 days (MPa)	42.4
28 days (MPa)	49.9

B. Aggregate

Pumice aggregate with a maximum size of 16 mm was used as coarse aggregate in this study. River sand in the grain size of 0-2 mm was used as fine aggregate in all mixtures. Four different aggregate sizes are used in concrete mix (0-2 mm, 2-4 mm, 4-8 mm and 8-16 mm). Physical properties of aggregates are given in Table III. The chemical composition of pumice aggregates is given in Table IV.

Grading curve for fine and coarse aggregate were determined in accordance with the principles specified in TS

706 EN 12620+A1(2009) [21]. Graving curve of aggregate is given in Fig. 1.

TABLE III
PHYSICAL PROPERTIES OF AGGREGATES

Aggregate of sieve (mm)	Specific gravity (g/cm^3)	Water absorption (%)
0-2	2,57	1,57
2-4	1,28	33,7
4-8	1,06	38,2
8-16	0,92	36,6

TABLE IV
CHEMICAL COMPOSITION OF PUMICE

Component	(%)
SiO_2	75,5
Al_2O_3	14,5
Fe_2O_3	2,55
Na_2O	0,2
MnO	0,05
K_2O	5,30
CaO	1,34
SO_4	-
Ignition Loss	3,33
Organic Substance	Negative

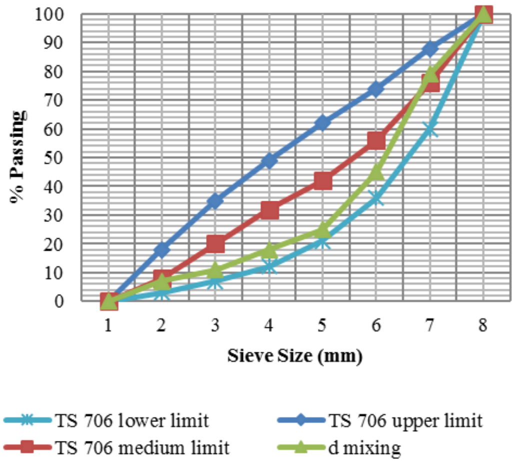

Fig. 1 Grading curve of aggregate

C. Marble Aggregate

In this study, marble waste aggregates were obtained from marble factories in Van. Marble waste aggregates were crushed in jaw breaker and sieved with 2 mm sieve and used in concrete mix. Fig. 2 shows the waste marble aggregate used in study. The chemical composition of marble aggregate is given in Table V.

D. Chemical Admixtures

Polycarboxylic ether based high range water reducing admixture (Glenium TC 1571) was used. All mixes had 1.5% of superplasticizer by weight of cement. The typical properties of Glenium TC 1571 obtained from BASF construction chemicals is shown in Table VI.

Fig. 2 Waste marble aggregate

TABLE V
CHEMICAL COMPOSITION OF MARBLE AGGREGATE

Components	(%)
SiO_2	1,79
Al_2O_3	0,45
Fe_2O_3	0,29
CaO	53,83
MgO	0,36
Ignition Loss	43,28

TABLE VI
TYPICAL PROPERTIES OF GLENIUM TC 1571

Form	Liquid
Colour	Brown
Density 20°C	1.06
Ph Value	5.0-7.0
Alkali content	Max 3%

E. Samples Preparation of and Testing

TABLE VII
MIX PROPORTION OF CONCRETES

Mix	C0	C1	C2	C3
Cement (kg)	500	500	500	500
Water (kg)	175	175	175	175
Marble (kg)	-	19,98	29,97	39,96
0-2 mm (kg)	393,49	373,72	363,98	354,14
2-4 mm	137,18	137,18	137,18	137,18
4-8 mm	220,72	220,72	220,72	220,72
8-16 mm	118,32	118,32	118,32	118,32

In this study, a total of four different mixtures designs of SCC were made. Marble aggregates added to the mix 5%, 7.5% and 10% by the weight of fine aggregates to determine waste marble aggregates effect on fresh and hardened state of concrete. Water/cement ratio was selected 0.35 and the quantitative of total binder was 500 kg/m^3. 100 mm × 100 mm × 100 mm cubic molds were used for the determination of compressive strength and ultrasonic pulse velocity were used. The samples were stayed at cube moulds for 24 hours and then moved to curing pool. Curing period was 28 days for this study. After reaching targeted curing age samples were implemented compressive strength. Ultrasonic pulse velocity was tested as well. There are four different types of mixing groups; C0, represents mix without any mineral additive, C1, C2 and C3 represent waste marbles added 5%, 7.5% and 10% by the weight of cement. Mix proportions of concrete are given in Table VII.

III. Results and Discussions

A. Fresh Concrete Test Results

In order to evaluate self compactability properties of fresh concrete, the following methods were used: Slump flow test and V funnel test. The slump flow test was conducted according to TS EN 12350-8 and V-funnel test was conducted according to TS EN 12350-9 [22], [23]. It is tested if these results were a match to EFNARC's (The European guidelines for SCC) limit values [24]. EFNARC limit values are given in Table VIII. The test results of fresh concrete are given Table IX.

TABLE VIII
EFNARC Limit Values

Test Name	Unit	Classification	Range
Slump flow	mm	SF1	550-650
		SF2	660-750
		SF3	760-850
T50 time	s	VS1	≤ 2
		VS2	>2
V funnel	s	VF1	≤ 8
		VF2	9-25

According to EFNARC, there are three different classifications for SCCs: SF1, SF2 and SF3. According to this report, SF1's flow diameter should be between 500-650 mm, SF2's 651-750 mm and SF3's 751-850.

TABLE IX
Fresh Concrete Test Results

Test name	Unit	C0	C1	C2	C3
Slump flow	mm	550	560	560	570
T_{50} time	s	9	5	4	5
V funnel	s	18	11	12	14

According to slump flow test results, slump flow values of self-compacting lightweight concretes vary between 560 and 570 mm. The lowest flow diameter was 560 mm with 5% marble aggregates and the highest flow diameter was 570 mm with 10% marble aggregate. According to this classification, C0, C1, C2 and C3 concur with SF1 class. And, they fulfill the conditions of SCCs.

According to EFNARC, there are two different T_{50} time classifications for SCCs: VS1 and VS2. According to this report, VS1's T_{50} time should be ≤ 2s and VS2's T_{50} time >2s. According to T_{50} time test results, T_{50} time values of self compacting lightweight concretes were measured between 4 and 9 s. As seen in Table VIII, all mixes are in limit of VS2. According to the test results, use of waste marble was positive affect the workability of self compacting lightweight concrete.

Fig. 3 Flow and T_{50} time testing

Fig. 4 V funnel test

B. Hardened Concrete Test Results

Ultrasonic pulse velocity was tested for self-compacting lightweight concretes at first. The ultrasonic pulse velocity tests are performed according to ASTM C 597-83 [25]. And then compressive strength tests were conducted. Hardened concrete tests were also performed on 28 day old concrete specimens. Compressive strength tests are performed according to Turkish Standard TS EN 12390-3. 100×100×100 mm cube specimens were used for compressive strength [26]. Mechanical properties of self-compacting lightweight concrete are given in Table X.

TABLE X
Mechanical Properties of Self Compacting Lightweight Concrete

Mix	Compressive Strength (MPa)	Ultrasonic Pulse Velocity (m/sn)
C0	15,03	2,94
C1	14,43	2,86
C2	16,10	2,98
C_3	13,20	2,84

In this study, river sand was replaced with four percentage

(0%, 5%, 7,5% and 10%,) of waste marble by weight. According to the test results, the compressive strength and ultrasonic pulse velocity values increased with addition of waste marble up to 7,5% replaced by weight of river sand. The replacement of 7.5% waste marble with fine river sand increases the compressive strength about 7.11%.

IV. Conclusion

In this study, the effect of waste marble on fresh and hardened characteristics of self compacting lightweight concrete using are studied. The following results are obtained from this study.

- The use of waste marble as a fine aggregate positive affects the workability of self compacting lightweight concrete.
- The replacement of 7.5% waste marble with fine aggregate increases the compressive strength about 7.11%.
- The use of waste marble slightly affects the ultrasonic pulse velocity of self compacting lightweight.

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