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GEOPOLYMER CONCRETE BASED ON RICE HUSK ASH

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Abstract: **Concrete is an essential building material is widely used in the construction of infrastructure such as buildings, bridges, highways, dams, and many other facilities. Cement the second most consumed product after the water in the world. Geopolymer concrete (GPC) is manufactured using industrial waste having Silica and alumina like fly ash, Red mud, RHA paper ash etc. which is consider as more economical and eco-friendly alternative to OPC based Concrete.**

The feasibility of production of GPC using Rice Husk Ash (RHA) is evaluated in this study. Additionally the initial and final setting time of Geopolymer paste based on RHA is also studied. For this Study the molarity of NAOH is kept constant that is M16and the alkaline solution ratio is 1:1.85 and alkaline solution to source material is 0.7 & 0.8. Study Show that Geopolymer concrete based on RHA gives good compressive and flexural strength as compare to Ordinary Portland Cement Concrete at different mix.

Keywords: **Geopolymer concrete (GPC), Rice Husk Ash (RHA), buildings, bridges, highways.**

1. INTRODUCTION

Concrete is an essential building material which is widely used in the construction of infrastructure such as buildings, bridges, highways, dams and many other facilities. Cement is one of the ingredients usually used as a binder in Concrete. The world-wide demand for Cement to meet infrastructure developments indicates that concrete will continue to be a chosen material of construction in the future. It is well known that cement production depletes significant amount of natural resources and releases large volumes of carbon-dioxide. Cement production is also highly energy-intensive, after steel and aluminium. On the other hand, Rice Husk burning produces huge quantities of Rice Husk Ash. The annual rice husk ash produce in India amounts is generally approximately 120 million tones. Most of the Rice Husk Ash is considered as waste and dumped in landfills.Cement concrete industry has grown astronomically in recent years; it will continue to grow as the result of continuous urban development.

Although the use of Cement is still unavoidable until the foreseeable future, many efforts are being made in order to reduce the use ofCement in concrete.These efforts include the utilisation of supplementary cementing materials such as Rice Husk Ash, fly ash, silica fume, granulated blast furnace slag, metakaolin etc. and finding alternative binders toCement.Further, an environmentally compatible disposal of waste material by appropriate technologies is of increasing concern and imposes interesting technical challenges. Construction industry is the one where bulk utilization of waste materials can be effectively done without any compromise on quality performance. It has been established that Rice Husk Ash can replace cement partially.The geopolymer technology developed by Dr. Davidovits in the 1980s offers an attractive solution.

Geopolymer:-

Dr. Davidovits (1988; 1994) proposed that an alkaline liquid could be used to react with the silicon (Si) and the aluminium (Al) in a source material of geological origin or in by-product materials such as Rice Husk Ash, Fly Ash and Red Mud to produce binders.Because the chemical reaction that takes place in this case is a polymerization process, he coined the term ‘Geopolymer’ to represent these binders.

Geopolymer binders might be a promising alternative in the development of acid resistant concrete. Since Geopolymer are a novel binder that relies on alumina-silicate rather than calcium silicate hydrate bonds for structural integrity, they have been reported as being acid resistant.

Geopolymerization is a very complex multiphase exothermic process, involving a series of dissolution-reorientation-solidification reaction analogous to zeolite synthesis. High alkaline solutions are used to induce the silicon aluminium atoms in the source material to dissolve, forming three dimensional polymeric structure of –Si-O-Al-O- bonds, represented as follows:

$$Mn\,[-(SiO_2)z\text{-}AlO_2]n.\ w\,H_2O.$$

Where M is the alkaline element or cat-ion such as potassium, sodium or calcium:

The symbol – indicates the presences of a bond

n is the degree of polycondensation or polymerization:

z is 1, 2, 3, or higher.

The exact reaction mechanism which explains the setting and hardening of Geopolymers is not yet quite understood, although it is thought to be dependent on aluminosilicate based material as well as on the composition of alkaline activator.

Geopolymers are members of the family of inorganic polymers. The chemical composition of geopolymer material is similar to natural zeolitic materials, but the microstructure is amorphous. The polymerization process involves a substantially fast chemical reaction under alkaline condition on Si-OAl-O bonds.

2. MATERIALS

Rice Husk Ash

RHA, produced after burning of Rice husks (RH) has high reactivity and pozzolanic property. The annual rice husk ash produce in India amounts is generally approximately 120 million tones.Silica is the major constituent of rice husk ash and with such a large silica content in the ash it becomes economical to extract silica from the ash, which has wide market and also takes care of ash disposal. Indian Standard code of practice for plain and reinforced concrete, IS 456- 2000, recommends use of RHA in concrete but does not specify quantities. Chemical compositions of RHA are affected due to burning process and temperature. Silica content in the ash increases with higher the burning temperature. As per study by Houston, D. F. (1972) RHA produced by burning rice husk between 600 and 700°C temperatures for 2 hours, contains 90-95% SiO2, 1-3% K2O and < 5% unburnt carbon. Under controlled burning condition in industrial furnace, conducted by Mehta, P. K. (1992), RHA contains silica in amorphous and highly cellular form, with 50-1000 m^2/g surface area. So use of RHA with cement improves workability and stability, reduces heat evolution, thermal cracking and plastic shrinkage. This increases strength development, impermeability and durability by strengthening transition zone, modifying the pore-structure, blocking the large voids in the hydrated cement paste through pozzolanic reaction. RHA minimizes alkali-aggregate reaction, reduces expansion, refines pore structure and hinders diffusion of alkali ions to the surface of aggregate by micro porous Structure.

Portland cement contains 60 to 65% CaO and, upon hydration, a considerable portion of lime is released as free $Ca\,(OH)_2$, which is primarily responsible for the poor performance of Portland cement concretes in acidic environments. Silica present in the RHA combines with the calcium hydroxide and results excellent resistance of the material to acidic environments. RHA replacing 10% Portland cement resists chloride penetration, improves capillary suction and accelerated chloride diffusivity.

Pozzolanic reaction of RHA consumes $Ca\,(OH)_2$ present in a hydrated Portland cement paste, reduces susceptibility to acid attack and improves resistance to chloride penetration. This reduces large pores and porosity resulting very low permeability. The pozzolanic and cementitious reaction associated with RHA reduces the free lime present in the cement paste, decreases the permeability of the system, improves overall resistance to CO_2 attack and enhances resistance to corrosion of steel in concrete. Highly micro porous structure RHA mixed concrete provides escape paths for the freezing water inside the concrete, relieving internal stresses, reducing micro cracking and improving freeze-thaw resistance.

Large availability of RHA worldwide creates opportunity to utilize this by-product of Rice milling, as a substitute for OPC to manufacture concrete. Milling of paddy grain produce high quantities of Rice Husk Ash. Most of the Rice Husk Ash is considered as Waste.

Chemical composition of Rice Husk Ash is shown in Table 1.

Aggregate

Aggregate is a collective term for the mineral materials such as sand, gravel, and crushed stone that are used with a binding medium (such as water, bitumen, Portland cement, lime, etc.) to form compound materials (such as bituminous concrete and Portland cement concrete). By volume, aggregate generally accounts for about 70 to 80 percent of Portland cement concrete and about 70 to 75 percent of Geopolymer concrete.

Alkaline Liquid

The alkaline liquid used was a combination of sodium silicate solution and sodium hydroxide solution. The sodium hydroxide with 93-95% purity, in flake form was purchased from a local supplier. The solids dissolved in water to make a solution with the required concentration. The sodium silicate solution was also was purchased from a local supplier.

Sodium based alkaline solutions were used to react with the fly ash to produce the binder. Sodium-silicate solution was used for the concrete production. The chemical composition Sodium Hydroxide solution was prepared by dissolving Sodium Hydroxide pellets in water. The Sodium hydroxide solution was prepared one to two days prior to the concrete batching to allow the exothermically heated liquid to cool to room temperature. The Sodium Silicate solution and the Sodium Hydroxide solution were mixed just prior to the concrete batching.

OBJECTIVES

- To study the properties and chemical composition of Rice Husk Ash.
- To determine the Optimum percentage of alkaline solution ($NaOH + Na_2SiO_3$) in Rice Husk Ash for Geopolymer to be used.
- To determine the initial and final setting time of geopolymer.
- To check the Compressive & Flexural strength of Geopolymer concrete at 50°C curing temperature.

3. EXPERIMENTS AND RESULTS

Table 1: Chemical Composition of Rice Husk Ash

S.No.	Constituents	Percentage %
1	Loss of ignition	80-90
2	Total sulphur	1 – 2.5
3	Available Alkalies	0.5
4	Silica SiO_2	1 – 2
5	Silica Alumina ferric Oxide	0.5 – 2.0
6	Reactive Silica	0.2 – 0.5
7	Magnesium Oxide	0.2
8	Chloride	10 - 20

pecific Gravity of

- Rice Husk Ash = 1.83
- Sodium silicate = 1.354
- River sand = 2.62
- Coarse aggregates 20mm = 2.71

Preparation of Alkaline Solution

The sodium hydroxide (NaOH) solids were dissolved in water to make the solution. The mass depend on morality on solution.

The sodium hydroxide with 97-98% purity, in flake or pellet form, is commercially available. The solids dissolved in water to make a solution with the required concentration.

1M = 1000gm of water + 40gm NaOH (40= molecular wt.)

Hence, 12M Solution = 1000gm water + 40x12 NaOH

=1000gm water + 480gm NaOH

And 14M solution = 1000gm water + 14x40 NaOH

= 1000gm water + 560gm NaOH

In the present study the morality of NaOH solution is kept 14M for all specimens. The sodium silicate solution and the sodium hydroxide solution were mixed together at least one day prior to use to prepare the alkaline liquid.

Determination of Consistency, Initial and final setting time:-

The consistency of geopolymer paste was founded by Vicat apparatus. For this the M14 morality for sodium hydroxide solution was mixed with sodium silicate solution to make alkaline liquid one day prior. The 10 mm diameter plunger was used for test the percentage weight of alkaline solution to source material (i.e. Fly ash / Red mud) at which plunger penetrated 5 to 7 mm was known the required consistency.

Table 2: Consistency, Initial and final setting time of Geopolymer

Consistency%	Initial Setting time (Min.)	Final setting time(Min.)
70	50	120

Table 3: Compressive strength of Rice Husk Ash based Geopolymer mortar

S.N.	RHA	SAND	*A:RHA	Alkaline Ratio	Strength	
	Ratio			NaOH : Na2SiO3	3 days	7 days
1	1	3	0.8:1	1:1.85	19.8	27.5
2	1	3	0.7:1	1:1.85	20.6	28.2
3	1	4	0.8:1	1:1.85	18.6	25.8
4	1	4	0.7:1	1:1.85	17.1	24.3
5	1	5	0.8:1	1:1.85	16.5	24
6	1	5	0.7:1	1:1.85	16.2	23.6

Manufacturing of Concrete

The source material (FA /RM) and Aggregates are mixed together as conventional concrete is mixed. The alkaline solution is mixed in the dry materials is required water is added. The fresh concrete was cast into the moulds immediately after mixing.

Curing of Specimen

After casting, the test specimens were kept for heat-cured at 60^{o}C for 24 hours. After the curing period, the test specimens were left in the moulds for at least six hours in order to avoid a drastic change in the environmental conditions. After demoulding, the specimens were left to air-dry in the laboratory until the day of test.

Compressive Strength Test

The compressive strength test is conducted on the 2000KN capacity compressive testing machine according to IS: 516-1959. The specimens used for this test are 150 X 150 X 150 mm cubes.

Compressive strength test is carried out on the various mixes with red mud, fly ash and keeping all parameters constant. The main objective of conducting the tests on various mixes is to find out the most suitable mix of having higher compressive strength.

Table 4: Compressive strength of Red mud based Geopolymer Concrete

S.N.	Ratio			*A/RHA	*Alkaline ratio	Compressive Strength (Mpa)	
	RHA	FA	CA		(NaOH: Na2SiO3)	7 days	28 days
1	1	1.9	3.5	0.8:1	1:1.85	18	24
2	1	1.9	3.5	0.7:1	1:1.85	17.5	23.6
3	1	1.8	3.6	0.8:1	1:1.85	19.2	28.2
4	1	1.4	4	0.8:1	1:1.85	20.2	37.5
5	1	1.7	3.3	0.7:1	1:1.85	18.2	25.3

Fig 1: Oven curing of geopolymer concrete cubes at 60˚C

Fig 2: Geopolymer Concrete cubes size 150 x 150 x 150

Flexural Strength Test

For the Flexural strength test specimens 10 × 10 × 50 cm was used. The load was applied without shock and increasing continuously at a rate of 180 kg/min for the specimens.

Table 5: Flexural strength of geopolymer concrete. ($F_{cr}=Pl/bd^2$) N/mm^2

S.N.	Ratio			*A/RHA	*Alkaline ratio (NaOH : Na2SiO3)	Flexural Strength (Fcr)	
	RHA	FA	CA			7 days	28 days
1	1	1.9	3.5	0.8:1	1:1.85	1.9	2.6
2	1	1.9	3.5	0.7:1	1:1.85	1.6	2.2
3	1	1.8	3.6	0.8:1	1:1.85	1.9	2.7
4	1	1.4	4	0.8:1	1:1.85	2.1	3.2
5	1	1.7	3.3	0.7:1	1:1.85	1.9	2.6

Fig 3: Flexural strength Test

4. DISCUSSIONS

This study will have a positive impact on the environment as it will reduce the volume of Rice Husk Ash to be disposed of by incineration and land filling. It has been seen that strength of geopolymer concrete is achieved within 7 days of casting. For better workability the ratio of alkaline solution to source material is kept 0.8. The early-age strength gain is a characteristics that can best be exploited in the precast industry where steam curing or heated bed curing is common practice and is used to maximize the rate of production elements. The geopolymer technology can be used to develop box culverts, sewer pipelineproducts, railway sleepers, building products including fire and chemically resistant wall panels, paving blocks, refractory bricks, etc. and other pre-cast structure.

5. CONCLUSION

- The initial setting time and final setting time ranged from 50 minutes to 120 minutes for Rice Husk Ash Geopolymer.
- The highest Compressive strength (35MPa) of the specimen produced by the 0.8 mass ratio (Activator / source material)
- The strength of geopolymer mortar are 28 MPa.
- The Compressive strength is varies from 20 MPa – 35 MPa.
- The Flexural strength of geopolymer concrete is 2.1 - 3.2 MPa.

Following ratio is suggested for Geopolymer Concrete mix given in table below

Table 6: Recommended Ratio for Geopolymer Concrete

GRADE	RATIO		
	(RHA : Sand : CA)	Alkaline : RHA	Sodium Hydroxide : Sodium Silicate
For M – 20	1 : 1.9 : 3.5	0.8 : 1	1 : 1.85
For M - 25	1 : 1.8 : 3.6	0.8 : 1	1 : 1.85
For M - 30	1 : 1.4 : 4	0.8 : 1	1 : 1.85

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