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Abrasion Resistance of Geopolymer Concrete with the Change in Curing Time and Curing Temperature

Shalika Sharma

Shalika Sharma, M.E.Scholar, National Institute of Technical Teacher's Training and Research, Panjab University, Chandigarh

Abstract

India is one of the developing countries that is laying lot of stress on infrastructure development. With the increase in construction at a fast pace, usage of concrete is increasing day by day. Cement is one of the main ingredients of concrete. The production of 1 ton of cement leads to emission of one ton of CO_2, which is responsible for emission of green house gases leading to global warming. To reduce environmental pollution caused by the production of Portland cement, the use of waste material was felt. Geopolymer concrete made by using source material rich in silica and aluminium and alkaline liquid as a binder can be used to replace the Portland cement .Hence, an aluminosilicate polymer ,Geopolymer was invented by Prof Davidovits. In addition, GPC also utilizes the abundantly available materials such as fly ash, rice husk, GGBS and foundry sand that are waste by products & not easily disposed. Geopolymer concrete doesn't use any cement, the production of cement shall be reduced and hence the pollution of atmosphere by the emission of carbon dioxide shall also be reduced. In this paper, the change in the abrasion resistance of Geopolymer concrete was observed with the change in the curing temperature.

Keywords: *abrasion resistance, aluminosilicate , CO_2, geopolymer concrete, global warming, fly ash, waste material.*

I. Introduction

With the boom in infrastructure, the demand for concrete and cement is increasing day by day. The production of cement is increasing 3 % annually. The production of one ton of cement will lead to emission of 1 ton of CO_2 into atmosphere.CO_2 contributes 65 % of global warming. Although the use of Portland cement is unavoidable in the future, many efforts are being made to reduce the use of Portland cement in concrete. It is time to use new eco friendly materials like geopolymers that offer waste utilization and emission reductions. The term geopolymer describes a family of mineral binders with chemical composition same as zeolite. Hardened geopolymer concrete has an amorphous microstructure which is quite similar to that of ancient structures such as Egyptian pyramids and Roman amphitheaters. Geopolymer pioneered by Joseph Davidovits is an inorganic alumino-silicate polymer synthesized from materials having silicon (Si) and aluminium (Al) or byproduct materials like fly ash, metakaolin, Granulated Blast furnace slag etc. The polymerisation process involves a substantially fast chemical reaction under alkaline condition on Si-Al minerals that result in a three dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds. The chemical reaction comprises of the following steps:Dissolution of Si and Al atoms from the source material through the action of hydroxide ions. Orientation or condensation of precursor ions into monomers.Setting or polycondensation or polymerization of monomers into polymeric structures. Compared with Portland cement concrete, geopolymers has many advantages.

Low-calcium fly ash-based geopolymer concrete has excellent compressive strength, very little drying shrinkage and low creep, excellent resistance to sulfate attack and good acid resistance. It can be used in many infrastructure applications. One ton of low-calcium fly ash can be utilized to produce about 2.5 cubic meter of high quality geopolymer concrete and the bulk cost of chemicals needed to manufacture this concrete is cheaper than the bulk cost of one ton of Portland cement. Given the fact that fly ash is considered as a waste material, the low calcium fly ash-based geopolymer concrete is, therefore, cheaper than the Portland cement concrete. Moreover, reduction of one ton of carbon dioxide yields one carbon credit and this carbon credit significantly adds to the economy offered by the geopolymer concrete. In terms of reducing global warming, geopolymer technology could reduce approximately 80% of CO_2emission to the atmosphere caused by cement and aggregate industry.

Abrasion resistance means the ability to resist being worn away by rubbing. Abrasion is the wearing down of rock particles by friction due to water, wind. Abrasion wear occurs due to rubbing or sliding of objects on the concrete surface. This type of wear is observed in pavements, floors or other surfaces on which friction forces are applied due to relative motion between the surfaces and moving objects. A large number of previous studies have indicated that concrete abrasion resistance is primarily dependent upon compressive strength of the concrete. The objective of the present study is to investigate the abrasion resistance of Geopolymer concrete at different temperatures.

II. EXPERIMENT

2.1. PREPARATION OF GEOPOLYMER CONCRETE

The manufacturing of geopolymer concrete is similar to cement concrete. The process involves the preparation of alkaline solution, dry mixing, wet mixing, curing & testing of samples. To prepare sodium hydroxide solution of 12 molarity, 480 g (12 x 40) i.e.(molarity x molecular weight) of sodium hydroxide pellets were dissolved in one liter of water. The mass of sodium hydroxide solids in the solution varies depending on the concentration of the solution expressed in terms of molar M. The prepared NaOH solution was added with sodium silicate solution proportionately according to the mix, 24 hours before casting. The ratio of NaOH to Na_2SiO_3 is 2.The coarse aggregate, fine aggregate, flyash were taken in required amount in a mixing tray and dry mixed manually for about two minutes. The alkaline solution was prepared 24 hours before and was thoroughly stirred, then the required amount was mixed with the alkaline solution and was added to the dry mix, addition of solution was done in small quantities so that there was no wastage of solution, usually the wet mixing time took about 10 to 15 minutes or greater. The mixing of total mass continued until the mixture became homogeneous and uniform in color. The fresh geopolymer concrete was casted in cubes of size 100 X 100 X 100 mm to three layers and was compacted by using the standard compaction rod so that each layer receives 25 strokes followed by further compaction on the vibrating table. The casted specimens were kept in oven for 25ºC for the curing period 120 hours and another specimens were kept in an oven for 60 ^{0}C , 40 ^{0}C, 80 ^{0}C for the curing period of 72 hours . The specimens were removed from the oven and were kept open at room temperature until testing.
Coarse aggregate of size 20mm having the specific gravity of 2.78 and fineness modulus of 7.21 were used. The fineness modulus of fine sand used was 2.41 with a specific gravity of 2.6. The ratio of flyash to alkaline liquid is 0.4. The ratio of sodium hydroxide to Sodium silicate is 2.

2.2. ABRASION RESISTANCE

The 100 mm diameter cylinder with a 2:1 diameter to length ratio will be fixed in the abrasion machine and a load of 154+2.5 N or 154-2.5 N shall be applied. The grinding machine shall then be put in a motion at a speed of 1000 rpm. Each specimen will be abraded for 5 minutes and the depth of grinding on the specimen surface will be measured at the fifth minute. *
The results for the grade of abrasion resistance will be evaluated using the following formula.

$$I_a = (R/P)^{1/2}$$

where I_a is the grade of abrasion resistance , R is the number of revolutions of grinding machine in 1000 rpm , P is the depth of grinding trace in mm.

*Reference from Research Paper by Shuguang Hu, Hongxi Wong, Gauzhan Zhang, Qingjing Ding "Bonding and Abrasion of geopolymeric repair material waste with steel slag", Cement and Concrete Composites (2008) 239-244.

TABLE 1
CONSTITUENTS OF FLY ASH

SiO2	P_2O_5	Cr_2O_3	Rb_2O
59,09 %	3,0 KCps	1,3 KCps	9,0 KCps
Al_2O_3	0,50 %	0,02 %	74 PPM
229,8 KCps	MgO	SeO_2	Ga_2O_3
30,77 %	3,9 KCps	5,7 KCps	2,5 KCps
Fe_2O_3	0,43 %	0,02 %	59 PPM
470,8 KCps	SO_3	La2O3	Nb_2O_5
3,85 %	1,7 KCps	0,1 KCps	8,4 KCps
TiO_2	0,16 %	0,01 %	58 PPM
45,2 KCps	Na_2O	CuO	PbO
2,06 %	0,3 KCps	3,7 KCps	1,7 KCps
CaO	0,07 %	0,01 %	46 PPM

31,3 KCps	BaO	Cl	As_2O_3
1,65 %	0,8 KCps	0,2 KCps	1,8 KCps
K_2O	0,06 %	0,01 %	9 PPM
21,0 KCps	ZrO_2	Y_2O_3	ZnO
1,06 %	80,4 KCps	11,9 KCps	3,5 KCps
MnO	0,06 %	85 PPM	3 PPM
3,7 KCps	V_2O_5	NiO	Intensity Scal
0,04 %	1,7 KCps	1,9 KCps	0,9803
Re	0,05 %	81 PPM	
3,5 KCps	SrO		
0,02 %	25,9 KCps		
	0,02 %		

III. RESULTS

Tests were conducted on samples of 100X100X100 at different temperatures of, 40^0 C, 60^0 C & 80^0 C. Tests were conducted on samples of 100X100X100 at different temperatures of 25^0 C, 40^0 C, 60^0 C & 80^0 C. The results are shown in the table below.

TABLE 2

S. No	TEMPERATURE	INITIAL WEIGHT(kg)	FINAL WEIGHT(kg)	DEPTH OF WEAR(mm)	$I_a = (R/P)^{1/2}$
1	25^0 C	2.344	2.140	3.0	166.66
2	40^0 C	2.346	2.146	3.0	166.66
3	60^0 C	2.245	2.004	2.6	192.31
4	80^0 C	2.344	2.112	2.6	192.31

IV. CONCLUSION

The paper presented brief details of abrasion resistance of fly ash-based geopolymer concrete. Geopolymer concrete sample cured at 25 ^{0}C requires 120 hours of curing whereas geopolymer concrete at high temperatures can be cured at 72 hours. Abrasion resistance increases with the increase in temperature.

A simple method to design geopolymer concrete mixtures has been described. Geopolymer concrete has excellent properties. To ensure future intake of geopolymer technology within the concrete industry, research is needed in the critical area of abrasion resistance with the increase in the ratio of alkaline liquids. Current research is focusing on the abrasion resistance of geopolymer concrete with NaOH to Na_2SiO_3 as 2.

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