"Geopolymer Mortar"– The Greener Future of Construction

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ABSTRACT

Cement is being used as a binder from many years in a construction industry. Though it is playing role of an excellent binder; it is associated with lot of hidden problems that are not directly visible but causing unacceptable toll on the environment. Geopolymer binder is a newly invented binder that is associated with the utilization of the industrial raw material and alkaline activators. The results are analyzed by testing the mortar cubes of 70.7 mm X 70.7 mm cubes; using natural sand as well as crushed sand. The mortar cubes are tested after adopting different methods of curing. The conclusion got was showing positive results in all respects as compared to traditional cement mortar cubes.

Key Words: fly ash, geopolymer, alkline activators, crushed sand.

1. INTRODUCTION

Today the construction industry is the leading tool for any country to become a developed platform on the global level. The construction industry is mainly dependent on its raw materials like binders and fillers. Binder are the materials that develops the bonding between fillers; while fillers are the materials which are not taking part in any chemical reaction but with the help of binder it becomes a solid material which called as concrete. Cement is a traditional binder since many years which is technically known as Ordinary Portland Cement (OPC). The survey reports of Statista shows that about 2.7 billion m3 of concrete was manufactured in 2002 globally, which was more than 0.4 m^3 of concrete generated per person once a year. It is predicted that the requirement for concrete will increase further to almost 7.5 billion m^3 (about 18 billion tons) a year by 2050.

Concrete is the most extensively used construction material in the world and stands after consumption of water. Such an enormous utilization of concrete affects on availability of natural aggregates and cement manufacturing process. It has hazardous impact on the environment. Increasing rate of urbanization and industrialization has lead to over exploitation of natural resources such as river sand and gravels, which is giving rise to sustainability issues.

The concrete contains OPC as a binding material. OPC is responsible for nearly 5-8 % of the total Carbon Dioxide (CO_2) emission; which works as a green house gas and also heavily responsible for the Global Warming. [8]

1.1 Industrial waste generation

The industrial development of any country is the key for its speedy development in financial and other important sectors. Following data were collected from the Central Elecricity Authority, New Delhi.

As per the report of fly ash generation around 40 % of the fly ash which is nearly 74 million tons of fly ash remains as it is and the utilized quantity of fly ash is for the application of dumping in dead mines, filling material in road work and lake filling etc; which is absolutely not an environmental friendly solution.

The fly ash is a residue after total burning of Lignite based coal. The fly ash is highly alkaline having average pH of 11-13; which is not in an acceptable limit of directly disposing it in open ground or soil.

As fly ash is highly alkaline and it is being used as a filling material for dead mines and road work it is causing tremendous hazards on many factors of the environment like polluting ground water sources, soil pollutions, damaging fertility of soil and lot more.

1.2 Geopolymerization

"Geopolymer" was introduced by "Joseph Davidovits" in 1978; he identified that the alkaline metals can react with the Si-Al rich materials and produces 3 dimensional alumino-silicate complexes with having strong binding property of Al-Si elements. After analyzing the fly ash it was observed that the fly ash is rich in silica and alumina content. The fly

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ash is also reactive in nature at room temperature hence there is no need of special arrangements for temperature change in geopolymer reaction.

1.4 Materials and methods

For completion of Geopolymerization process any reactive agent having high quantity of silica-aluminium is required along with alkali activators which will react with silica to form alumino-silicate binders and water as a byproduct.

1.5 Characteristics of materials

Fly ash sample

This sample of ash was collected from the thermal power plant, Ratnagiri. The physical and chemical characteristics were studied in institute laboratory and NAR pvt Ltd.,Sangli. The obtained results of the sample – 1 fly ash were as follows;

Table 1 - Chemical Characteristics of FlyAsh

Chemical tests	***Observation***
SiO_2 Content	81.41 %
CaO Content	0.39%
Ph (PH Meter)	11.5
Al_2O_3 Content	10.39 %

Natural Sand

Natural sand is used as fine aggregate in mixture; it is also known as river sand in local language. Now there are lots of problems on the river basin and water structure due to over extraction of natural sand from the river bed. There is need of finding some alternative to natural sand.

Followings are the characteristics of natural sand.

Table 2 - Physical Characteristics of Natural Sand

Characteristics	***Observations***
Gradation	4.75mm – 150 microns
Shape	Rounded Grains
Sp.Gravity	2.38

Crushed Sand

Crushed sand is used as fine aggregate in mixture; it is also known as manufactured sand which is a byproduct in stone crushers. Crushed sand can be a better option for natural sand there is comparative analysis in between natural and crushed sand in this research.

Followings are the characteristics of crushed sand.

Table 3- Physical Characteristics of Crushed Sand

Characteristics	***Observations***
Gradation	4.75mm – 150 microns
Shape	Flaky
Sp.Gravity	2.7

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Sodium Silicate –

Sodium silicate is highly used in textile, paper and soap industry. Same chemical is used in the research work. This chemical is also known as "alkaline-sodium silicate" in local language; this chemical is non-hazardous to the environment. which is having following characteristics

Table 4 - Chemical Characteristics of Sodium Silicate

Compound	***% by mass***
Na_2O	14.7
SiO_2	29.4
H_2O	55.9
Form	Gel
Color	Light yellow

Sodium Hydroxide –

Sodium Hydroxide releases high amount of heat when mixed with water hence it is recommended to prepare the sodium hydroxide solution 24 hours prior to mix with fly ash which will help to get the solution at normal temperature. Followings are the characteristics of the sodium hydroxide solution;

Table 5 - Characteristics of Sodium Hydroxide

Characteristics	***Observations***
Color	White
Form	Flakes
Molecular Weight	40
Molarity	16 Molar

2. EXPERIMENTLE PROGRAMME

The mortar cubes were casted of size 70.7 X 70.7 mm. 3 cubes of each sample mix were casted and final results were drawn from their mean values. The fine aggregates used were Natural sand and Crushed Sand.

The results of compressive strength were checked after 3 days of hot air oven curing and after 7 days of ambient temperature curing.

1.1 Preparation of Alkaline activators

The sodium hydroxide solution of 16 molar concentrations was prepared 24 hours prior to mixing with sodium silicate to normalize its temperature. The ratio of Sodium silicate to Sodium Hydroxide was kept as 2.5 in all mixes. The quantity of alkaline activators was kept as 55% by weight of fly ash.

Both chemicals were mixed together just prior to mixing with the fly ash to avoid improper bonding.

1.2 Preparation of Mix

The ratio of fine aggregate to fly ash was kept constant as 70:30 by weight. The extra water added in the mix was 0.06 times (6%) of weight of fly ash. Dry mixing of Fly ash and fine aggregate in the required proportion and followed by mixing of two alkali solutions with dry mix along with extra water.

1.3 Curing method

By considering the availability of the equipments and economy hot air oven curing and ambient temperature curing were selected for the research work.

Rest Day Curing- This is another way of curing in which rest days are introduced between the day of casting and the starting day of curing.

For example; 3 Rest day cured (3RDC) means specimen is casted and kept 3 days as it is in normal environment and kept in oven for curing on 4th day.

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Aging- Aging is the process of allowing the cured cubes to lower its temperature at the normal level by keeping it in open atmosphere.

3. RESULT AND DISCUSSION

There are 3 mix samples were designed with various replacements. These are elaborated in tabular format as below;

Table 6 - Composition of Mixes

Mix	*Fly ash Kg/m3*	*Activators%*	*Type of fine aggregate*	*Replacement Qty.*
Mix A	400	55	Natural Sand (NS)	100 %
Mix B	400	55	Crushed Sand (CS)	100%
Mix B	400	55	NS + CS	50% + 50%

Above table shows the percent contribution of fine aggregate as crushed sand and natural Sand. The quantity of fly ash and the alkali activators were kept constant that is 400 kg/m^3 and 55% of weight of fly ash respectively.

Table 7 - Quanities of Materials

	Quantities in Kg/m3		
Mix	*Alkaline Activators Kg/m3*	*Natural Sand*	*Crushed Sand*
Mix A	220	1334 Kg	0 Kg
Mix B	220	0 Kg	1334 Kg
Mix C	220	667 Kg	667 Kg

Above tables shows the exact quantities of the various materials in the different mixes. Mix A is composed of pure natural sand while Mix B is composed of pure crushed sand. Similarly Mix C is composite mix of crushed sand and Natural sand by 50-50% weight.

Followings are the results of compressive strength test carried out with 3 rest day hot air oven curing and 7 days ambient temperature curing of various mix designs.

Table 8 - Compressive Strength and Weight

	Compressive Strength in MPa		*Weight in Grams*	
Mix	*3RDC*	*7DAC*	*3RDC*	*7DAC*
Mix A	8.40	15.44	658	740
Mix B	9.33	17.90	745	788
Mix C	8.76	16.34	703	767

3RDC- 3 rest days curing, 7DAC -7 days ambient curing

Results in above table show large variance; when change occurs in the curing method and material composition. The Mix B gives the highest strength that is of 17.9 MPa which contains pure crushed sand and fly ash.

The weight comparison of the geopolymer cubes and cement cubes also shows positive results; the weights of geopolymer cubes are affected by the method of curing and change in the material composition.

4. CONCLUSION

It is possible to form a binder that is compatible with traditional cement binder with the utilization of industrial waste.

After analyzing the results of compressive strengths of all mixes it is found that the higher compressive strength can be achieved by use of crushed sand as fine aggregate due to its high flakiness value.

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To achieve better strength the geopolymer mix should be cured in ambient temperature which will reduce its manufacturing cost.

The geopolymer cubes are around 20 % less weighted than that of cement cubes having same proportion.

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