STEEL SLAG INCORPORATED LOW CALCIUM FLYASH BASED GEOPOLYMER CONCRETE

[1]Sourav Kumar Das, [2]Vishnu Sharma
[1]Assistant Professor, [2]Student
[1]Civil Engineering
Manipal University Jaipur, Jaipur, India

Abstract: Pollution now-a-days is a big issue worldwide and the production of OPC makes a huge contribution to this pollution by creating almost 0.9 tonne of CO_2 for the production of 1 tonne OPC. This OPC production has also reduced the natural resource of lime stone. So as a substitute the concept of flyash based geopolymer concrete came and in this study author find out some good compressive and flexural strength of flyash based geopolymer mortar and concrete by incorporating some amount of steel slag a replacement of flyash. This paper describe the experimental work done by casting different batches of geopolymer concrete considering parameters like curing temperature, molarity of sodium hydroxide solution, sodium hydroxide to sodium silicate mixing ratio, ratio of Na_2O to SiO_2, mixing period for both of the alkaline solution.

Keywords- Flyash, steel slag, NaOH, Na_2SiO_3, curing.

I. INTRODUCTION

In India concrete is the mostly used material after water and day to day with the boost in the infrastructure development the use of concrete increases rapidly [1]. But this use of concrete is using a huge amount of cement with contributes a huge amount of carbon di oxide to our environment [2]. India which is the second largest cement manufacturer world wise reports almost 150 MT of CO_2 emission in 2015 [3]. So to curb this huge amount of pollution the use of and eco-friendly concrete urge its demand.

In 1978 Prof J. Davidovits invented the concept of geopolymerization [4] and later on with different research works flyash based geopolymer concrete came into our view which fully replaces the use of cement and uses the mix of flyash and alkaline solution as a cementitious mix. It also doesn't require the use of water for curing. Till date the mixing of geopolymer concrete was done by using the conventional process of mixing of cement concrete. There were no proper mix design process to mix a geopolymer mix as because the mix is having a lot of parameters to follow like chemical composition of flyash, slags (having a good amount of CaO), chemical compositions of alkaline solution plus the mixing ratio of them.

In this study author used flyash of class F, steel slag in finely grinded form, sodium hydroxide pellets having lab grade and commercially available sodium silicate solution and computed the mixes. One of the major target was to obtain a good amount of strength in atmospheric curing condition as because heat curing which were done by a lot of researchers' doesn't show a practicability [5]. In field during the time of erection of a structure it will not be possible to heat cure a huge member or else prefabricated members are to be used which is a big issue for concrete structure construction. So keeping this all into view atmospheric temperature curing was done where during day time concrete blocks were cured at an average temperature of 35^0 C and during night this temperature falls to an average of 20^0 C to 22^0 C with a light amount of dew during the August – September period in Jaipur, Rajasthan.

II. EXPERIMENTAL PROGRAMME

Material used

Flyash used in this study was of class F having a low calcium content brought from a local vendor of Jaipur. The chemical composition of flyash and slag are giver below in Table no. 1.

Table – 1 Chemical composition of Flyash & Steel Slag

Oxides	SiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O	K_2O	TiO_2	MgO	P_2O_5	SO_3	LOI
Flyash	53.36	26.49	10.86	1.34	0.37	0.80	1.47	0.77	1.43	1.70	1.39
Slag	35.26	13.81	0.87	38.27	0.35	0.30	0.37	4.64	0.05	3.76	2.34

The sodium hydroxide pellets are of laboratory grade having 98% purity bought from Loba Chemie and the sodium silicate solution was of commercial grade which was also bought from a local vendor of Jaipur. Coarse aggregate and fine aggregate used in this study was sieved properly. Coarse aggregates are taken as 1:1 ratio of 10 mm down and 20 mm down.

Alkaline Solution

The alkaline solution is the mixture of sodium silicate and sodium hydroxide solution. Different researchers used different time period of mixing this alkalis before using it in the concrete mix like some of the researchers mixed it 24 hours prior to the casting of concrete [6], where some researchers mixed it 2 to 3 hours prior to the final casting. In this study the alkali solution was mixed just before the casting of geopolymer concrete.

III. MIXING PROCEDURE

Mixing was done by initially mixing the flyash, slag and aggregates in the defined proportions and mixed till a homogenous mixture is formed. Then alkali solution (NaOH solution : Na_2SiO_3 :: 1:2) is mixed with it and again the total mixture was mixed for another 6 to 7 minutes to get a homogenous mix. Compaction was done by filling each cube in three layer and by tamping each layer by a 16 mm φ bar for 25 times. Then the compacted cubes was placed in table vibrator for 15 seconds to get a proper compaction. In the case of mortar mix flyash,

slag and sand was mixed initially than the alkali solution was added and mixed for another 3 to 4 minutes to get a homogenous mixture. After mixing the mortar cubes was placed in mortar cube vibrating machine and vibrate for 10 seconds to get good amount of compaction. Details of mix proportion are given below:

Table - 2 Details of mix proportions for concrete in Kg/m^3

Sl. No	Flyash	Steel Slag	Sodium Silicate Solution	Sodium Hydroxide Solution	Molarity	Curing Type	Alkali Solution/ Flyash
1	350	150	105	70	8	Atmospheric temperature	0.5
2	350	150	105	70	10	Atmospheric temperature	0.5
3	350	150	105	70	12	Atmospheric temperature	0.5
4	350	150	105	70	14	Atmospheric temperature	0.5
5	350	150	105	70	16	Atmospheric temperature	0.5
6	400	100	133.33	66.67	8	Atmospheric temperature	0.5
7	400	100	133.33	66.67	10	Atmospheric temperature	0.5
8	400	100	133.33	66.67	12	Atmospheric temperature	0.5
9	400	100	133.33	66.67	14	Atmospheric temperature	0.5
10	400	100	133.33	66.67	16	Atmospheric temperature	0.5

IV. CURING PROCESS

All the concrete cubes are cured in atmospheric temperature condition where the cubes are left at the atmospheric condition after remoulding which was done after 24 hours of casting and left for the entire period till testing. During this process the cubes felt a huge temperature variation of almost 16^0 to 18^0 centigrade for every single day.

V. RESULTS AND DISCUSSION

Ratio of alkaline liquid to flyash and Molarity of NaOH solution

For all the mixes the ratio of alkaline liquid to flyash was kept 0.5 and the compressive and flexural strength test was conducted at the interval of 3, 7, 14 and 28 days. For flexural test three point loading apparatus was used.

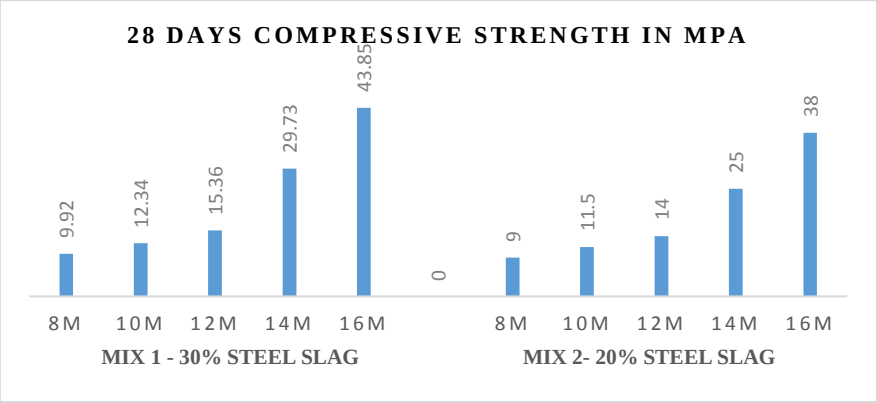

Figure 1. Compressive strength of different mixes at 30% and 20% steel slag addition

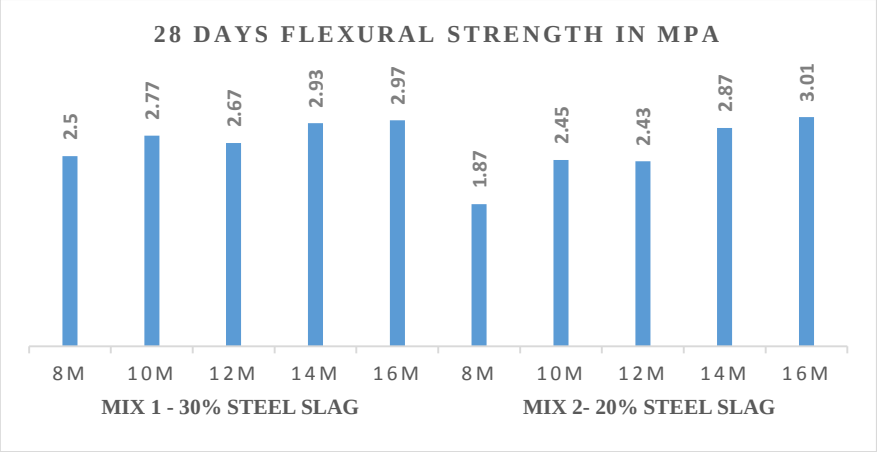

Figure 2. Flexural strength of different mixes at 30% and 20% steel slag addition

From figure-1 and figure-2 it's significant that with the increment in the molarity of NaOH solution there was an increment in the compressive and flexural strength of geopolymer concrete mix and the maximum strength was obtained in the case of 16M solution.

Effect of Curing Temperature

Previous research shows that to generate strength in geopolymer mix it was heat cured but in this present study all the mixes was left in the environment and cured at that temperature only after remoulding which was done after 24 hours of casting. During this dry curing state all the cubes was exposed to and extreme temperature of 35^0C to as well as minimum of 17^0C which is very much practicable for any construction work. Because during construction heat curing is not possible for the full structure.

Effect of Molarity of Sodium Hydroxide Solution

From figure.1 and figure.2 it's pretty much observed that with the increment in the molarity of the NaOH solution the compressive and flexural strength increases and we are able to get higher amount of strength with 16M solution rather than other molarity.

Effect of the incorporation of Steel Slag

The main objected of the incorporation of the steel slag is to increase the calcium oxide content as because with only class F grade flyash the calcium oxide content is bounded within 2% to 3% which requires heat curing for the polymers to bind and to gain strength but with the incorporation of steel slag which is having a calcium oxide content in the range of 30% to 40% , in this case 38.27%, helps in the bonding of the materials in atmospheric temperature condition and doesn't mandatorily require heat curing to gain strength [7]. Figure. 1 and figure.2 shows the increment in strength for the replacement of flyash with steels lag by 30% and 20% respectively and in all the cases we have seen increment in compressive and flexural strength.

VI. CONCLUSION

Going through the full experimental research the following conclusions can be made:

- With the incorporation of steel slag, flyash based geopolymer concrete can be cured in the atmospheric temperature and be able to get good compressive and tensile strength.
- With the increment in the replacement percentage of flyash by steel slag there was an increment on the compressive and tensile strength.
- With the increment in the molarity of sodium hydroxide solution both compressive and tensile strength got increased and attain a maximum of 43.85 MPa and 2.97MPa respectively.

Though in this study the main focus was concentrated on the strength generation in atmospheric condition with different molarity of sodium hydroxide solution but then also a lot of research is awaited in this field as because a slight change in the chemical properties changes the final results also.

VII. ACKNOWLEDGEMENT

I would like to thank my Head of Department and Research lab of Manipal University Jaipur to help me conduct my experiments with newly equipped instrument and financially whenever it's required.

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