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REVIEW ON STRENGTH BEHAVIOR OF FLY ASH-BASED GEOPOLYMER CONCRETE WITHOUT USING PORTLAND CEMENT

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Abstract

Geopolymer is a class of aluminosilicate binding materials synthesized by thermal activation of solid aluminosilicate base materials such as fly ash, with an alkali metal hydroxide and silicate solution. The geopolymer was activated with sodium hydroxide, sodium silicate and heat. The grade chosen from the investigation were M-25, the mix were designed for14 molarity. The alkaline solution used for present study was the combination of sodium silicate and sodium hydroxide solution with the varying ratio of 2, 2.50, 3, 3.50, and 4. The test specimens were 150x150x150 mm cubes are heat cured at 100°C in an oven and mortar specimens are of size 75x75x75 mm cured at varying temperature. The results revealed that the workable flow of geopolymer concrete was dependent on the mass of sodium silicate and sodium hydroxide. The freshly prepared geopolymer mixes were cohesive and their workability increased with the increase in the ratio of alkaline solution.

The strength of geopolymer concrete can be improved by decreasing the water/binding and aggregate /binding ratio. The curing period improves the polymerization process resulting in higher compressive strength. The geopolymer concrete do not have any Portland cement, they can be considered as less energy interactive. It utilizes the industrial wastes such as fly ash or producing the binding system in concrete. After study it was found that compressive strength of GP concrete cube was found to be at a maximum at ratio of sodium silicate to sodium hydroxide 4.

Index Terms: Fly ash-based geopolymer, alkaline solution, compressive strength,*etc.*

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1. INTRODUCTION

In the view of global warming efforts are on to reduce the emission of CO2 to the environment. Cement Industry is major in contributor in the emission of CO2 as well as using up high levels of energy resources in the production of cement. By replacing cement with a material of pozzolanic characteristic, such as the fly ash, the cement and the concrete industry together can meet the growing demand in the construction industry as well as help in reducing the environmental pollution. India is a resourceful country for fly ash generation with an annual output of over 110 million tones, but utilization is still below 20% in spite of quantum jump in last three to four years.

Availability of consistent quality fly ash across the country and awareness of positive effect of using fly ash in concrete are pre requisite for change of perception of fly ash from a waste material to a resource material. Technological efforts have been made to improve the quality of fly ash. At present most of the power plants are using Electro Static Precipitators (ESP) through which fly ash is collected in different chambers according to its particle size. To study the impact of replacement of cement by fly ash on the properties of concrete, experiments were conducted on different concrete mixes. In terms of global warming, the geopolymer technology could significantly reduce the CO2 emission to the atmosphere caused by the cement industries.

2. EXPERIMENTAL WORK

2.1 MATERIALS

In the proposed mix proportioning method, low calcium processed fly ash of thermal power plant was used as source material. The laboratory grade sodium hydroxide in flake form (97.8 % purity) and sodium silicate (50.72 % solids) solution are used as alkaline activators. Locally available river sand is used as fine aggregate and locally available 20 and 12.5 mm sizes crushed basalt stones are used as coarse aggregates.

2.2 PARAMETERS CONSIDERED FOR MIX PROPORTIONING OF GEOPOLYMER CONCRETE

For the development of fly ash based geopolymer concrete mix design method, detailed investigations have been carried out and following parameters were selected on the basis of workability and compressive strength.

2.2.1 FLY ASH

Quantity and fineness of fly ash plays an important role in the activation process of geopolymer. It was already pointed out that the strength of geopolymer Concrete increases with increase in quantity and fineness of fly ash. Similarly Higher fineness shows higher workability and strength with early duration of heating. So, the main emphasis is given on quantity and fineness of fly ash in the development of mix proportioning procedure of geopolymer concrete. So, in the proposed mix design procedure, quantity of fly ash is selected on the basis of fineness of fly ash and target strength.

2.2.2 ALKALINE ACTIVATORS

In the present investigation, sodium based alkaline activators are used. Single activator either sodium hydroxide or sodium silicate alone is not much effective as clearly seen from past investigation. So, the combination of sodium hydroxide and sodium silicate solutions are used for the activation of fly ash based geopolymer concrete. It is observed that the compressive strength of geopolymer concrete increases with increase in concentration of sodium hydroxide solution and or sodium silicate solution with increased viscosity of fresh mix. Due to increase in concentration of sodium hydroxide solution in terms of molarity (M) makes the concrete more brittle with increased compressive strength. Secondly, the cost of sodium hydroxide solid is high and preparation is very caustic. Similarly to achieve desired degree of workability, extra water is required which ultimately reduce the concentration of sodium hydroxide solution. So, the concentration of sodium hydroxide was maintained at 14 M while concentration of sodium silicate solution contains Na_2O of 16.37 %, SiO_2 of 34.35 % and H_2O of 49.72 % is used as alkaline solutions. Similarly, sodium silicate-to-sodium hydroxide ratio by mass was varied and solution to fly ash ratio considered as 0.35. which set cubes within 24 h after casting and study of workability, density and compressive strength of mix

2.2.3 WATER

From the chemical reaction, it was observe that the water comes out from the mix during the polymerization process. The role of water in the geopolymer mix is to make workable concrete in plastic state and do not contribute towards the strength in hardened state. Similarly the demand of water increases with increase in fineness of source material for same degree of workability. So, the minimum quantity of water required to achieve desired workability is selected on the basis of degree of workability, fineness of fly ash and grading of fine aggregate.

2.2.4 AGGREGATES

Aggregates are inert mineral material used as filler in concrete which occupies 70–85 % volume. So, in the preparation of geopolymer concrete, fine and coarse aggregates are mixed in such a way that it gives least voids in the concrete mass. This was done by grading of fine aggregate and selecting suitable fine-to-total aggregate ratio. Workability of geopolymer concrete is also affected by grading of fine aggregate similar to cement concrete. So, on the basis of grading of fine aggregate, fine-to-total aggregate ratio is selected in the proposed mix.

2.2.5 DEGREE OF HEATING

For the development of geopolymer concrete, temperature and duration of heating plays an important role in the activation process. In the present investigation n, cubes were demoulded after 24 h of casting and then place in an oven for heating at 100 °C for a period of 24 h. After specified degree of heating, oven is switched off and cubes are allowed to cool down to room temperature in an oven itself. Then compression test is carried out on geopolymer concrete cubes after a test period of 7 and 28 days. Test period is the period considered in between testing cubes for compressive strength and placing it in normal room temperature after heating. It is observed that the compressive strength of geopolymer concrete increases with increase in duration and test period. From the design point of view, 24 h of oven curing at 100 °C and tested after a period of 7 and 28 days was fixed as per past research.

2.2.6 SOLUTION TO FLY ASH RATIO

As solution (i.e. sodium silicate + sodium hydroxide) to fly ash ratio increases, strength is also increases. But the rate of gain of strength is not much significant beyond solution to fly ash ratio of 0.35. Similarly the mix was more and more viscous with higher ratios and unit cost is also increases. So, in the present mix design method, solution-to-fly ash ratio was maintained at 0.35, 0.45, and 0.60.

2.2.7 CURING PROCESS

Setting time of geopolymer depends on many factors such as composition of alkaline solution and ratio of alkaline liquid to fly ash by mass. However, the curing temperature is the most important factor for geopolymer. As the curing temperature increases, the setting time of concrete decreases. During curing process, the geopolymer concrete experience polymerization process. Due to the increasing of temperature, polymerization become more rapid and the concrete can gain 70% of its strength within 3 to 4 h of curing.

3.0. PROPERTIES OF GEOPOLYMER

3.1 WORKABILITY OF FRESH GEOPOLYMER

Water also play important role in geopolymer concrete as much as normal concrete. The used of water in geopolymer is to improve the workability, but it will increase the porosity in concrete due to the evaporation of water during curing process at elevated temperature. To improve the workability of mortar, superplasticiser or extra water can be added. However, the use of superplasticiser had an adverse effect on the strength of geopolymer. As such, extra water gives higher strength than addition of superpsticiser.

3.2 COMPRESSIVE STRENGTH

Compressive strength is an essential property for all concrete where it also depends on curing time and curing temperature. When the curing time and temperature increases, the compressive strength also increases. With curing temperature in range of 60 to 100 ℃, within tie in 24 to 72 h, the compressive strength of concrete can be obtained about 35 to 45 n/mm2. In addition, the compressive strength of geopolymer also mainly depended on the content of fly ash fine particles (smaller than 43um). The compressive strength was increase when the finest of fly ash increase. Hence the nature and the concentration of the activators were dominant factors in the reaction of alkali activation. The highest compressive strength was obtained using a solution of sodium silicate as an activator . Sodium silicate is the most suitable as alkaline activator because it contains dissolved and partially polymerized silicon which reacts easily, incorporates into the reaction products and significantly contributes to improving the mortar characteristics.

3.3 RESISTANT TO HEAT AND COLD

It has the ability to stay stable even at temperatures of more than 2200 degrees Fahrenheit. Excessive heat can reduce the stability of concrete causing it to spall or have layers break off. Geopolymer concrete does not experience spalling unless it reaches over 2200 degrees Fahrenheit. As for cold temperatures, it is resistant to freezing. The pores are very small but water can still enter cured concrete. When temperatures dip to below freezing that water freezes and then expands this will cause cracks to form. Geopolymer concrete will not freeze.

3.4 VERY LOW CREEP AND SHRINKAGE

Shrinkage can cause severe and even dangerous cracks in the concrete from the drying and heating of the concrete or even the evaporation of water from the concrete. Geopolymer concrete does not hydrate; it is not as permeable and will not experience significant shrinkage. The creep of geopolymer concrete is very low. When speaking of creep in concrete terms it means the tendency of the concrete to become permanently deformed due to the constant forces being applied against it.

3.5 CHEMICAL RESISTANCE

It has a very strong chemical resistance. Acids, toxic waste and salt water will not have an effect on geopolymer concrete. Corrosion is not likely to occur with this concrete as it is with traditional Portland concrete.

3.6 RESISTANCE AGAINST AGGRESSIVE ENVIRONMENT

In acidic exposure, high-performance geopolymer materials Detroiter with the formation of fissures in amorphous polymer matrix, while low-performance geopolymer through crystallization of zeolites and formation of fragile grainy structures. The formation of aluminosilicate gel is important to determine the stability of geopolymer. More hydroxide was more stable in the aggressive environment of sulfuric and acetic acid solutions than amorphous geopolymer prepared with the sodium silicate activator.

The geopolymer mortar in 10% sulfuric acid and found specimen still intact and did not show any recognizable change in colour after 18 weeks. When observed under optical microscope the exposed surface a reveled a corroded structure and it progressivity time of exposure. in addition, the weight loss result obtained in the study showed better performance than OPC and the specimen with higher alkali content were observed to lose more weight than specimens with lower alkali content. Specimens with varying alkali content showed varying degree of deterioration when exposed to sulfuric acid.

4. TRIAL MIX OF M-25 GRADE SUSTAINABLE GEOPOLYMER CONCRETE

The GPC mix design used in study was based on M-25 grade of concrete. The mix proportion for casting the concrete specimen are calculated with fine aggregate and course aggregate. The alkaline to binder ratio is taken as 0.35 and molarities of sodium hydroxide are taken as 14M. While the rest of the components are varied according to the requirements of optimization method. Sample calculations for a mix design are shown in table.1.

Table-1: Mix proportion of Geopolymer concrete

MIX PROPORTION FOR 6 CUBES OF GPC(1:1:2:0.35:0.20)	
Sodium Silicate	3.295 kg
Sodium Hydroxide Solution	1.138 kg
Extra Water Required	2.66 kg
Fly Ash	13.18 kg
Fine Aggregate	13.18kg
Course Aggregate	26.37 kg

5.0 RESULTS

5.1COMPARISION BETWEEN COMPRESSIVE STRENGTH OF ORDINARY CONCRETE AND GEOPOLYMER CONCRETE

The compressive strength of fly ash-based geopolymer concrete is high as compare to the ordinary Portland cement concrete

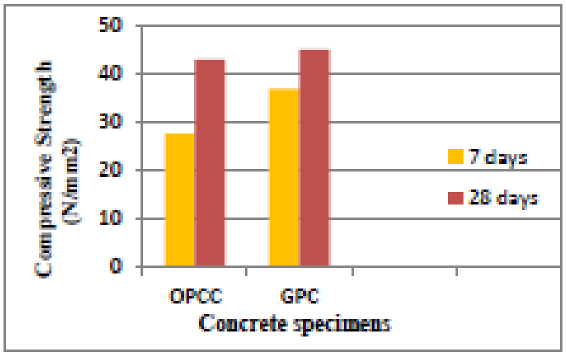

Fig.1 Comparison between 7 and 28 days Compressive strength of ordinary Portland cement concrete and geopolymer concrete

5.2 RATIO OF ALKALINE LIQUID TO FLY ASH.

Three concrete mix-1, mix-2 and mix-3 with the alkaline liquid to fly ash ratio 0.35, 0.4 and 0.6 have been cast using the ingredients. The effect of alkaline liquid to fly ash ratio by mass on compressive strength of concrete at age 7 days has been evaluated by comparing results of both the Mixes. The results are presented in fig.2. It has been observed that the ratio of alkaline liquid to fly ash, by mass, is not much effective in varying the compressive strength of the geopolymer concrete.

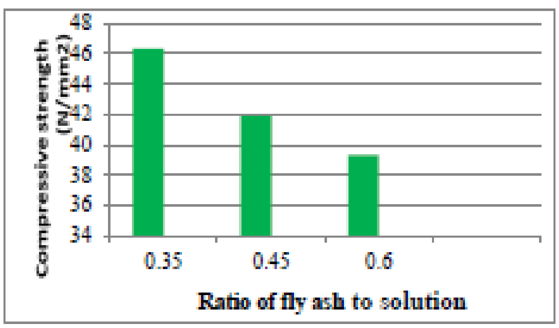

Fig.2 Effect of varying alkaline liquid to fly ash ratio on 7 days compressive strength

5.3 RATIO OF SODIUM SILICATE SOLUTION TO SODIUM HYDROXIDE SOLUTION

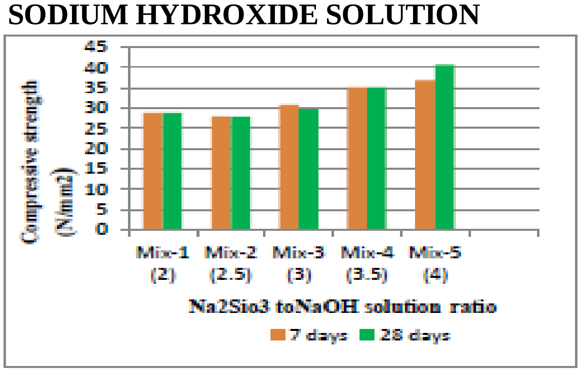

Fig.3 Effect of sodium silicate to sodium hydroxide ratio on compressive strength on GPC

The effect of sodium silicate to sodium hydroxide by mass on compressive strength of concrete has been observed by comparing results of Mix-1, Mix-2, Mix-3, Mix-4 and Mix-5 having ingredients. The results are presented in fig.3. Higher compressive strength has been observed in concrete in Mix-5 as compare to that of concrete Mixes.

5.4 COMPRESSIVE STRENGTH OF GEOPOLYMER MORTAR ON VARYING THE CURING TEMPERATURES

Compressive strength of geopolymer mortar specimen increases with decreasing the curing temperature. The maximum value is obtained at temperature 60°c.

Table.2 Compressive strength test on geopolymer mortar specimens at 7 days varying the curing temperature

6.0 CONCLUSIONS

1. The fly ash can be used to produce geopolymeric binder phase which can bind the aggregate system consisting of sand and course aggregate to form geopolymer concrete. Therefore these concretes can be considered as Eco-friendly materials.
2. The fresh mortar mixture was grayish in colour and was very cohesive. As expected the mixture becomes more workable with the increase of fluid to fly ash ratio.
3. The optimum dosage for alkaline solution which is used the geopolymer binder can be considered as 4, because for that ratio, the GPC specimens produced maximum compressive strength.
4. It was found that geopolymer concrete has good engg properties with reduced global warming potential resulting from the total replacement of OPC.
5. With the increase in concentration of activator fluid, mix becomes less workable due to the less amount of available free water in the mixture. It may also be noted that with the increase in mixing time, the mixture becomes more workable and compactable. The fresh mortar can be easily handed up to 60-90 minutes easily and doesn't show any exothermic action at green stage.
6. Reduce the emission of carbon dioxide to the atmosphere.
7. Sulphate resistance and free from any chemical attack.

References

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