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The Effect of Air Entraining Agents on Compressive Strength

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***Abstract*—**Freeze-thaw cycles are one of the greatest threats to concrete durability. Lately, protection against this threat excites scientists' attention. Air-entraining admixtures have been widely used to produce freeze-thaw resistant at concretes. The use of air-entraining agents (AEAs) enhances not only freeze-thaw endurance but also the properties of fresh concrete such as segregation, bleeding and flow ability. This paper examines the effects of air-entraining on compressive strength of concrete. Air-entraining is used between 0.05% and 0.4% by weight of cement. One control and four fiber reinforced concrete mixes are prepared and three specimens are tested for each mix. It is concluded from the test results that when air entraining is increased the compressive strength of concrete reduces for all mixes with AEAs.

***Keywords*—**Concrete, air-entraining, compressive strength, mechanical properties.

I. Introduction

AIR entrainment is an essential component of concrete mixtures subject to freezing and thawing environments. The mechanical properties of concrete exposed to the wet conditions decrease strength of the concrete. This damage can be observed at the upper surface of the materials. Water expands upon freezing and repeated cycles of freezing-thawing can be result in cracks. The significance of entrained air was first discovered during the 1930s by accident when particular parts of highway were found to be damaged the effects of the freeze-thaw cycles [1]. Because of the hydration (cement and water hardening), concrete has some capillary holes in it. If concrete is subject to environmental reflexion, these holes fill with water. During freezing, water expands about 9% and as a result of this concrete gets some pressure, with that pressure concrete's tensile strength exceeds and at some specimens, it causes cracking [18]-[20]. The reason why entrained airs are so important is that they create little holes to fill by pressure. One other thing to worth mention is these holes do not connect with each other. Therefore, filled pressure cannot proceed further. One of the disadvantages of using air-entraining admixtures is that they can affect compressive strength negatively. To be able to avoid these negative effects, it is important that these agents should add the mix according to manufacturer's description. The air content test should be conducted in ASTM. The size of aggregate and volume of exposure affects the advised air content. AEAs are usually added to the concrete mix in a range from 16-196 ml/kg. AEAs can be based on natural resins or synthetic materials. From its first usage, these agents have been produced by manufacturers various different types. Air entraining agents serve for the same purpose. This purpose is to get concrete more stable and durable for the outdoor usage. Entrained air is being used in mostly outdoor applications such as highway technics, pavements and road concretes. At this point, it is vital to mention that entrained air is not the same as entrapped air. Mixing of concrete and placing it is not the reason of entrapped air. It has negative effect on semblance, durability and strength. With using proper vibration techniques, entrapped air can be removed [2]-[10].

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II. Experimental Study

All the concrete mixes are designed according to Turkish standard TS EN 206–1 (2002) [11]-[17]. The concrete mixtures described in this paper were prepared using CEM1 42.5R Portland cement. Specific surface and specific gravity of cement are 3.08 and 3656 cm^2/g respectively. The aggregates used in this study were locally supplied crushed limestone and sand. These aggregates were separated into three different size fractions as 0-5 mm (A1), 5-12 mm (A2), and 12-19 mm (A3). Specific gravities of A1, A2, and A3 aggregates were 2.59, 2.69, 2.62, respectively. The maximum nominal aggregate size was 19 mm. In addition, polycarboxylate based hiperplasticizer is used at 0.5% by weight of cement. W/c ratio of 0.4 was chosen to be able to get ideal slump. One type of air entrainer was used with two different volumes. AEAs were added concrete mix at 0.05%, 0.1%, 0.15%, 0.2%, 0.3% and 0.4% by weight of cement. Chemical and physical properties of cement are given in Tables I and II. The concrete mix proportions are given in Table III and cement oxide analysis is given in Table IV.

III. Test Results

Concrete samples with six different volumes of AEAs were produced and after 28 days of curing, their compressive strength was investigated. Mechanical properties of concrete mixtures acquired from test results are given in Table III. Cube specimens are shown in Fig. 1, mixing process is shown in Fig. 2, specimen after compressive strength is given in Fig. 3, curing equipment is shown in Fig. 4, and compressive strength test equipment is shown at Fig. 5.

TABLE I
CHEMICAL PROPERTIES OF CEMENT

Chemical Properties	%
SO_2	2.9
MgO	2.07
CaO	0.56
Al_2O_3	4.56
K_2O	0.62
SiO_2	17.73
Na_2O	0.29
Fe_2O_3	3.07
Cl^-	0.02

Fig. 1 Cube specimens used for experiment

Fig. 2 Mixing process

TABLE II
PHYSICAL AND MECHANICAL PROPERTIES OF CEMENT

Physical and mechanical properties	MPa
Compressive strength (2 days)	27.7
Compressive strength (7 days)	45.8
Compressive strength (28 days)	57.2
Initial setting time (min.)	200
Final setting time (min.)	260
Specific gravity (g/cm^2)	3.10
Specific surface (cm^2/gr)	3547
Total volume exp. (mm)	4

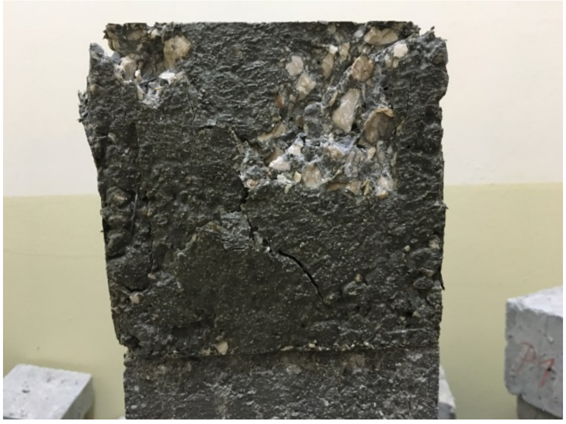

Fig. 3 Specimen after compressive strength test

TABLE III
M35 CONCRETE MIX PROPORTIONS

Component	Quantity (kg/m^3)
Cement (C)	400
Water (W)	160
Coarse aggregate (5-12 mm)	350
Coarse aggregate (12-20 mm)	900
Fine aggregate (0-5 mm)	700
Superplasticizer	2
W/C	0.4
Entrained air	0.05– 0.4

TABLE IV
CEMENT OXIDE ANALYSIS

SiO_2	Al_2O_3	Fe_2O_2	Cao	MgO	SO_2	Na_2O	K_2O	C_2S	C_3S
20.1%	4.3%	2.7%	63.5%	2.7%	2.0%	0.2%	0.2%	56.0%	15.4%

Fig. 4 Curing equipment

TABLE V
MECHANICAL PROPERTIES OF CONCRETE MIXTURES

Mixture code	Entraining air (%)	Compressive strength of concrete (MPa)
Plain	-	36.22
A1	0.05	36.10
A2	0.01	35.86
A3	0.15	35.41
A4	0.20	35.24
A5	0.30	34.57
A6	0.40	33.47

IV. CONCLUSIONS

In this study, it is observed that if the dosage of AEAs increases compressive strength of concrete decreases apparently. The main reason of this is that air bubbles occur in the concrete mix. AEAs cost these bubbles. The highest difference in compressive strength between the plain and mixes is 7.6% for mix A6.

Fig. 5 Compressive strength test equipment

Fig. 6 Cube specimens after abstracting

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