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Experimental Study of Fly Ash Based Geo-Polymer Concrete Using Silica Fume and Quartz Powder

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ABSTRACT

Geo-polymer concrete has gained attention of Civil engineers due to low carbon foot prints. In this study, M30 grade geo-polymer concrete is developed with fly ash, silica fume and quartz powder as source materials & Sodium Silicate and Sodium Hydroxide as an alkaline solution. Geo-polymer concrete mixes are prepared with alkaline solution to binder ratio as 0.35 by weight. The fly ash is replaced with silica fume & quartz powder in ratio of 5% and 10% to enhance mechanical properties, respectively. The concrete is cured at 60°c temperature in oven for 24 hours. The various parameters such as compressive strength, split tensile strength and workability are studied. Mechanical properties and optimum percentage of silica fume and quartz powder are investigated. In this experimental study, it is observed that presence of silica fume and quartz powder enhances the compressive strength up to 26% and split tensile strength up to 45%.

Keywords : Alkaline solution, Fly Ash, Quartz Powder, Silica fume, Compressive strength, Split tensile strength.

I. INTRODUCTION

From last one or two decades, engineers deal with energy saving concept. Cement using in concrete increases harmful greenhouse gas like CO_2. To reduce the pollution from environment and make the construction work pollution free, cement can be replaced by binder.

Waste materials from industries like fly ash, red mud, quartz powder, etc. are commonly used as a geo-polymer binder and it reduces carbon dioxide. Disposal of fly ash needs large area that may affect underground water region. After testing of fly ash, it was found that fly ash can be used as a binder material in geo-polymer concrete.

Use of industrial waste materials instead of cement makes concrete ecofriendly. Use of these types of materials in concrete showed improvement in fire resistance, high compressive strength, low creep, good bonding property, and good resistance against acid and sulphate attack. Previous studies showed that compressive strength was affected by weight of oxides, ratio of liquid to solid, molarity of sodium hydroxide, ratio of sodium silicate to sodium hydroxide and CaO

content in binder material. Heat curing gave higher compressive strength compared to the ambient temperature curing for geo-polymer concrete. Curing temperature of 60°c to 90°c to the specimens for about 24 to 48 hours gave the best results [1-2].

The aim of this study is to investigate the effect of fly ash (FA), silica fume (SF) and quartz powder (QP) on the split tensile strength and compressive strength of geo-polymer concrete. For this purpose, up to the 20% by weight of the FA is replaced with SF and QP.

II. METHODS AND MATERIALS

In this study, a low-lime Class F FA, SF and QP are used as the binder materials. The chemical and physical properties of the binder materials obtained from their manufacturers are presented in Tables I and II, respectively.

In all of the mixtures, water to binder ratio is kept constant as 0.35 by weight. Slump values of the fresh concrete are determined in accordance with IS 1199:1959. The recorded value is in the range of 100±20 mm. The lowest slum value is obtained in the mixtures containing with SF and QP. This could be due to the extremely high fineness values of these admixtures [6].

NaOH/KOH and Na_2SiO_3/K_2SiO_3 can be used as the alkaline liquid in geo-polymer concrete. Potassium is little expensive then sodium. Therefore, sodium hydroxide and sodium silicate is preferred for geo-polymer concrete. Sodium hydroxide with 95% purity as shown in Figure 1 is used with pure water for required molarity solution. In this study, 14 molar NaOH and Na_2SiO_3 gel are used as alkaline solution.

Figure 1: Sodium Hydroxide flakes

The ratio of 2.5 is taken for sodium silicate and sodium hydroxide. Sodium hydroxide and sodium silicate are mixed with each other before one day to have proper reaction in concrete. The sodium silicate solution is used with ratio of SiO_2 to Na_2O as 2.0 by mass, i.e., SiO_2 = 32%, Na_2O = 16%, and water = 52% by mass [2-3].

TABLE I
CHEMICAL PROPERTIES OF MATERIAL

Oxides	FA	SF	QP
SiO_2	39.20	92.00	98.5
Al_2O_3	24.70	0.59	0.17
Fe_2O_3	4.80	0.33	0.56
CaO	11.10	0.91	0.03
MgO	1.80	0.07	-
SO_3	2.10	-	-
LOI	5.62	2.0	1.0

TABLE II
PHYSICAL PROPERTIES OF MATERIAL

Material	Property	Value
FA (Class F type)	Specific gravity	2.3
	Colour	Gray
	Form	Powder
Fine aggregate	Specific gravity	2.70
	Zone	I
	Fineness modulus	3.03
	Particle size	< 4.75 mm

Coarse aggregate	Specific gravity Fineness modulus Particle size	2.59 7.19 4.75 to 20 mm
Sodium hydroxide	Form Colour Purity	Flakes White > 95%
Sodium silicate	Form Colour	Gel Light brown

Oil the machine and the moulds properly so that the concrete would not get stuck and can be easily removed. Take the coarse aggregate, fine aggregate and FA in the machine and properly mix them until it is uniformly mixed. Now pour the Sodium hydroxide and Sodium silicate solution in the mixture along with the extra water and again mix them for few minutes until it is uniformly mixed. This addition of extra water is for the workability purpose. Now, fill the moulds with the concrete with proper compaction such that no voids should remain in the mould. Place moulds in the oven for 24 hours at 60°c for the curing purpose as shown in Figure 2. After 24 hours of curing, remove the specimens from the moulds and keep them at room temperature for 7 and 28 days for split tensile strength [5] and compressive strength [4]. Table III shows various mixes used in the study.

Figure 2: Hot air oven curing

TABLE III

GEOPOLYMER CONCRETE MIXTURE PROPORTIONS

Material	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6
FA (kg/m^3)	400	380	360	340	340	320
SF (kg/m^3)	-	20	20	20	40	40
QP (kg/m^3)	-	-	20	40	20	40
NaOH (kg/m^3)	40	40	40	40	40	40
Na_2SiO_3 (kg/m^3)	100	100	100	100	100	100
Fine aggregate (kg/m^3)	669.2	669.2	669.2	669.2	669.2	669.2
Grit (kg/m^3)	596.2	596.2	596.2	596.2	596.2	596.2
Coarse aggregate (kg/m^3)	596.2	596.2	596.2	596.2	596.2	596.2
Extra water (lit/m^3)	45	45	45	45	45	45

III. RESULTS AND DISCUSSION

a. Workability test

In this research work, slump test is carried out to determine the consistency of fresh concrete. It is observed that slump is found between 80 to 100 mm as shown in Figure 3.

Figure 3: Slump of Geo-polymer concrete

b. Compressive Strength

Compressive strength test of geo-polymer concrete specimen is shown in Figure 4. From the test, it is observed that mix having 85% FA, 5% SF and 10% QP shows the highest compressive strength value. FA based geo-polymer concrete shows the lowest compressive strength. The compressive strength of the concrete mixtures containing QP and SF is higher than that of the FA based geo-polymer concrete at all ages as shown in Figure 5.

Figure 4: Failure of cube specimen in compressive strength

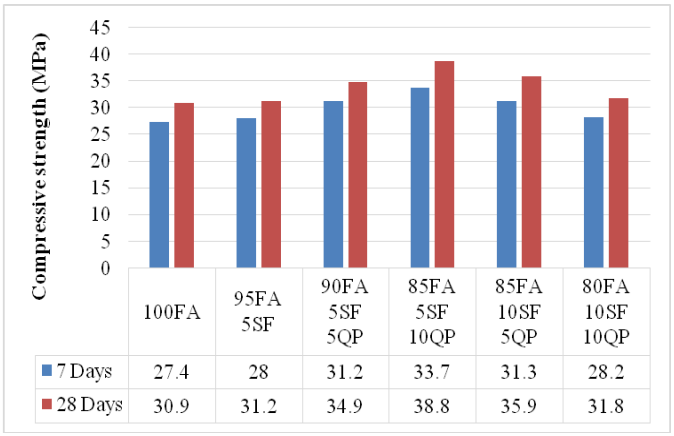

Figure 5: Compressive strength of Geo-polymer concrete

c. Split tensile Strength

Split tensile strength test of geo-polymer concrete specimen is shown in Figure 6. Highest value of split tensile strength is obtained when 85% FA, 5% SF and 10% QP used in mixture. Split tensile strength values of the geo-polymer concrete mixtures are shown in Figure 7.

Figure 6: Failure of cylinder in split tensile strength

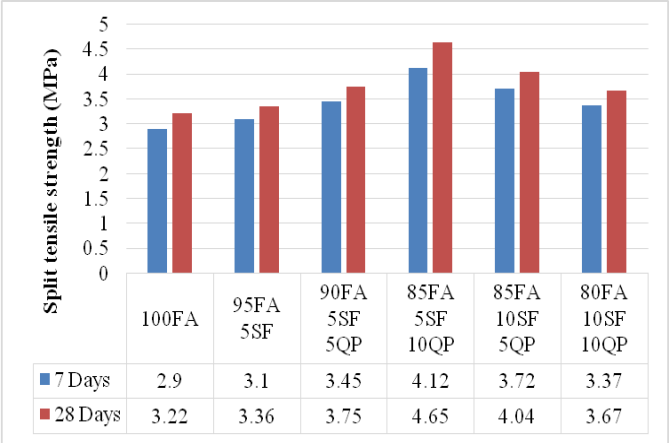

Figure 7: Split tensile strength of Geo-polymer concrete

IV. CONCLUSIONS

In this experimental study, FA based geo-polymer concrete is partially replaced with SF and QP. Quantity of extra water, grading of fine aggregate, binder to solution ratio and NaOH to Na_2SiO_3 ratio of 2.5 is maintained to get desire strength of concrete.

1. Replacement of 100% FA with 90% FA, 5% SF and 5% QP increases the compressive and split tensile strength by 12.95% and 16.46%, respectively.

2. Replacement of 100% FA with 85% FA, 5% SF and 10% QP increases the compressive and split tensile strength by 25.56% and 44.41%, respectively.

3. Replacement of 100% FA with 80% FA, 10% SF and 10% QP increases the compressive and split tensile strength by 2.91% and 13.97%, respectively.

4. Si to Al ratio from 1.8 to 2.2 gives the higher result of compressive and split tensile strength. Ratio of Si to Al is higher than 2.3 decreases the value of compressive and split tensile strength.

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