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Research Paper

BEHAVIOR INVESTIGATION OF NAOH-ACTIVATED PUMICE-BASED GEOPOLYMER COMPOSITES EXPOSED TO ELEVATED TEMPERATURE

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In this study, the effect of elevated temperatures on the compressive strength, Ultrasonic Pulse Velocity (UPV), Thermal Conductivity (TC) and density of pumice based geopolymer concretes have been investigated. Totally 27 cylindrical (10*20 cm) specimens have been manufactured from the NaOH-activated pumice based geopolymer. After 28 days curing they have been exposed to temperature of 100°C, 200°C, 300°C, 400°C, 500°C, 600°C, 700°C, 800°C for 3h in ceramic furnace. Afterwards the compressive strength, UPV, thermal conductivity and density of the specimens were determined. As a result all of the mentioned features have been deteriorated after exposing to elevated temperature than of control geopolymer concrete samples. But the produced geopolymer concrete can be fabricated for construction intents and have good potential for engineering applications.

Keywords: Elevated temperature, Geopolymer concrete, Pumice, Thermal conductivity, UPV

INTRODUCTION

Geopolymers are kinds of inorganic polymers that have been gradually attracting world attention as potentially revolutionary materials. Similar to natural zeolite minerals, geopolymer is a class of three-dimensionally networked alumino-silicate materials, and first developed by Joseph Davidovits in 1978 (Comrieand Davidovits, 1988; Davidovits *et al.*, 1990). According to former research, a wide range of natural Al-Si minerals, wastes, and slags could serve as potential source materials for the synthesis of geopolymers [1-4]. Under highly alkaline conditions, in the presence of alkali hydroxide and silicate solution, polymerization takes place when reactive aluminosilicates are rapidly dissolved and free [SiO_4] and [AlO_4] tetrahedral units are released in solution [5-11]. The tetrahedral units are alternatively linked to polymeric precursors by sharing oxygen atoms forming thus

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amorphous geopolymer. Demand pull by a carbon conscious market continues to be a key driver for the short term adaption of geopolymer cement [12].

MATERIALS AND EXPERIMENTATION

Pumice

Natural pumice used in present study has been obtained from Hasankale region near Erzurum located in the east of Turkey. The pozzolan firstly has been characterized for its chemical composition. The chemical composition has been shown in Table 1. X-ray diffractogram for the ground pumice showed very amorphous phase in sample textures that has been sown in Figure 1 [6]. All of the powdered pumice was finer than 200 μm and 93.8% is finer than 90 μm. Blaine's specific surfaces was 2980 cm^2/g and the density of ground pumice is 2.38. The used pumice is grounded in FRITSCH mill made in Germany.

Sodium hydroxide

In this study the liquid sodium hydroxide was used and its physical and chemical properties are given by the manufacturer has been shown in Table 2.

Sodium silicate

In this study ratio between SiO_2 to Na_2O is 1.95-2.3 chemical specifications and the physical properties for used sodium silicate have been shown in Table 3. The production has been purchased from MERCK Company.

Testing the Concrete Specimens

Twenty seven 100 mm diameter 200 mm high cylindrical mold were cast out of which three samples were used to determine the compressive strength, UPV, thermal conductivity and density of the specimens before and after exposing to the elevated temperatures. All

Figure 1: X-Ray Diffraction Pattern of Hasankale pumice

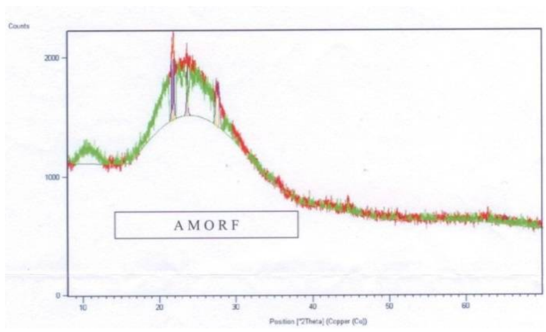


Table 2: Physical and Chemical Properties of Sodium Hydroxide

Chemical Formula	$NaOH*H_2O$
NaOH	32-33
H_2O	67-68
Appearance	Gel
Specific Gravity (20°C)	1.35

Table 3: Physical and Chemical Properties of Sodium Silicate

Chemical Formula	Na_2O*SiO_2 Colorless
SiO_2	22-24
Na_2O	11-12
H_2O	64-67
Appearance	Gel
Specific Gravity (20°C)	1.38-1.397

Table 1: Chemical Composition of Hasankale Ground Pumice

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O+Na_2O	Others	LOI
67.08	14.06	1.91	0.87	0.25	0.11	15.72	3.94

Table 4:Mix Proportions for Geopolymer Concrete								
Pumice (kg)	Aggregate (kg)				NaOH Solution (kg)	Na_2SiO_3 Solution (kg)	H_2O (kg)	Super(kg) plasticizers
	0-2 mm	2-4 mm	4-8 mm	8-16 mm				
393.93	519.97	259.99	346.65	608.96	86.61	117.044	4.72	15.75

geopolymer concrete samples were made with the mix design that has been shown in Table 4.

It is recommended to have necessary precaution on working because of acidic nature of the concrete.The components of concrete ingredients are collected and mixed for about 3 min. The alkaline liquid were then added to the mixture and the mixing was done for 3 min.Flow test (workability) was carried out by slump cone test as described for ordinary cement concrete and the result have been shown 3-4 cm for slump test. The concrete was cast and compacted by the usual methods used in the case of Portland cement. The specimens immediately wrapped in plastic film and cured at 65 °C in the curing chamber for 48 hours. Demoulding was done at 48 hours at the time of curing age. After the heat treatment process the specimens left at the room temperature for about 26 other days and ready for testing. After the curing period, 3 specimens of the mixture were exposed to the 100°C, 200°C, 300°C, 400°C, 500°C, 600°C, 700°C, and 800°C for 3h in ceramic furnace then cooled in air until the room temperature. Reported strength was the average of the three specimens.The results of the tests for concrete after elevated temperature were compared with the test results of unheated concrete specimens.

RESULTS AND DISCUSSION

The summaries of tests have been given in Table 5. Comparatively, the recorded results have been shown that the elevated temperature in geopolymers cause property deterioration for all conducted tests. The results of the tests have

Table 5: Summaries of Geopolymer Concrete Tests Before and After Exposing to the Elevated Temperature

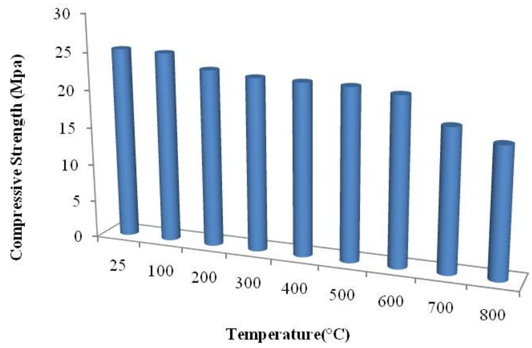
Temp. (°C)	Sample Name	Density of Fresh Geopolymer Concrete kg/m^3	Density of hardened Geopolymer Concrete kg/m^3	TCresults (W/Mk)	UPVresults (m/s)	Compressive Strength (Mpa)
25°C	Control	2360	2176	2.10	2886	25,22
100°C	C100	2360	2170	2.06	2700	25,07
200°C	C200	2360	2169	1.96	2710	23,29
300°C	C300	2360	2151	1.93	2749	22,73
400°C	C400	2360	2132	1.68	2620	22,61
500°C	C500	2360	2110	1.63	2611	22,51
600°C	C600	2360	2033	1.49	2100	21,98
700°C	C700	2360	1915	1.07	1750	18,62
800°C	C800	2360	1801	0.86	1700	16,97

Figure 2: Volume Expansions for Geopolymer Samples Orderly (left to right 100°C-800°C)

been discussed in addition of the volume expansions have been occurred after 600 °C that has been shown in Figure 2.

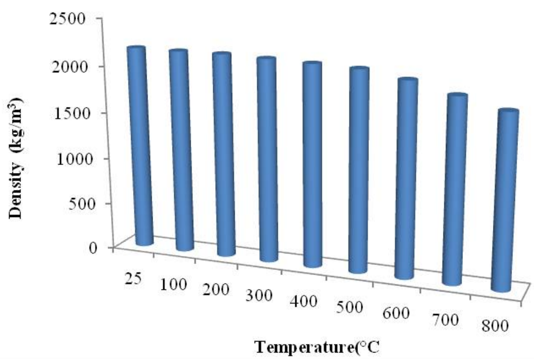
Elevated temperature reduced compressive strength, UPV results, thermal conductivity results and densitýes of pumice based geopolymer concretes at all levels of temperature, i.e., 100°C, 200°C, 300°C, 400°C, 500°C, 600°C, 700°C, 800°C at 28 days. Reductions were very high after 500°C. For 28-day compressive strength, reduction wasless than 10% until 300°C. The compressive strength for geopolymer concrete at the temperature range between 400-500°C are very similar and the sudden change can be observed for temperature range between 600-800°C that the reduction in compressive strength reach approximately 30% of the control samples. And we can observe samples expansions. As a result from vydra *et al*. research [13] after 570°C temperature alpha quartz will change to the beta quartz and the aggregate expanded approximately 5% and it the expansion reason at the samples after 500°C. The relationship between compressive strength and temperature has been shown in Figure 3.

Figure 3: Relationship Between Temperature and Compressive Strength



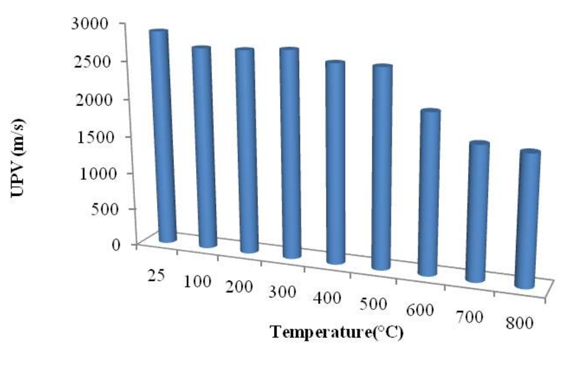
Similar to the compressive strength elevated temperature reduced densities of pumice based geopolymer concretes at all levels of temperature i.e., 100°C, 200°C, 300°C, 400°C, 500°C, 600°C, 700°C, 800°C at 28 days. Reductions were very high after 500°C. For 28-day density reduction was less than 1.15% until 300°C. The densities for geopolymer concrete at the temperature range between 400-500°C are very similar and approximately 3% and the sudden change can be observed for temperature range between 600-800 °C that the reductions in density reach approximately 17.2% of the control samples. The results have been illustrated at Figure 4.

Figure 4: Relationship Between Temperature and Density



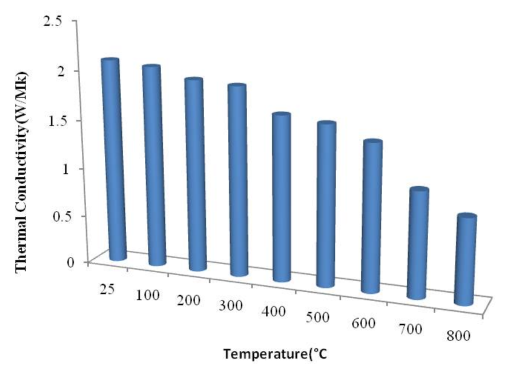
Similar to the compressive strength elevated temperature reduced UPV results of pumice based geopolymer concretes at all levels of temperature, i.e., 100°C, 200°C, 300°C, 400°C, 500°C, 600°C, 700°C, 800°C at 28 days. Reductions were very high after 500°C.For 28-day UPV reduction were less than 4.7% until 300°C. The UPV quantity for geopolymer concrete at the temperature range between 400-500°C are very similar and approximately 10% and the sudden change can be observed for temperature range between 600-800°C that the reduction in UPV results reach approximately 41% of the control samples. The results have been illustrated at Figure 5.

Figure 5: Relationship Between Temperature and UPV



Similar to the compressive strength elevated temperature reduced thermalconductivity (TC) results of pumice based geopolymer concretes at all levels of temperature, i.e., 100°C, 200°C, 300°C, 400°C, 500°C, 600°C, 700°C, 800°C at 28 days. Reductions were very high after 500 °C. For 28-day TC reduction were less than 8% until 300°C. The TC quantity for geopolymer concrete at the temperature range between 400-500°C are very similar and approximately 22% and the sudden change can be observed for temperature range between 600-800°C that the reduction in TC results reach approximately 60% of the control specimens. The results have been illustrated at Figure 6.

Figure 6: Relationship Between Temperature and Thermal Conductivity



CONCLUSION

NaOH-activated pumice-based geopolymer concrete can be used as a substitution for normal concrete. And in this study the 28-day compressive strength have been reached up approximately 25 Mpa.

Elevated temperature will cause the physical properties deterioration at all elevated temperature between 100-800°C.

ACKNOWLEDGMENT

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