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Effect of the use of mineral filler on the properties of concrete

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Abstract

Engineers of the concrete technology are increasingly concerned with the material passing through a sieve of the size under 0.149 mm. Materials called very fine aggregate or mineral filler may affect the performance of concrete in an either positive or a negative way. Discussions on aggregate containing very fine material are vitally important. Washing the aggregate residue has been the sole way to solve this matter to date. This is mainly based on the debatable opinion that materials of this kind are regarded as clay material. The goal of the study was to determine how the content of mineral filler might affect properties of concrete. Two types of aggregates with different amounts of cement and mineral filler were used. Basically, mineral filler replaced sand. The effect of applying different amounts of mineral filler on concrete was then determined. The addition of 7–10% of mineral filler to fine aggregate (0–2 mm) was found to considerably improve the properties of concrete.

Keywords: Mineral filler; Clay; Compressive strength; Flexural strength; Permeability

1. Introduction

Some experiments were conducted to determine the suitability of the concrete components before the production of the concrete. If the values obtained in the experiments showed the materials to pass through the #200 sieve, the aggregate was used after being washed. The basic idea of the application of aggregate after being washed is that it is possible for the material of this size (< 0.005 mm) to be clay. When the concrete is produced with crushed calcareous aggregate with a size of 0.05–0.0005 mm (between #100 and #200 sieves), it may cause openings as fine as the mineral filler. In the applications done until recent years, the fine material in the concrete aggregate was considered clay, irrespective of its petrographic origin, which is a false impression. The existence of the clay in the aggregate has such an adverse affect as weakening the bond of the cement paste and aggregate in the concrete; in addition, it does delay the cement hydration as well as spoiling the volume stability of the concrete [1]. On the other hand, the materials like silt class and the mineral filler are quite dissimilar to clay. Silt and mineral filler materials were not used until recently. Because mineral fillers have a high specific surface and high water-holding capacities that tend to cause a high shrinkage, this may lead to an increase in the amount of the concrete mixing water, and thereby increase water–cement ratio [1–5]. If the fine material within the aggregate is above the standard limits, the aggregate should be used only after being washed [6–8]. These applications technically weaken the aggregate and cement bond, let alone prove too costly [9].

A large amount of material in the size of mineral filler is produced during the course of crushing the weak limestone, in particular, which may well be used as aggregate. If they are not of a clay type, the application of these materials is beneficial to improving concrete composition [9,10]. We aimed to find out the extent of improvement in concrete properties for different amounts of mineral filler. On the other hand, the low cohesion of the weak concrete compositions produced by using the crushed calcareous aggregate lead to some problems. It is not always possible to place and compress the concrete on grounds of the difficulty confronted in the workability [3,9].

Since these kinds of concretes do not have a high composition or enough fine materials to hold the mixing water in the body after placement, they throw a certain

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Table 1
Mixture proportions of concrete series *

Crushing calcareous					River calcareous				
Water/cement ratio	Mineral filler (%)	Cement content (kg/m^3)	Aggregate content (kg/m^3)		Water/cement ratio	Mineral filler (%)	Cement content (kg/m^3)	Aggregate content (kg/m^3)	
			Sand	Coarse				Sand	Coarse
0.92	0	200	681	1268	0.84	0	200	774	811
0.94	3	200	579	1176	0.85	3	200	496	790
0.95	7	200	507	1175	0.86	7	200	413	740
0.98	10	200	434	1132	0.87	10	200	363	727
0.98	15	200	330	1071	0.88	15	200	278	670
0.71	0	275	650	1208	0.60	0	275	600	1117
0.71	3	275	582	1182	0.61	3	275	531	1085
0.71	7	275	490	1142	0.62	7	275	442	1032
0.72	10	275	421	1097	0.63	10	275	380	990
0.73	15	275	324	1065	0.65	15	275	285	912
0.60	0	350	668	1245	0.50	0	350	574	1073
0.61	3	350	580	1177	0.54	3	350	500	1014
0.62	7	350	480	1111	0.56	7	350	413	962
0.61	10	350	403	1064	0.56	10	350	338	909
0.62	15	350	302	978	0.57	15	350	267	878

* Slump values are constant.

amount of the mixing water out rather than holding it in the body. As a result of this excessive bleeding, plastic shrinkage cracks are nearly always observed over the surface of the concrete. No wonder a concrete of low strength and durability is obtained due to high permeability and porosity [11–13]. Although using additives can be one solution to such problems, this adds to the cost of production of concrete. Mineral filler-like materials are used for filling in such cases, but this does not help build bonds.

2. Experiment

2.1. Goal, content and program

The goal of the study is to examine some concrete properties by making a comparison between reference concretes devoid of mineral filler and those containing different amounts of mineral filler. Six series (30 units) of concrete, the maximum grain size of which was 32 mm, were prepared. In the first three series, crushed calcareous aggregate was used, the last three series being river aggregate. For each series prepared, slump value were determined to be 10–11 cm, which remained constant throughout the test. Each concrete series consisted of five groups. The first group was the reference group, the remaining four groups being produced with mineral filler, which were replaced by sand (0–2 mm) of 3%, 7%, 10% and 15%. Cement dosages were determined to be 200, 275 and 350 kg/m^3, respectively, for crushed and river calcareous aggregates. No additives were used in the mixture. Twelve specimens of $12 \times 12 \times 12$ cm for the compressive strength, 12 specimens of $7.5 \times 7.5 \times 38$ cm for the flexural strength and 12 specimens of ϕ 20×12 cm for the permeability experiments were taken from every mixture. The specimens prepared were stored under standard cure conditions until the launch of the experiment. Compressive and flexural strength was determined for 7 and 28 days. Permeability experiments were carried out 40 days after the casting time.

Table 2
Physical characteristics of aggregates

Sieve size (mm)	Unit weight[a] (kg/m^3)	Specific gravity[b] (kg/m^3) (absorption [%])	Material finer than #200 sieve[c] (%)	Clay lumps[d] (%)	Organic impurities[e]	Los Angeles abrasion loss[f] (%)
Crushed limestone aggregate						
32–16	1540	2650 (0.80)	0.2	0.24	Light yellow	100 period (5.8)
16–8	1540	2630 (1.10)	0.2	0.13		
8–4	1545	2640 (0.80)	0.3	0.37		500 period (25.5)
4–2	1580	2680 (1.00)	2.2	1.80		
2–0	1590	2700 (0.90)	2.9	2.10		
Kocaçay River aggregate						
Sand	1630	2630 (2.50)	3.6	0.8	Yellow	100 period (5.6)
Coarse	1790	2580 (2.60)	0.5	3.2		500 period (26.5)

[a] ASTM C 29 [19].
[b] ASTM C 127, C 128 [18].
[c] ASTM C 117 [20].
[d] ASTM C 142 [21].
[e] ASTM C 40 [22].
[f] ASTM C 131 [23].

Table 3
Properties of mineral filler

Physical properties		Chemical properties		Grading of mineral filler	
				Sieve size	Amount retained (wt. %)
Specific gravity (kg/m^3)	2820	Insoluble residue %	0.331	#8	0.0
Water absorption (%)	0.4	Ignition loss %	43.1	#16	0.0
Fineness modulus	2.0	Chemical analysis %		#30	0.2
pH	7.26	CaO	55.6	#50	0.5
		SiO_2	0.33		
		MgO	0.27	#100	1.5
		Al_2O_3	0.11		
		Compound	Limestone	Pan	97.8

2.2. Materials and methods

Mixture proportions of the concrete series for two different aggregates used in study are presented in Table 1. The properties of the two different types of aggregate used in the experimental studies are presented in Table 2.

Crushed calcareous aggregate was obtained by crushing and sieving the limestone transferred from Urfa, Turkey. River aggregates were obtained from Kocaçay, Ankara, Turkey. These two types of aggregates were classified into five different grain groups as (32–16 mm) 32%, (16–8 mm) 22%, (8–4 mm) 11%, (4–2 mm) 13% and (2–0 mm) 22%. They were used in such a way as to be able to obtain a standard grading curve for maximum grain size of 32 mm at TS 706 (Turkish Code) [8].

Materials used as the mineral filler in the slurry trench study conducted in the Tahtali Dam were transferred from Izmir, Turkey. The properties of the mineral fillers are shown in Table 3. Blended hydraulic cement produced by Ankara Cement Factory was used in the study [14]. Table 4 shows its physical and chemical properties.

Table 4
Properties of cement

Physical properties		Mechanical properties	
Specific surface (m^2/kg)	3124	Compressive strength (MPa)	
Residue on 200 μm (%)	1.0	7 days	28 days
Residue on 90 μm (%)	1.2	23	34
Specific gravity (kg/m^3)	3120	Flexural strength (MPa)	
Initial setting time	2 h 20 min	7 days	28 days
Final setting time	3 h 15 min	4.4	5.7

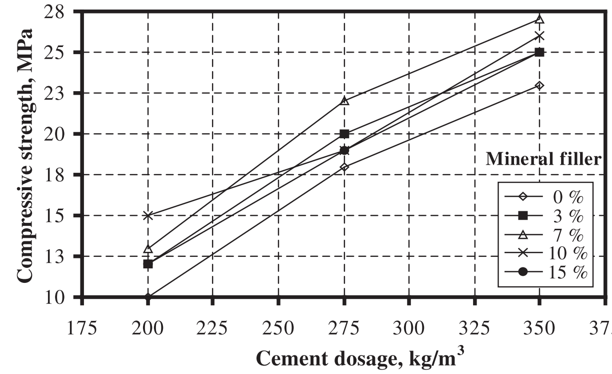

Fig. 1. Compressive strengths (28 days) versus mineral filler contents for crushing calcareous aggregate.

ASTM C 39 for the compressive strength [15], ASTM C 293 for the flexural strength [16], TS 3455 for the permeability [17], ASTM C 127 for the specific gravity of aggregate absorption [18] and porosity were used as a basis to determine the hardened concrete properties.

2.3. Experimental results

The results obtained from the hardened concrete experiments done on the specimens obtained from different mixtures are shown in Figs. 1, 2, 3, 4, 5 and 6. The 12 cylindrical specimens (ϕ 20 × 12 cm) were used for the permeability test for each series. A constant water pressure (4 atm) was considered to be sufficient for 60-day-cured specimens. The permeability tests were carried on for 168 h. The upper surface of the concrete specimen was subjected to water pressure, and then the amount of water percolating from the lower surface was measured. It is known that after a minimum duration of 168 h, the law of permanent laminar flow will govern water movement through concrete voids and the percolated amounts may be expressed by Darcy's formula. In the course of permeability test results evaluation, the evaluation was thought to prove difficult, the reason being that the results obtained had far too small values, Therefore, they were

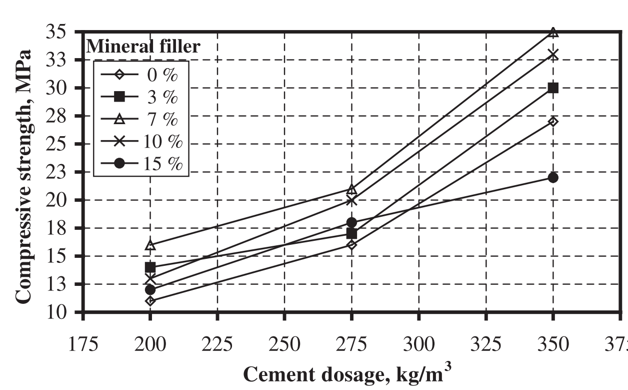

Fig. 2. Compressive strengths (28 days) versus mineral filler contents for river aggregate.

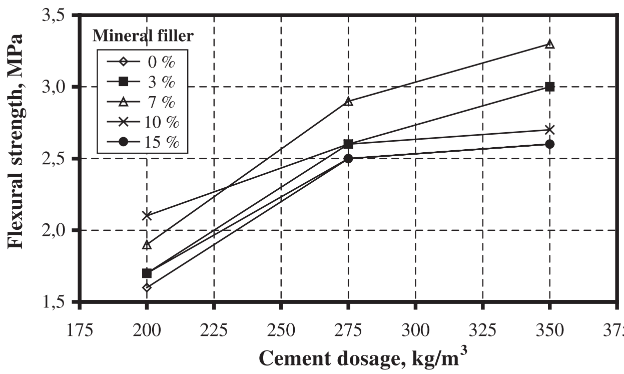

Fig. 3. Flexural strength versus mineral filler contents for crushing calcareous aggregate.

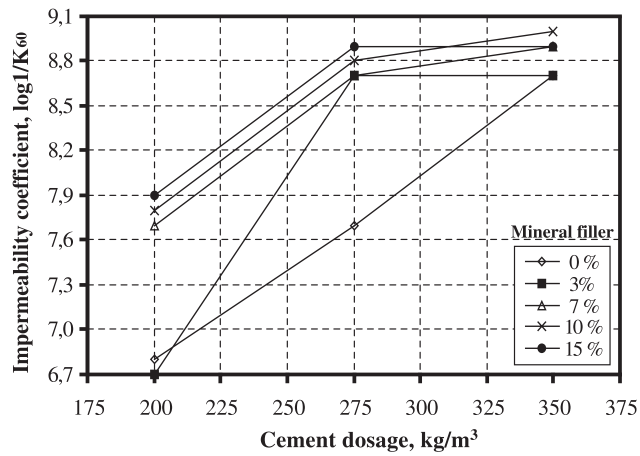

Fig. 5. Effect of mineral filler on impermeability for crushing calcareous aggregate.

evaluated as the values expressing impermeability by taking the inverse logarithmic ($1/K_{60}$) of the values obtained (K_{60}) and making them linear.

3. Examinations and interpretation

The experimental results obtained were evaluated for both the concrete made of crushed calcareous aggregate and the concrete made of river aggregate separately. Results are shown in the figures. As it can be seen from Figs. 3 and 4, there is a linear proportion between the flexural strength and the cement dosages that reach their maximum values in 7–10% of the mineral filler.

As it can be seen from Figs. 5 and 6, with an increase in the cement dosage, the permeability of the concrete decreases at a maximum degree of 7–10% of the mineral filler. In the mixtures prepared with the increase in the mineral filler content, this decrease continues linearly in defiance of an increase in the water–cement ratio. All these favorable results change adversely for 15% mineral filler.

4. Results

A great amount of material the size of mineral filler is produced, particularly during the crushing of the weak stone. This could be used as aggregate. If they are not of a clay type, the application of these materials is beneficial to improving the concrete so as to decrease air voids, permeability while increasing the workability and strength. Using crushed aggregate leads to some problems in the production of weak compositions of low cohesion. Because such concretes possess neither a high enough composition nor enough fine materials to hold the mixing water in the body after the placement, they throw a certain amount of the mixing water out rather than holding it in the body. As a result of this excessive bleeding, plastic shrinkage cracks are nearly always observed over the surface of the concrete. Finally, a concrete of low strength and durability is obtained due to high permeability and porosity. Although using additives can solve these problems, this process adds to the cost of production of the concrete. For such cases, mineral filler-like materials are used for filling, but this does not help build bonds. As a result of these studies, some characteristics of fresh and hardened concrete were observed

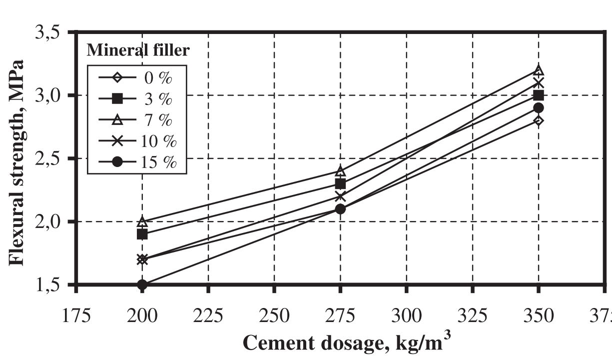

Fig. 4. Flexural strength (28 days) versus mineral filler contents for river aggregate.

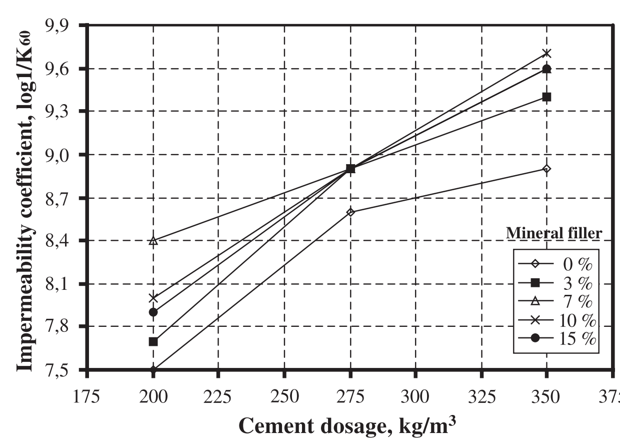

Fig. 6. Effect of mineral filler on impermeability for river aggregate.

to change with mineral filler of various amounts in the concrete. In conclusion, we obtained the following results;

- It was determined that there was an improvement in the compressive and flexural strength of the concrete with the addition of mineral filler to the concrete. A decrease in the permeability, absorption and porosity of the concrete were observed.
- Improvements in the properties of concrete were true for the maximum values of 7–10% of the mineral filler. If the percentage of the filler exceeds 10%, concrete properties either remain constant or change in a negative way.
- In the studies conducted through the application of crushed calcareous aggregate, using mineral filler in the low cement dosage (200 kg/m^3) is a necessary step for the improvement of the technical properties of the concrete due to the difficulties likely to be encountered in the processing of the crushed aggregate.

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