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Physical properties of cement mortars containing steel fiber

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ABSTRACT

In this paper, some physical properties such as dry unit weight, porosity, water absorption and capillarity were investigated for cement mortars containing steel fibers. Steel fibers were used at 0% (control), 0.5%, 1.0% and 1.5% by volume. While sand/binder ratio was 3.0, water/cement ratio was 0.50 in the mixtures. After the production of mortar specimens with size of 40 x 40 x 160 mm, dry unit weight, porosity, water absorption and capillarity values were determined at 7, 14 and 28 days. The results obtained from the tests showed that steel fiber produced a decrease in porosity, water absorption and capillarity values of cement mortars.

Introduction

Concrete is a poor material in terms of fatigue strength, wear resistance, tensile strength, load bearing strength after cracking and energy absorption capacity. Various studies are carried out to improve these properties of concrete. One of these researches is steel fibers of different sizes added to concrete mixtures. Steel fiber is a material that changes the structure of concrete and gives it the ability to plastically deformation and absorption of energy [1].

Due to the fact that the steel fibers, which are included in the mixture as glued bundles, do not separate into grains during the mixing, the voids form in the concrete and this leads to the increasing of porosity in steel fiber concretes, which negatively affects the permeability. The increase in permeability may cause corrosion of the steel fiber or increase the deterioration of the concrete as a result of chemical reactions. This durability problem in steel fiber concrete can be avoided by a good mixture, good placement, good compaction and good maintenance in fiber concretes. For instance, Yıldırım [2] reported that the weight of steel fiber concretes increased with an increase in the fiber content and the water absorption rate decreased with the increasing steel content. In this study, the effect of steel fiber addition on the physical properties of cement mortars was investigated.

Material and Method

In the mortars, CEM I 42.5 R ordinary Portland cement (OPC) according to TS EN 197-1 [3] was used. Chemical and physical properties of OPC are given in Table 1. Water / binder ratio was 0.50 and sand / binder ratio was 3.0 in the mortar mixtures where standard sand was used as fine aggregate in compliance with TS EN 196-1 [4]. Mixture preparation was conducted according to the TS EN 196-1 [4] procedure. In the production of the mortars, RC 65/60 BN type, which has a length of 60 mm, a diameter of 0.90 mm and a fineness (length / diameter) of 65, was used with two ends of hooks, uncoated and low carbon steel fiber. The steel fibers were used in the mixtures at a rate of 0% (control), 0.5%, 1.0% and 1.5% by volume. The notations of the mixtures used in the study are shown in Table 2.

Table 1. Chemical and physical properties of OPC

Composition (%)	OPC
SiO_2	14.3
Al_2O_3	3.33
Fe_2O_3	2.85
CaO	67.3
MgO	1.60
Na_2O	0.41
K_2O	1.09
SO_3	4.51
Cl^-	0.35
Blaine value (cm^2/g)	3250
Specific gravity	3.15

Table 2. Mixture notations

Mixture	OPC	Steel Fiber
0 SF (Reference)	100%	0%
0.5 SF	100%	0.5%
1.0 SF	100%	1.0%
1.5 SF	100%	1.5%

In order to determine the physical properties of the mortars, 40 x 40 x 160 mm prism samples were produced from each mixture. The prism samples taken out of their molds after 24h were cured for 7, 14 and 28 days in water with a temperature of 21 ± 1 °C. Then, these specimens were subjected to dry unit weight, capillarity, water absorption and porosity tests. TS 4045 [5] standard was used in capillarity tests while TS 3624 [6] standard was used in the determination of water absorption and porosity.

Results and discussion

The dry unit weights of the mortar samples measured in time are shown in Table 3.

Table 3. Dry unit weights (kg/m^3)

	7	14	28
0 SF	2090	2070	2050
0.5 SF	1960	2090	2090
1.0 SF	2160	2120	2110
1.5 SF	2190	2170	2120

As seen in Table 3, dry unit weight values of reference mortar were 2090 kg/m^3, 2070 kg/m^3 and 2050 kg/m^3 at 7, 14 and 28 days, respectively. For mortars with steel fiber, dry unit weight values changed between 1960 kg/m^3 and 2190 kg/m^3 at 7 days. These values were between 2090 kg/m^3 and 2170 kg/m^3 at 14 days and 2090 kg/m^3 and 2120 kg/m^3 at 28 days. The dry unit weight values of all steel fiber mortars were higher than reference mortar for all curing ages. The increase in steel fiber dosage increased the dry unit weights of the mortars due to its high specific gravity value.

The porosity values of the mortar samples measured in time are shown in Table 4.

Table 4. Porosity (%)

	7	14	28
0 SF	17.41	16.74	15.36
0.5 SF	15.82	15.87	15.22
1.0 SF	15.70	15.63	15.19
1.5 SF	15.17	15.14	15.11

As shown in Table 4, porosity of reference mortar was determined as 17.41%, 16.74% and 15.36% for 7, 14 and 28 days, respectively. For mortars with steel fiber, porosity values ranged from 15.17% to 15.82% at 7 days. These porosity values were between 15.14% and 15.87% at 14 days and 15.11% and 15.22% at 28 days. The

porosity values of all steel fiber mortars were lower than reference mortar for all curing ages. Additionally, an increase in curing time decreased porosity for all mortars depending on C-S-H gel formation in the structure.

The water absorption values of the mortar samples measured in time are shown in Table 5.

Table 5. Water absorption (%)

	7	14	28
0 SF	8.93	8.31	7.26
0.5 SF	7.79	7.72	7.34
1.0 SF	7.35	7.26	7.16
1.5 SF	7.03	7.16	7.05

As observed in Table 5, water absorption rates of reference mortar were measured as 8.93%, 8.31% and 7.26% for 7, 14 and 28 days, respectively. For mortars with steel fiber, water absorption rates changed between 7.03% and 7.79% at 7 days. These values were between 7.16% and 7.72% at 14 days and 7.05% and 7.34% at 28 days. The water absorption values of reference mortar were higher than those of all steel fiber mortars for all curing ages. The amount of water absorbed decreased with an increase in curing time as a result of C-S-H gel formation in cement matrix for all mortars, similarly to porosity findings.

The capillarity coefficients determined at 7, 14 and 28 days for the mortar samples are given in Table 6.

Table 6. Capillarity (cm/sn^{½})

	7	14	28
0 SF	0.0039	0.0031	0.0022
0.5 SF	0.0037	0.0020	0.0013
1.0 SF	0.0032	0.0012	0.0011
1.5 SF	0.0037	0.0030	0.0021

As seen in Table 6, capillarity coefficients of OPC mortar were 39.10^{-4} cm/sn^{½}, 31.10^{-4} cm/sn^{½} and 22.10^{-4} cm/sn^{½} at 7, 14 and 28 days, respectively. For mortars containing steel fiber, capillarity coefficients ranged from 32.10^{-4} cm/sn^{½} to 37.10^{-4} cm/sn^{½} at 7 days. These values were between 12.10^{-4} cm/sn^{½} and 30.10^{-4} cm/sn^{½} at 14 days and 11.10^{-4} cm/sn^{½} and 21.10^{-4} cm/sn^{½} at 28 days. Capillarity coefficients of all steel fiber mortars were lower than those of reference mortar for all curing ages.

Conclusion

The findings obtained from the tests of mortar samples at 7, 14 and 28 days showed that the dry unit weight values of all steel fiber mortars were higher than reference mortar for all curing ages. Also, the incorporation of steel fiber into the mix produced a decrease in porosity, water absorption and capillarity values of cement mortars compared to reference mortar without steel fiber.

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