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Flexural Behavior of Rice Husk Ash based Geopolymer Concrete Beams

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Abstract: Concrete is the world's most important and unavoidable construction material next to water. At present Geopolymer Concrete is a growing field in the construction industry for the effective use of various byproducts from industries and solid wastes. This study involved the investigation on the mechanical properties of Rice Husk ash based geopolymer concrete partially replaced with Ground Granulated Blast furnace Slag (GGBS) for various percentages the mass of total binder. For the geopolymerization, sodium hydroxide (NaOH) and sodium silicate (Na_2Sio_3) were used as activators, mass ratio of Na_2Sio_3/NaOH is 2.5, various molarities for NaOH have been used as 10M and the mass ratio of alkaline liquid to binder is kept as 0.4. The increase in GGBS content decreases the workability and enhances the setting property of geopolymer concrete. The specimens were prepared and cured for 28 days at ambient conditions and it results the compressive strength from at the ages. In this project compressive strength, split tensile strength, flexural strength tests have been performed. Beams specimens were cast to find the flexural behavior, total energy, load deflection, ductility and stiffness of GPC beams. The Rice Husk ash GPC beams results were compared with controlled beam specimen. Experimental results have been compared with analytical and theoretical results.

Keywords—Rice Husk Ash, Geopolymer Concrete, Ground Granulated Blast Furnace Slag, Molarity.

I. INTRODUCTION

A. Geopolymer Concrete

Concrete is an important construction material it requires large quantities of Portland cement. During the production of cement large amount of CO_2 is emitted to atmosphere. It creates global warming problems. And also Ordinary Portland Cement Concrete brittleness is very less. So it's inevitable to find an alternative material for cement. Geopolymer concrete was invented by Chemistry professor Davidovits in 1978; after further researches were carried out by B V Rangan in construction industry and also he proves that the Geopolymer concretes (GPCs) are new class of building materials that have emerged as an alternative to Ordinary Portland Cement Concrete (OPCC) and possess the potential to revolutionize the building construction industry. In geopolymer concrete So far many researches were carried out and also it enhances the strength and durability than OPC concrete. This concrete proves their environmental benefits. Geopolymer concrete is describes as it is a combination of source materials which may rich in silicon and aluminium and alkaline liquids. The process carried out in Geopolymer concrete is named as polymerization process. And in this process Source materials and alkaline liquids are main constituents. The silicon and aluminum present in the source materials reacts with alkaline liquids which may be sodium hydroxide and sodium silicates or potassium hydroxide and potassium silicate solution, this process is known as polymerization process likewise the reactions takes place between OPC and water is known as hydration process. The outcome of polymerization process is a three dimensional network of aluminates and silicates it helps to enhance the properties of concrete. The waste materials or by products from various industries can be used as a source materials, for example the materials like Fly ash, Rice Husk Ash, Metakaoline, Silica fume

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and GGBS can be used as source materials. Sodium silicate and sodium hydroxide or potassium hydroxide and potassium silicate can be used as alkaline liquids according to the requirements, availability, usage and cost. In the world while comparing the different source materials fly ash is abundantly dumped as a waste material in thermal power stations and it is produced during the combustion of coal. .[11] discussed about Microwave Semiconductor Devices such as Tunnel diode, Gunn diode and valanche transit time devices and analyzes Monolithic Microwave Integrated Circuits (MMIC)

II. RESEARCH SIGNIFICANCE

The significance of the present investigation is to study the performance of GPC with RHA and GGBS. Totally three beam specimens were cast to find the flexural behaviour, ductility and stiffness. The specimens were cured in ambient condition. The structural parameters such as load deflection behavior, first crack load, ultimate load were investigated.

A. *Rice husk ash geopolymer concrete:*

The compressive strength of geopolymer depends on both the ratio of Si-Al and the types of the raw materials used. As the raw materials come from different source and different manufacturing conditions, it is difficult to maintain a standard chemical composition. For achieving a suitable chemical composition (Si-Al) to produce geopolymer, the preferred method is to blend the primary binding material (GGBS, fly ash etc.) with another high silica source like RHA. Although the use of RHA in geopolymer has been rather limited, there have been a few attempts in investigating the possibility of adding RHA in geopolymer production. From this study geopolymer concrete is taking the quantum leap and now available to consider geopolymer as the alternative for OPC concrete. GGBS as a primary source of material for geopolymer concrete has a lot of advantages and has been proved to perform better over fly ash, whereas RHA as silica source brings additional benefits to the table, when used as a partial replacement material.

III. EXPERIMENTAL STUDY

A. *Materials*

The following materials were used for the preparation of test specimens.

- Ground Granulated Blast Furnace Slag was used as a source material to prepare Geopolymer concrete.
- Locally available river sand conforming to grading zone III of IS 383-1970 with specific gravity 2.5 as fine aggregate.
- Crushed blue granite stones aggregates of maximum size 12mm and graded as per IS 383-1970 with specific gravity 2.68 as coarse aggregate.
- Sodium silicate and Sodium hydroxide solution is used as activators.
- Distilled water is used to dissolve sodium hydroxide pellets in 10M.

RICE HUSK ASH:

Rice husk ash (RHA) is a by-product form biomass power plant from which rice husk and eucalyptus bark are burnt together as fuel at control temperature about 800- 900°C in fluidized bed combustion. In recent years, RHBA was used as a pozzolanic material in partial replacement of Portland cement in concrete. Thus, if RHBA can be used as a binder in geopolymer, it will reduce the use of Portland cement, reduce the air pollution due to exploding Limestone Mountain, reduce green house effect from burning raw material to produce cement, and reduce solid waste of RHBA. Rice husk ash (RHA) is a material that can play a similar role to silica fume as a pozzolanic material in concrete. Raw rice husks, which are residues from de husked paddy rice, pose an enormous disposal problem and environmental load. RHA is produced from the controlled incineration of raw rice husks, which is then ground to the required fineness. On average, each unit weight of raw husks would yield approximately 18–20% of RHA, which can be optimized positively in concrete technology.

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Table 1.1 Chemical composition of the RHA (% by mass)

S.NO	Chemical composition of RHA	Values in %
1	Sio_2	82.6
2	Al_2o_3	0.4
3	Fe_2o_3	0.5
4	Cao	0.9
5	Na_2o	0.1
6	K_2o	1.8
7	So_3	0.1

B. Mix proportions

The design mix can be arrived by assuming the density of geo polymer concrete as 2400 kg/m^3. The total volume occupied by fine and coarse aggregate is around 77-80% and the various materials used in this project are given below.

- Density of aggregate is 77%.
- The alkaline liquid to fly ash ratio is kept as 0.4.
- Sodium hydroxide is taken as 10M.
- The ratio of sodium silicate to sodium hydroxide is kept as 2.5.
- Extra water is added as 15% of cementetious material.
- Super Plasticizer is added as 3% of cementitious material.
- The materials required for 1m^3 of geopolymer concrete are given in below Table.

TABLE II MATERIALS REQUIRED FOR 1M^3 OF CONCRETE

S.no	Materials	Qty (Kg/m^3)
1	Fly ash	394.3
2	FA	554.4
3	CA	1293.4
4	NaOH	45.1
5	Na_2SiO_3	112.1
6	Water	59.14
7	SP	11.83

C. Casting of Specimens

The cube of size 100mm x 100mm x 100mm, Cylinders of size 300mm height and 150mm dia. Prisms of size 500mm x 100mm x 100mm were cast to find out the compressive strength, split tensile strength, flexural strength respectively. The fresh concrete mix was filled in the steel moulds in three equal layers and each layer was well compacted using table vibrator. After de-moulding they were kept at room temperature for 28 days. Fig 2 shows casting of controlled cube, cylinder and prism specimens for test. Beams of size 1600mm x 150mm x 100mm were cast to find out the first crack load, ultimate load and load deflection behavior. Beams were kept at room temperature for curing up to test period of 28 days. The beams designed as under reinforced section. It is reinforced with 2-10# at tension zone, 2-10 # at compression zone using 8 mm diameter stirrups at 100 mm c/c.

D. Testing

The compressive strength, split tensile and flexural strength of the controlled and fibre reinforced geopolymer concrete specimens were tested at the age of 28 days. Three identical specimens were tested in all the mixtures.

E. Experimental setup for testing of beams

The experimental setup for testing of beams are shown in fig 4 the beams was supported on the two Simply supported edges and tested in 100T of loading frame in laboratory. The load was gradually applied to the specimen by using hand operated hydraulic jack. The intensity of load was measured by the load cell having capacity of 50KN. The load is applied at an increment of 5 KN up to the failure of specimen.

A Linear Variable Differential Transformer (LVDT) were used to measure the deflection at mid span and two dial gauges were used at l/3 distance from supports under the load acting point.

At each increment of loads, deflection and crack pattern were recorded. The failure mode of the specimen was observed.

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IV TESTS CONDUCTED:

Over hundred specimens were casted and tested to examine the strength of GPC with five levels of RHA replacement as 10%, 20%, 30%, 40%, 50%. The results show variation in compressive strength of GPC with respect various replacements of RHA at 3, 7, and 28 days of testing. Further the flexural strength, split tensile strength and elastic modulus of GPC specimens were also tested.

A. COMPRESSIVE STRENGTH:

The compressive strength of Geopolymer concrete was tested as per IS 516:1959. The cube specimens 100 m in size were cast for each proportion and tested for their compressive strength at the ages 3, 7, 28 days. All the specimens were tested using compression testing machine (CTM) until failure and ultimate load at failure were used to calculate compressive strength.

B. SPLIT TENSILE TEST:

The split tensile test was carried out as per IS 5816: 1999 cylindrical specimens 100mm in diameter and 200mm in height were casted the specimens were then tested using UTM at ages of 3,7, and 28 days.

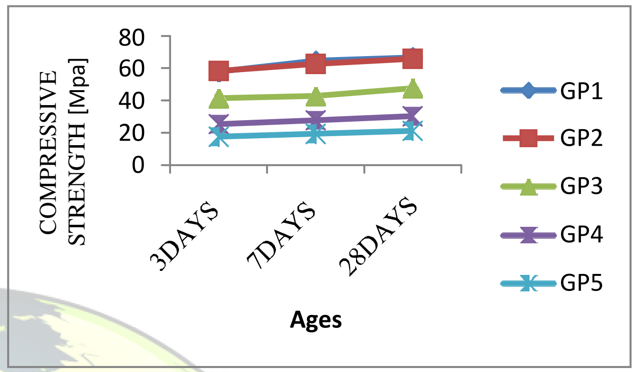
C. FLEXURAL STRENGTH TEST:

The flexural strength test was carried out as per IS 5816: 1959. Beams measuring 150 mm x 100 mm x 1600mm. were cast and then subjected to flexural strength test using UTM at ages of 3, 7, and 28 days.

V. RESULTS AND DISCUSSIONS:

A. COMPRESSIVE STRENGTH

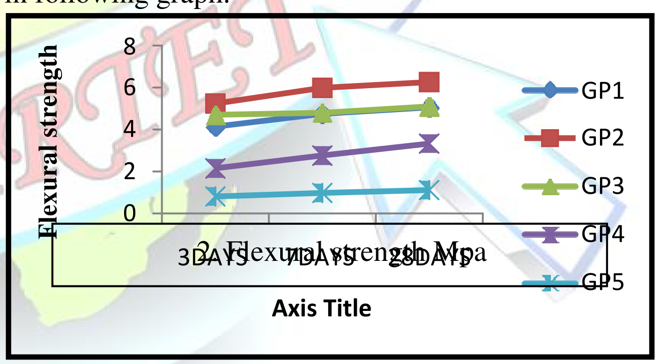
The compressive strength results obtained for geopolymer concrete at 3, 7, 28 days are shown in following graph. With increase in RHA content it was observed that the strength decreases and it is found that the optimum replacement of RHA is of 10-20%. At 7 days the compressive strength of geopolymer concrete with 20% of replacement of RHA 42.7Mpa with 10M where it is better than conventional geopolymer concrete cubes. The effect of RHA on the compressive strength of concrete is discussed. Geopolymer concrete made with 100% GGBS was kept as the control specimen. Geopolymer concrete exceeds the target strength of 30 MPA and attained 28 days strength of around 65 Mpa for 10% addition. The specimens exceeding 25% replacement of RHA did not achieve any strength.



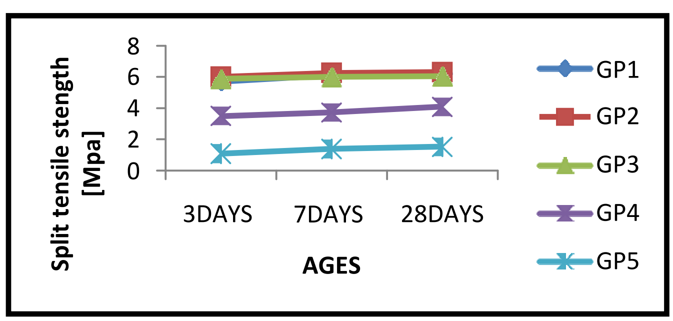
1. Cube Compressive strength Mpa

B. SPLIT TENSILE AND FLEXURAL STRENGTH TEST:

The splitting tensile and flexural strength results for geopolymer concrete at 3, 7, & 28 days are shown in following graph.



2. Flexural strength Mpa



3. Split Tensile strength Mpa

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When comparing the 10% RHA replacement with the control mix, it cn be seen that there is a slight improvement in both the split tensile and flexural strength values. The split tensile and flexural strength values seem to decrease with a further increase in the RHA content. Similar results were reported by Jakrapan Wongpa [5].

C. ULTIMATE LOAD DEFLECTION OF BEAM:

The summary of test results for all beams, showing the first crack load, deflection at first crack load, and deflection at the point of failure, is varying based on the percentage of RHA replacement. It can be observed that all beams exhibited some delay in the formation of first crack, when compared to that of the control beam. The replacement of RHA upto 20% shows better result and beyond 30%the beam gets failed soon when compared to the previous beam. The improvement in ultimate loads of beams U1, U2 and U3 was 10.57 %, 14.83 % and 18.60 %, respectively, as compared to the control beam. This shows that the ultimate load carrying capacity increases with less replacement of RHA.

D. LOAD DEFLECTION RESPONSE:

The process of load deflection response is analyzed for two single layer lattice dome of big size as particle examples. The non linear behaviors of perfect beams and deflection shapes at several points after buckling are the first investigated. Two methods for imperfection analysis are suggested. The beam with 20% RHA replacement exhibits lower deflection compared to control beam. The deflection values of each and every beam were compared at ultimate load of other beams.

E. LOAD STIFFNESS CHARACTERISTICS:

Load stiffness of the beams for the various ratio of the RHA is established. The beams with 20% replacement of RHA show more stiffness than other replacements beyond 30%. GP1 beams and GP2 beams shows higher stiffness than control beam.

F. ENERGY ABSORPTION CHARACTERISTICS:

For all beams tested, the energy absorption is obtained by calculating the area under the load deflection curve, and the corresponding values are given in Joules (J). The comparison of energy absorption capacity is shown for all beams in Figure 12. The energy absorption of the control beam amounts to 231.3J. The Energy Absorption of the U1, U2 and U3 increases by 40.54 %, 67.56 %, and 100 %, respectively, when compared to that of control beam. Similarly, the energy absorption of S1, S2, and S3 increases by 8.43 %, 20.72 %, and 38.55 % when compared to the unwrapped beam. Among all beams, the beam U3 attained the highest energy absorption when compared to the control beam. When comparing the Group A and Group B beams, the beams that were wrapped with GFRP layers on three sides present better energy absorption characteristics.

VI. CONCLUSION:

Based on the experimental results, the following conclusions can be drawn. This study analyses aspects of compressive strength containing various replacement levels and these were evaluated for various properties.

Workability of GPC containing RHA decreases at the higher replacement levels compared to that of the control mixture due to the pore structure of RHA. In replacement of range of 10 – 20% RHA there exists an optimum range RHA content resulting in the highest compressive strength at each age. Water absorption is more than the requirement levels when RHA content is increased. Balling effect may occur during the wet mix this is because of the higher temperature at which is boiled. While comparing oven curing at a temperature of 60°C and ambient curing, the strength increases at 28 days was 20% for the GP1 and tow times for GP2. Addition of RHA beyond 20% had a retarding effect on the compressive strength. Addition of RHA beyond 30% is not beneficial in geo polymer concrete. The 30% RHA replaced specimens neither achieved significant strength nor proved to be durable. The strength results show that the optimum proportion of RHA that can be used is 10% in case of ambient curing and 20% in case of oven curing, considering the target strength of M30. The results from this study are very important in the development of such innovative concretes which completely omit OPC. Thus it was concluded that the optimum replacement of 20% gives better results.

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