Effect of the Type of Mineral Additive on the Compressive Strength Of Concrete Exposed to High Temperature

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Abstract

In this study, the effect of high temperature in concrete by mineral additive types was examined experimentally. For this purpose, two different minerals as Barite powder and Diatomite Powder were used by rotation in the rates of 0%, 10%, 20%, 30% and 40% with CEM I 42,5 R cement. Samples of 10*10*10 cm in size were produced from the mixes prepared in accordance with TS EN 802. After keeping in lime saturated curing pools for 28 days, they were exposed to high temperatures such as 200, 400, 600 and 800°C. Then the changes that occur in compressive strength were examined by dosage and type of mineral additives. The results obtained were compared.

Key words: High Temperature, Barite Powder, Diatomite Powder, Concrete

1. Introduction

One of the most significant physical effects causing durability problems in buildings is high temperature. Although it is believed that concrete is a fire resistant material, studies conducted showed that concrete is damaged heavily in high temperatures [1]. Considering the concrete as a whole, it is known that the thermal expansion of its components such as hardened cement paste and aggregate are generally different from one another. Thus, the temperature changes in concrete lead to changes in the volume of its content, the formation of cracks and the decrease in the strength of concrete. This phenomenon is known as the "thermal incompatibility of concrete components" [2]. Hardened cement paste expands at rate of 0.2% when it is heated up to around 150ºC [3]. When the temperature rises to 300ºC from 150ºC, the hardened cement paste starts to shrink. And when the temperature rises to 800ºC, the shrinkage in the cement paste may rise up to 2.2%. Generally, while the aggregates start to expand and disperse at temperatures higher than 150ºC, the cement paste shrinks as a consequence of the dehydration of hydration products [4].

Strength of the concrete against high temperatures is affected by the materials entering into the concrete mix. In a concrete mix; cement, aggregate and water are used. If necessary, are also used chemical and mineral additives. Additives are used in order to improve the properties of fresh concrete such as processability, consistency, need for water and setting time; decrease its bleeding; increase the performance of the concrete and/or ensure that the concrete is more economical [5]. Mineral additives that are usually used in concrete production are pozzolanic materials such as fly ash, silica fume, trass and granulated blast furnace slag. Mineral additives to be used in concrete must be definitely in a very fine grained state. Fly ash and silica fume are obtained as very fine grained are pozzolanic materials. In order to use trass and similar natural pozzolans or granulated blast furnace slag as concrete additives, these materials are grained and turned into a fine-grained state. Apart from pozzolanic materials, fine-grained materials such as stone flour that are non-pozzolanic can also be used as concrete additives [6].

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In this study, concrete samples were prepared by the changing substitution of mineral additives such as Barite powder and Diatomite powder with cement, which is the binder of the concrete. Compressive strength under high temperature effect test was applied to these samples that are prepared under the same conditions. The test results were compared with each other and comparatively.

2. Material and Method

In this study, the amount of cement entering into the concrete mix that is poured in accordance with TS EN 802 [7] was reduced by weight at a percentage of 10%, 20%, 30% and 40%, and natural minerals such as Barite powder and Diatomite powder were added instead. In all mixtures, two different dosages in such a way that the total amount of binder is 300-400kg/m^3 were taken into consideration. A new generation super plasticizer (Sika ViscoCrete Hi-Tech 28 chemical additive at a rate of 0,5% of the amount of barite mineral added concrete, and 0.8% in those with diatomite addition) was used in order to keep the water/cement ratio stable as the water need of the mix will change depending on the type of mineral used while making mix designs. The amount of sedimentation was set to be 5 to 10 cm in slump test conducted by taking the Water/Binder ratio as 0,50.

The mortar prepared was gradually placed into greased moulds that are 10*10*10 in size by compression. Samples with the strength of 28 days were first kept in a drying-oven at 105°C for 24 hours until they reach a stable weight. The samples which were then exposed to the temperatures of 200, 400, 600 and 800 ^{0}C, respectively at room temperature were taken from the drying-oven, let cool and subjected to a pressure test [8].

In this study; the control sample is signified by C, barite powder mineral by BT, and diatomite powder mineral as DT, in such a way that their ratio in the mixture will be next to the letter. The chemical analysis results of the grained barite powder used in tests are shown in Table 1, and the chemical analysis results of Diatomite powder are shown in Table 2. The mixture ratios used are shown in Table 3, Table 4, Table 5 and Table 6.

Table 1. Chemical properties of barite [8]

Component (%)	$BaSO_4$	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	SrO	MnO	Loss of Ignition	Specific Weight
Barite	94,24	2,23	0,30	0,13	0,15	0,04	2,61	-	0,14	4,35

Table 2. Chemical properties of diatomite [8]

Component (%)	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	SO_3	K_2O	Loss of Ignition	Specific Weight (g/cm^3)
Diatomite	67,20	10,09	2,74	0,63	1,36	0,36	-	0,67	8,00	0,15-0,40

Table 3. Mixture ratios for BT added concrete at 300 dosage of 1000 dm^3 [8]

Explain		C		BT 10		BT 20		BT 30		BT 40	
		Volume (dm^3)	Weight (kg)	Volume (dm^3)	Weight (kg)	Volume (dm^3)	Weight (kg)	Volume (dm^3)	Weight (kg)	Volume (dm^3)	Weight (kg)
Cement		97	300	87	270	77	240	68	210	58	180
Water		150	150	150	150	150	150	150	150	150	150
Air		10	--	10	--	10	--	10	--	10	--
Normal Aggregate	0-4 mm 60%	445	1202	447	1206	448	1211	450	1215	452	1220
	4-8 mm 40%	297	801	298	804	299	807	300	810	301	813
Amount of BT		--	--	7	30	14	60	21	90	28	120
Chemical Additive		2	2	2	2	2	2	2	2	2	2
Total		1000	2455	1000	2462	1000	2470	1000	2478	1000	2485

Table 4. Mixture ratios for BT added concrete at 400 dosage of 1000 dm^3 [8]

Explain		C		BT 10		BT 20		BT 30		BT 40	
		Volume (dm^3)	Weight (kg)	Volume (dm^3)	Weight (kg)	Volume (dm^3)	Weight (kg)	Volume (dm^3)	Weight (kg)	Volume (dm^3)	Weight (kg)
Cement		129	400	116	360	103	320	90	280	77	240
Water		200	200	200	200	200	200	200	200	200	200
Air		10	--	10	--	10	--	10	--	10	--
Normal Aggregate	0-4 mm 60%	395	1068	398	1074	400	1080	402	1086	404	1092
	4-8 mm 40%	264	712	265	716	267	720	268	724	270	728
Amount of BT		--	--	9	40	18	80	28	120	37	160
Chemical Additive		2	2	2	2	2	2	2	2	2	2
Total		1000	2382	1000	2392	1000	2402	1000	2412	1000	2422

Table 5. Mixture ratios for DT added concrete at 300 dosage of 1000 dm^3 [8]

Explain		C		DT 10		DT 20		DT 30		DT 40	
		Volume (dm^3)	Weight (kg)	Volume (dm^3)	Weight (kg)	Volume (dm^3)	Weight (kg)	Volume (dm^3)	Weight (kg)	Volume (dm^3)	Weight (kg)
Cement		97	300	87	270	77	240	68	210	58	180
Water		150	150	150	150	150	150	150	150	150	150
Air		10	--	10	--	10	--	10	--	10	--
Normal Aggregate	0-4 mm 60%	445	1200	410	1108	376	1016	342	924	308	831
	4-8 mm 40%	296	800	274	739	251	677	228	616	205	554
Amount of DT		--	--	67	30	133	60	200	90	267	120
Chemical Additive		2	2	2	2	2	2	2	2	2	2
Total		1000	2453	1000	2299	1000	2145	1000	1991	1000	1837

Table 6. Mixture ratios for DT added concrete at 400 dosage of 1000 dm^3 [8]

Explain		C		DT 10		DT 20		DT 30		DT 40	
		Volume (dm^3)	Weight (kg)	Volume (dm^3)	Weight (kg)	Volume (dm^3)	Weight (kg)	Volume (dm^3)	Weight (kg)	Volume (dm^3)	Weight (kg)
Cement		129	400	116	360	103	320	90	280	77	240
Water		200	200	200	200	200	200	200	200	200	200
Air		10	--	10	--	10	--	10	--	10	--
Normal Aggregate	0-4 mm 60%	395	1066	349	943	304	820	258	697	212	574
	4-8 mm 40%	263	711	233	629	202	547	172	465	142	382
Amount of DT		--	--	89	40	178	80	267	120	356	160
Chemical Additive		3	3	3	3	3	3	3	3	3	3
Total		1000	2380	1000	2175	1000	1969	1000	1764	1000	1559

3. Experimental Study

After the samples were exposed to the temperatures of 200, 400, 600, 800 ^{0}C with Protherm HLF 150 High temperature machine, they were allowed to come to normal room temperature and then crushed using Ela International Auto Test 3000 pressure device. As a result of the tests carried out, the maximum compressive strengths that can be carried by the samples were determined in N/mm^2 and the loading speed was set as 3kN/s in a way that it will have no blast effect. Three samples were prepared for each set, and the average compressive strength values were calculated. The results obtained are shown in Table 7 collectively.

When the results in Table 7 are investigated, no significant change occurred in the compressive strengths of the control samples with a dosage of both 300 and 400 up to 400°C, however significant changes occurred after 400°C. And even some increase was observed in the samples with the dosage of 400 up to 400°C. Naturally, the compressive strengths of the samples with a dosage of 400 under high temperature effect found to be higher than those with a dosage of 300.

In the samples that are added barite powder, an increase of around 10% increase occurred in BT 10% set with a dosage of 400 at a strength of up to 400°C, and the strength decreased at higher temperatures. When compared with the control sample, the compressive strength at 400°C increased around 25%. In those with a dosage of 300, a horizontal course was followed up to 400°C and then a decrease occurred. Lower strengths were obtained when compared to the control sample. In BT 20% set, lower strengths were obtained in both dosages when compared to the control sample. When the results at 800°C are investigated, these decreases are higher when compared to the previous set. In BT 30% set, the compressive strengths of the samples with a dosage of 400 started to decrease after 200°C. In those with the dosage of 300, a decrease happened after 400°C. The strengths in this set were found lower both than the control samples and the BT 10% set. A behaviour similar to BT 30% was observed in BT 40% set. While the compressive strengths of the samples with a dosage of 400 in all other sets were higher than those with a dosage of 300, the pressure of the sample with a dosage of 300 at 800°C was found higher than that with a dosage of 400 here.

Table 7. Compressive strengths of mineral added concrete exposed to high temperature [8]

Mineral Additive	Mixture Ratio	Dosage	Compressive Strength (N/mm^2)				
			Under Normal Conditions	200°C	400°C	600°C	800°C
Control Sample	C	300	29.1	28.9	28.1	20.2	9.2
		400	38.8	39.4	39.6	26.6	13.1
Barite Powder	BT 10%	300	23.0	23.1	24.6	18.8	9.8
		400	46.0	47.4	49.8	41.0	22.9
	BT 20%	300	18.7	18.8	19.8	14.5	7.9
		400	28.2	29.0	29.1	19.9	12.3
	BT 30%	300	16.2	16.5	16.7	12.1	7.0
		400	19.9	20.9	19.9	14.2	7.8
	BT 40%	300	10.3	10.7	10.7	8.3	4.8
		400	14.1	15.5	13.2	8.3	3.7
Diatomite Powder	DT 10%	300	18.2	20.9	23.0	15.5	10.3
		400	33.3	35.3	37.0	32.5	22.6
	DT 20%	300	17.7	20.1	21.3	17.0	8.3
		400	22.8	23.1	24.4	17.5	8.3
	DT 30%	300	14.0	15.2	16.8	13.1	6.6
		400	18.9	18.4	18.0	10.8	3.9
	DT 40%	300	12.5	12.3	12.2	10.4	6.9
		400	13.6	13.3	13.2	7.3	0.5

In diatomite powder added samples, increases of 10-15% occurred in DT 10% set in compressive strengths up to 400°C in both dosages, and decreases were observed again at 600 and 800°C. Furthermore, the strengths of the samples with a dosage of 400 at 600 and 800°C were found higher than the control sample although their strength in the first three temperatures were found lower than the control sample. It is believed that this results from the mineral structure of Diatomite. In DT 20% set, some increase occurred up to 400°C for both dosages, and decreases occurred after 400°C. The results show that samples with a dosage of 300 and 400 yield nearly the same strengths at 600 and 800°C. In DT 30% set, while a near horizontal decrease occurred in the strength of the samples with a dosage of 400, a sharp decrease was observed after 400°C, and the strengths of the samples with a dosage of 300 first increased up to 400°C and then decreased. Furthermore, at temperatures after 400°C, the strengths of the samples with a dosage of 400 were found to be lower than those with 300. In DT 40% set, a horizontal course occurred up to 400°C in both dosages; and the strengths of the samples with a dosage of 300 were found to be higher as in the previous sets, despite the decreased after 400°C.

4. Results and Discussion

In mineral added concrete, the compressive strengths under the effect of high temperature vary by the mineral additive and dosage. In general, in almost all sets, an increase or a horizontal course occurred almost in all sets up to 400°C, but then decreases occurred after 400°C. The compressive strengths of all samples with a dosage of 400 were found to be higher than those with a dosage of 300. While the highest strength in control samples is obtained in the samples with a dosage of 400 at 400°C as 39.6 N/mm^2, it was measured as 29.1N/mm^2 in samples with a dosage of 300 under normal conditions.

Examining the barite powder added concrete, the highest strength was measured in the samples with a dosage of 400 in BT 10% set as 49.8N/mm^2 at 400°C. This is also the highest strength obtained in this study so far. The highest strength in the samples with a dosage of 300 was measured as 24.6N/mm^2 at 400°C, again in the same set. When compared with the control sample, the mixtures of BT 10% set with a dosage of 400 exhibited a better performance against high temperature. However, it is not possible to say this for the other sets.

When it comes to diatomite added concrete, the highest strength was obtained in DT 10% set for both the dosages of 300 and 400. While the highest value for the dosage 400 is obtained at 400°C, it was measured as 23.0N/mm^2 for the dosage 300 at the same frequency. These values are lower values when compared to the control samples.

After these results obtained, it is possible to say that 10% barite powder added concrete with a dosage of 400 yields better results under high temperature, but the diatomite powder added concrete exhibits a bad performance.

Note

This study was inspired by and is an extension of Alper Kurt' M.A. thesis supervised by Dr. Yuksel Esen, which was submitted to Firat University's Institute of Science.

5. References

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