ALKALI-ACTIVATED FLY ASH CONCRETE

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Abstract

Fly ash concrete was produced without Portland cement incorporated in this work. Sodium hydroxide and sodium silicate solution were used as alkali activated in 7 different ratios to substitute calcium hydroxide from hydration process. Water was added to adjust their slump to about 200 $\pm$ 25 mm. Cube samples 100 x 100 x 100 mm were cast to perform compressive strength test and cured at 2 different temperatures. The first was cured at room temperature and the other was cured at 60 ^oC for 24 hours and leave at room temperature until the tested date. The results show that high alkalis content can substitute the use of Portland cement in concrete. MIX 5 in this study can exhibit compressive strength more than 30 MPa within 3 days.

1. Introduction

Fly ash or coal ash has been partly used to replace cement in concrete industry for a long period because it contributes the beneficial properties to concrete. Fly ash is often incorporated into the ordinary Portland cement as a value adding filler. In this system, fly ash is not highly reactive, but it improves properties of concrete such as workability and durability. Up to 55% of the cement binder can be replaced with fly ash to make normal or high performance concrete. The idea to make concrete without manufactured cement has been pursued but not yet succeeded.

Highly alkali activated fly ash concrete gradually earns an interest from material scientists [1,2]. Fly ash is to replace totally manufactured cement to make concrete-like material. This will turn the construction material to the new era. It is an inorganic alumino-silicate polymer synthesized from predominantly silicon and aluminium material of geological origin or by-product materials such as fly ash. Sometimes, it is called geopolymer. Fly ash-based geopolymer is made by mixing fly ash with sodium silicate solution and highly caustic hydroxide solution and cured at room temperature or at higher temperature.

Geopolymer was first used by Davidovits [3]. Utilization of such a material to produce the valuable-added products is of considerable commercial interest.

The exact mechanism by which geopolymer setting and hardening occur is not fully understood. Most proposed mechanisms consist of a dissolution, transportation or poly-

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condensation. Temperature is also considered as one of the most factor that affects to any polymerization.

The purpose of this research is to study the effect of chemical composition and curing temperature on the compressive strength of concrete

2. Experimental program

2.1 Materials

Class F fly ash (FA), with specific surface area of 2120 cm^2/g was used as the base material in this work. The chemical composition of the fly ash is given in Table 1. Commercial grade sodium hydroxide in flake form (98% purity) conformed to TIS:150-2518 and sodium silicate solution conformed to TIS: 433-2539 (Na_2O=14.7%, SiO_2=29.4%, Water = 55.9%) were used as the alkali activators.

Table 1 - Chemical composition of fly ash (%)

SiO_2	Al_2O_3	Fe_2O_3	CaO	SO_3	LOI
45.32	20.92	10.7	7.6	1.8	0.2

Concrete proportioning was first trial as ACI 211.1 guided. River sand and lime stone (max size = 3/8 in.) in saturated surface dry condition was used. The mixtures were adjusted by adding water to obtain the slump of 200 $\pm$ 25 mm. Tap water was used in this test. Table 2 shows mix proportion of concrete.

Table 2 – Mix proportions of concrete in this study

Mix ID	W/B	FA	Agg.	S	W	$Na_2O : SiO_2$	NaOH
		kg/m^3					
1	0.40	514	1056	700	95	127	55(15 M)
2	0.42	514	1056	700	119	79	79(15 M)
3	0.41	514	1056	700	119	79	79(20 M)
4	0.47	475	1056	700	79	158	79(15 M)
5	0.46	475	1056	700	79	158	79(20 M)
6	0.48	475	1056	700	79	119	119(15 M)
7	0.46	475	1056	700	79	119	119(20 M)

w/b = water to binder ratio, FA = fly ash, Agg. = Aggregate, S= sand, W= water

2.2 Mixing and curing

All mixtures were mixed in room temperature. The temperature of all solutions was as ambient (25 ^oC). The samples were cured at 2 different temperatures. The first was cured at room temperature and the other was cured at 60 ^oC for 24 hours then left at room temperature until the tested date.

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3. Results and Discussion

Compressive strengths of concretes were shown in Table-3. It was found that MIX 1, 2 and 3 exhibited very low compressive strengths and it is not suitable to use as structural concrete even thought it were cured at 60 ^{o}C. MIX 4, 5, 6, and 7 gave considerable compressive strength. It was 25.7 MPa at the first day and increased to 35.8 MPa within 28 days, MIX 5 with 60^{o}C cured for example. It should be noted that no Portland cement involved in these mixtures. Fig.1 clearly shows that higher curing temperature significantly affects the early strength of concrete more than that of the late strength.

Table -3 Compressive strength of concrete

MIX ID	Compressive strength (MPa)							
	Cured at room temperature				Cured at 60^{o}C			
	1-day	3-day	7-day	28-day	1-day	3-day	7-day	28-day
MIX 1	0.9	1.3	2.4	3.1	4.1	4.4	4.9	6.6
MIX 2	0.6	1.6	2.8	10.9	7.8	10.7	11.6	13.7
MIX 3	0.7	0.8	1.6	11.5	8.6	9.4	13.4	16.6
MIX 4	1.7	5.5	12.4	26.6	21.1	22.7	25.5	28.9
MIX 5	3.4	8.3	16.3	29.7	25.7	32.1	32.9	35.8
MIX 6	1.8	4.5	9.1	15.8	17.5	18.7	21.9	24.4
MIX 7	1.8	5.4	10.6	21.8	21.6	24.7	27.0	28.4

In order to observe the influence of chemical composition on the compressive strength of concrete, chemical ratios of paste were tabulated in Table 4. Each chemical is calculated from both solid and liquid parts of the paste. For example, SiO_2 was obtained from both fly ash and sodium silicate solution.

Table-4 Chemical ratios of alkali activated fly ash paste

MIX ID.	Chemical Ratios			
	Na_2O/SiO_2	SiO_2/Al_2O_3	H_2O/Na_2O	Na_2O/Al_2O_3
MIX 1	0.115	4.276	22.135	0.492
MIX 2	0.139	4.051	20.249	0.563
MIX 3	0.160	4.051	17.173	0.647
MIX 4	0.162	4.488	17.648	0.727
MIX 5	0.182	4.488	15.304	0.818
MIX 6	0.213	4.285	14.080	0.914
MIX 7	0.245	4.285	11.804	1.051

It can be observed that when the Na_2O/SiO_2 increases from 0.115 to 0.182, compressive strength increases as well. However, when this ratio reaches 0.213, compressive strength

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of concrete becomes lowers. The Na_2O/Al_2O_3 ratios can be observed in the same way. The SiO_2/Al_2O_3 ratio was optimum at 4.488 and it tends that the increase of water reduces the compressive strength of concrete.

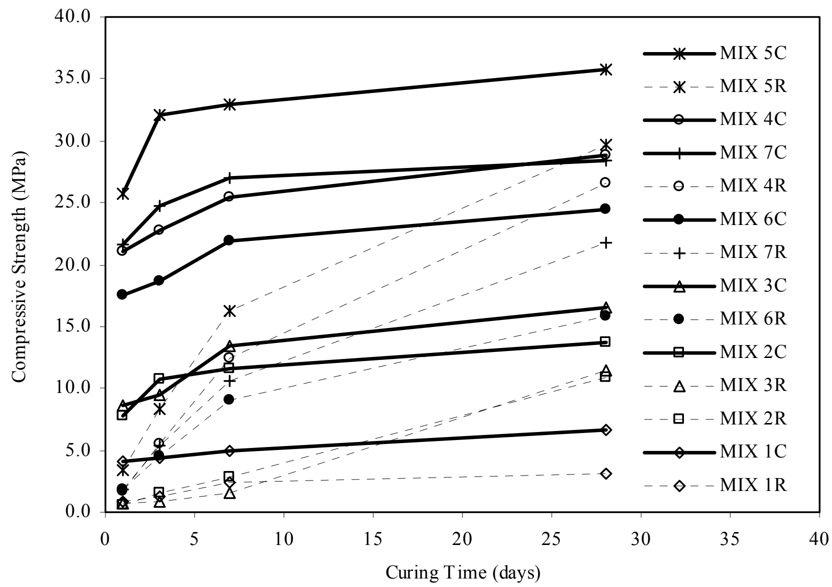

Figure 1 – Relationship between compressive strength and curing time of concrete

4. Conclusions

From the test results, the follow conclusions can be drawn:

1. Curing temperature at 60 ^{o}C affects on early compressive strength of concretes more than those of late strength.
2. Compressive Strength of alkali activated fly ash concrete seems to depend on chemical ratios of the paste.

5. References

1. A. Fernandez-Jimenez and A. Palomo. (2004) Activation of fly ashes: A general view, *Fly ash, Silica Fume, Slag, and Natural Pozzolans in Concrete, Proceedings Eighth International Conference*, V.M. Malhotra editors, Las Vegas, USA., 351-366.
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