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A REVIEW ON FLY ASH BASED GEO-POLYMER CONCRETE

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ABSTRACT

Geopolymer concrete is a 'New' material that does not need the presence of Portland cement as a binder. Instead, the source of materials such as fly ash, that are rich in Silicon (Si) and Aluminium (Al) are activated by alkaline liquids to produce the binder. Hence concrete with no cement is prepared.The rate of production of carbon dioxide released to the atmosphere during the production of Portland cement and fly ash, a by-product from power stations worldwide is increasing with the increasing demand on infrastructure development and hence needs proper attention and action to minimize the impact on the sustainability of our living environment.

I. INTRODUCTION

Portland cement production is under critical review due to high amount of carbon dioxide gas released to the atmosphere. In recent years, attempts to increase the utilization of fly ash to partially replace the use of Portland cement in concrete are gathering momentum. Most of this by-product material is currently dumped in landfills, thus creating a threat to the environment.Geopolymer concrete is a 'New' material that does not need the presence of Portland cement as a binder. Instead, the source of materials such as fly ash, that are rich in Silicon (Si) and Aluminium (Al) are activated by alkaline liquids to produce the binder. Hence concrete with no cement is prepared.The rate of production of carbon dioxide released to the atmosphere during the production of Portland cement and fly ash, a by-product from power stations worldwide is increasing with the increasing demand on infrastructure development and hence needs proper attention and action to minimize the impact on the sustainability of our living environment.De-carbonation of limestone in the kiln during manufacturing of cement is responsible for the liberation of one ton of carbon dioxide to the atmosphere for each ton of Portland cement as can be seen from the following reaction equation:

$$5\,CaCO_3 + 2\,SiO_2 \rightarrow 3\,CaO.SiO_2 + 2\,CaO.SiO_2 + 5\,CO_2$$

The production of Portland cement worldwide is increasing 3% annually. The current contribution of green house gas emission from the Portland cement production is about 1.35 billion tons annually or about 7% of the total greenhouse gas emissions to the earth's atmosphere. Furthermore, Portland cement is also among the most energy-intensive construction materials after aluminum and steel.

Fly ash, "The finely divided residue that results from the combustion of ground or powdered coal and that is transported by flue gases from the combustion zone to the particle removal system" is available abundantly worldwide. In 2001, the fly ash production in the USA was in the order of 68 million tons, but only 32 percent was used in various applications such as in concrete, structural fills, waste stabilisation/solidification, etc. Worldwide, the estimated production of coal ash in 1998 was more than 390 million tons. The main contributors for this amount were China and India. Only about 14 percent of this fly ash was utilized, while the rest was just disposed in landfills. By the year 2010, the amount of fly ash produced worldwide is estimated to be about 780 million tons annually.

II. NECESSITY OF UTILIZATION OF FLY ASH IN CONCRETE

In India 65% power generation are coal based. At present 72 power plants produce around 100 million tones of fly ash per year and only 13% being currently used. It highly heterogeneous material as individual fragments of pulverized coal, suspended in hot air, moving rapidly through brief exposure to high temperature. It affects the human health if present in large amount. It is an air pollutant. The large amount of fly ash is being pumped into the sea, after mixing with sea water this water material produces several heavy metal which represents potential danger to the environment. When it disposed in open areas or into sea it creates dust problem and seepage of heavy metal into ground water. Where fly ash collection system are not very efficient a portion of it escapes into atmosphere causing environmental pollution. Although accurate data about the influence of the polluted atmosphere on the state of health of person inhabiting the vicinity of the power station is not available cases of pulmonary diseases including asthma, silicosis are found to be on the increase. In recent time, the importance and use of fly ash in concrete has grown so much that it has almost become a common ingredient in concrete, particularly for making high strength and high performance concrete. Extensive research has been done all over the world on the benefits that could be accrued in the utilization of fly ash as a supplementary cementitious material. High volume fly ash concrete as a subject of current interest all over the world.The use of fly ash a concrete admixture not only extends technical advantages to the properties of concrete but also contributes to the environmental pollution control. In India alone, we produce about 100 million tones of fly ash per year, the disposal of which has become a serious environmental problem. The effective utilization of fly ash in concrete making is, therefore attracting serious considerations of concrete technologies and government departments.

III. CHEMICAL COMPOSITION CLASS F FLY ASH

The use of fly ash has additional environment advantages. The annual production of fly ash in Australia in 2007 was approximately 14.5 million tonnes of which only 2.3 million tonnes were utilized in beneficial ways; principally for the partial replacement of Portland cement . Development of geopolymer technology and applications would see a further increase in the beneficial use of fly ash, similar to what has been observed in the last 14 years with the use of fly ash in concrete and other building materials

Oxides	Quantity (%)
SiO_2	50.18
Al_2O_3	26.31
Fe_2O_3	13.68
CaO	2.63
MgO	1.29
SO_3	0.02
Na_2O	0.32
K_2O	0.53
TiO	1.66
SrO	0.30
P_2O_5	1.55
Mn_2O_3	0.09

IV. ALKALINE LIQUIDS

1 Sodium Hydroxide :-

Generally the sodium hydroxides are available in solid state by means of pellets and flakes. The cost of the sodium hydroxide is mainly varied according to the purity of the substance. Since our geopolymer concrete is homogenous material and its main process to activate the sodium silicate, so it is recommended to use the lowest cost i.e. up to 94% to 96% purity. In this investigation the sodium hydroxide pellets were used. Whose physical and chemical properties are given by the manufacturer is shown in Table 1 and 2.

Table 1: Physical Properties Sodium hydroxide

Colourless	Sp. gravity
20%	1.22
30%	1.33
40%	1.43
50%	1.53

Sodium hydroxide pellets are taken and dissolved in the water at the rate of 16 molar It is strongly recommended that the sodium hydroxide solution must be prepared 24 hours prior to use and also if it exceeds 36 hours it terminate to semi solid liquid state. So the prepared solution should be used within this time

2 Sodium Silicate :-

Sodium silicate is also known as water glass or liquid glass, available in liquid (gel) form. In present investigation sodium silicate 2.0 (ratio between Na2O to SiO2) is used. As per the manufacture, silicates were supplied to the detergent company and textile industry as bonding agent. Same sodium silicate is used for the making of geopolymer concrete. The chemical properties and the physical properties of the silicates are given the manufacture is shown as below :-

Assay	-97%
MinCarbonate	-2% Max
Chloride (Cl)	-0.01% Max
Sulphate	-0.05% Max
Lead (Pb)	-0.001% Max
Iron (Fe)	-0.001% Max
Potassium (K)	-0.1% Max
Zinc (Zn)	-0.02% Max

V. GEOPOLYMER CONCRETE MIX DESIGN

ILLUSTRATION:-

An example illustrating the mix design for a Geopolymer concrete of M 30 grade is given below:

Design stipulations :-

a)Characteristic compressive strength required
at age of=30 Mpa

b)Maximum size of aggregate(angula)= 20mm

c)Specific gravity of fly ash=1.9

d)Specific gravity of coarse aggregate=2.8

e)Specific gravity of fine aggregate=2.78

f)Sand conforming =zone III

g)Specific gravity of NaOH=1.45

h)Specific gravity of Na_2SiO_3=1.58

SOLUTION;

Step 1:

Selection of fly ash to the compressive ratio

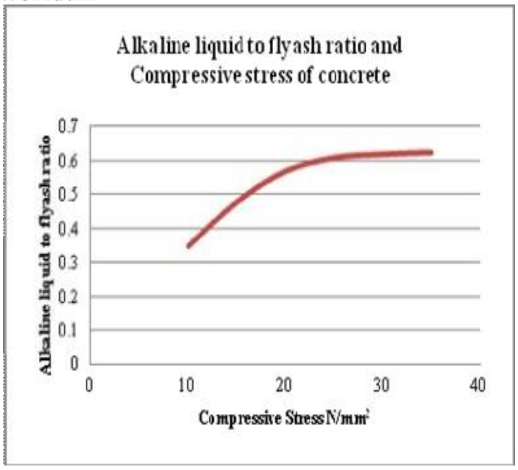
Taking the amount of fly ash for M30 grade

=500 Kg/m3

Step 2:

Selection of alkaline liquid ratio

Figure.;Generalised relation between free alkaline liquid to fly ash ratio and compressive strength of concrete.The amount of alkaline liquid required accordance to compressive stress from the below Figure.



Step 3:

The amount of Alkaline liquid = 0.61 x fly ash content =0.61 x 500 = 305 Kg/m3

Amount of Sodium silicate Solution = 217.86 Kg/m3

Amount of Sodium Hydroxide Solution = 87.14 kg/m3

Step 4:

Morality to be used in the concrete is 16 molar in which 444 grams of NaOH solids dissolved in 556 grams of water.

Solids = 38.69 kg/m3

Water = 48.45 kg/m3

Sodium hydroxide to sodium silicate ratio accordance to compressive Strength

Step 5:

Selection of water content

The maximum water content and the minimum water content to be added extra is 0.06 and 0.02 water to fly ash ratio respectively. According to workability extra water can be added this is due to fly ash is arrived from various plant which have different properties in absorption of water in order to match extra water is added. Amount of water add extra 0.03 to water fly ash ratio = 0.03 x 500 = 15 kg/m3

Step 6:

Determination of aggregate content

The total aggregate content per unit volume of concrete may be calculated from the following equations:

$$V = \left[\frac{SO}{S_{SO}} + \frac{S}{S_S} + \frac{F}{S_F} + \frac{1\ F_a}{P\ SF_a}\right] \frac{1}{1000}$$

FINEAGGREGATE:-

Fa = 486.86 Kg / m3

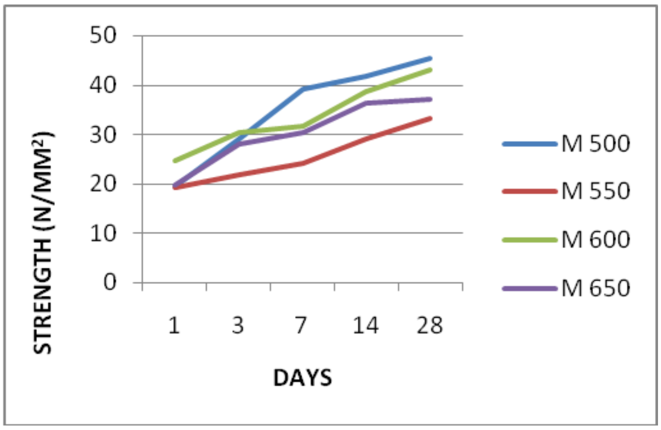
$$V = \left[\frac{SO}{S_{SO}} + \frac{S}{S_S} + \frac{F}{S_F} + \frac{1\ C_a}{(1-P\ SC_a)}\right] \frac{1}{1000}$$

COURSE AGGREGATE : Ca

= 1011.17 Kg / m3

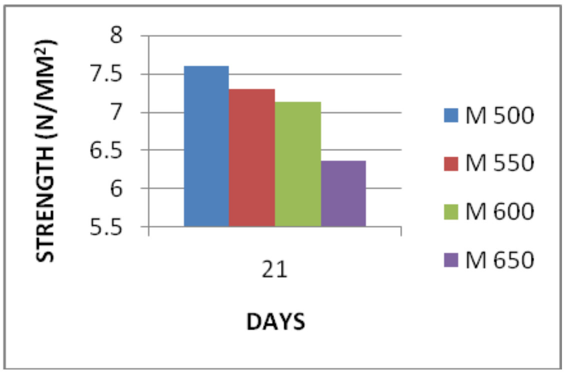
VI. RESULTS GRAPH OF FLY ASH BASED GEOPOLYMER CONCRETE

COMPRESSIVE STRENGTH :-



In experimental work for geopolymer concrete design we have taken IS method for mix design. In which four trials are taken with 16 molar sodium hydroxide concentration i.e. M 500,M 550,M 600,M 650. In which we have changed the variation in the fly ash content. In this we have taken tests for 1,3,7,14,28th days. At 1st day mix M 600 got the maximum strength but after 28th day it gets lower strength than M 500. The compressive strength of M 500 after 28 days is 45.28 N/mm2.

TENSILE STRENGTH :-



From the of tensile strength we get that the strength of M500 is 7.6 N /mm2 at 21st day which is higher than other proportion .For the ordinary concrete it is 3 to 5 N /mm2

VII. CONCLUSIONS

The report presented information on heat – cured fly ash based geopolymer concrete. Low-calcium fly ash is used as the sources material instead of the port land cement to make effective concrete. Geopolymer concrete cubes and cylinders were made and tested. The test result were compared with the prediction of the methods of calculations available for Portland cement concrete and the design provision given in the Indian Standard for concrete structure.

Based on test results, the following conclusions are drawn:

1. The geopolymer concrete achieves 50% to 75% compressive strength within 1 day of heat curing.

2. The tensile strength of geopolymer concrete is comparatively more than the ordinary concrete, it is 7.60 N / mm2 for M 30 design stregth of geopolymer concrete.

3. The strength of geopolymer concrete increases with increase in molarity of sodium hydroxide solution.
4. The geopolymer concrete is lighter in weight as compared to ordinary concrete.
5. Individually geopolymer concrete is costly due to the alkaline liquid (sodium silicate & sodium hydroxide) but if we consider the Carbon Credit the geopolymer concrete is economical.
6. The strength of geopolymer concrete increases with increase in curing temperature as well as duration.

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