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STRENGTH ASSESSMENT OF GEOPOLYMER CONCRETE USING M-SAND

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ABSTRACT

The production of Ordinary Portland cement and the usage of normal river sand are increased due to the demand of concrete in construction Industries. The emission of Co_2 increases during the production of cement and at the same time the availability of river sand is also becoming costlier and scarcity due to illegal dredging of river sand. The main intension of this research paper is to focus the eco friendly alternative material for the cement and river sand. The Geopolymer concrete material having low calcium fly ash is an inorganic non metallic alternative material for cement and manufactured sand an alternative for river sand. Concrete mix design of G30 was done based on Indian standard code (IS 10262) and modified guidelines. Concrete cubes and cylindrical specimens were tested for evolving the compressive strength and split tensile strength by varying the percentage of M-sand in Geopolymer concrete. The percentage replacement of M-sand in Geopolymer concrete is assessed from the results.

Key words: Geopolymer concrete, M-sand, Cement.

INTRODUCTION

General

In construction industries, the usage of concrete increase as the demand for the production of cement is also increases and leads to releases of large quantity of green house gas -Co_2 into the atmosphere. According to the consumption of cement in world, the requirement of Portland cement is currently exceeding 2.6 billion tonnes per year.

Also one tonne of production of cement emits the 0.8 tonne of green house gas of Co_2 in atmosphere. Hence it is an intent need to find an alternative material instead of cement. At the same time a large volume of fly ash is generated around the world. Many research work were carried out on the usage of supplementary materials for Portland cement

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such as Fly ash, Fumed silica, Silica fume, Ground granulated blast furnace slag, Metakaolin etc. At the same time a large volume of fly ash and GGBFS is generated around the world of 450 million ton & 550 million ton per annually which leads to a disposal problem.

For making concrete one more important material is river sand, which is commonly used as fine aggregate. Now a days it is becoming scarcer and costlier due to illegal sand mining, law of land and hence government restriction on sand quarrying. So the researchers move to find an alternative material for river sand which is most reliable, inexpensive and easily available. Manufactured sand (M-Sand) become an alternative solution to natural sand which is produced by crushing of hard stone aggregate to the size of natural aggregates. Because of the above current issues the alternative materials were taken for the research and the strength properties were found using the supplementary materials instead of cement with M-Sand.

Geopolymer concrete

The term ‘Geopolymer’ was mainly discovered by Chelokovski in 1950 and then called Geopolymer by French professor Davidovits in 1978. It is characterized by network of inorganic molecules.

It is nothing but a geopolymer concrete does not utilize Portland cement as a binder. Hence the binding properties are mainly produced by the chemical reaction of an alkaline liquid with a silica and alumina rich materials such as Fly ash, GGBFS, Metakaolin, Rice husk ash etc.

Review of literature

Gokulram. H and Anuradha. R considered that Fly ash & GGBFS as a complete replacement for cement and manufactured sand as a complete replacement for river sand with the adding up of polypropylene fibre in the mixes. They mainly analyzed the mechanical properties such as compressive strength, split tensile strength and flexural strength of Geopolymer concrete composites (GPCC) at the period of 28 days of ambient curing and 24 hrs of heat curing. It was inferred that the compressive strength of heat cured GGBS based GC does not depends upon the age. But ambient cured GGBS based GC depends on age. All mechanical properties showing that the high strength in 100% replacement of GGBS compared with 100% replacement of fly ash.

Janani. R and Revathi. A investigated that fly ash based Geopolymer concrete and partial replacement of river sand by M-Sand with the alkaline solution of NaOH & Na_2Sio_3 for finding the properties of compressive strength, tensile strength, and flexural strength. The

river sand was replaced by M-sand in the percentage of 0%, 20%, 40%, 60%, 80% and 100% and the specimens were cured by steam curing at temperature of 60°C for 24 hrs. It was concluded that compressive strength, tensile strength, and flexural strength was increased by 9%, 12% and 10%, respectively when M-sand was fully replaced by river sand. Vignesh. P, Krishnaraju. A. R and Nandhini. N found that fly ash based geopolymer concrete with the substitute of river sand by M-Sand. Along with this 0.25% of Glass fibers have been taken for finding the material properties of M25 grade Geopolymer concrete with a concentration of 16 Molar NaoH & Na_2Sio_3 solution. It was inferred that the properties of compressive strength, split tensile strength and flexural strength of 1% of glass fibre reinforced concrete has found to be increase in strength of 10%, 10% & 20%, respectively.

Priyanka. A. Jadhav and Dilip kulkarni discussed the fresh and hardened properties of concrete and workability was also evaluated in terms of slump and compacting factor with the partial alternate of natural sand by M-Sand and by varying W/C ratio for the grade of M20 water cement ratio and % replacement of M-sand by natural sand as 0.4, 0.45, 0.5 & 0.55 and 0%, 20%, 40%, 60%, 80% & 100%, respectively. The results for compressive, tensile & flexural strength of 0.45 water cement ratio were discussed. It was concluded that 60% replacement of M-sand reveals higher strength when compared with other mixes. Abdul Aleem, M. S. Arumairaj. P. D and Vairam. S. described that the chemical reaction involved in the formation of new compound in Geopolymer concrete and its formulation. In the experimental study PXRD pattern, SEM images for Fly ash, M-Sand and SEM images for Geopolymer concrete has been discussed. It was inferred that the new compound of Albite has been formed. It is belong with polymer containing polysialate and it was proved that geopolymer concrete has very high compressive strength. Praveen Kumar K and Radhakrishna presented a paper on replacement of natural sand in 1:6 cement mortar by M-Sand at different percentages like 0%, 20%, 40%, 60%, 80% & 100%. It was concluded that the workability of mortar increases with the replacement of M-Sand upto 80% but the strength of M-Sand Mortar is high at all replacement levels of M-Sand. Hence the M-Sand can be recommended for masonry work. Nimitha Vijayaraghavan & Wayal. A.S discussed with the workability and compressive strength of ordinary Portland cement with the replacement level of M-Sand with natural sand. The M-Sand was replaced like 0%, 50% and 100%. It was inferred that 100% of M-Sand given the max compressive strength.

Priyanka A., Jadhav, Dilip K. Kulkarni investigated the effect of w/c ratio on hardened properties of cement mortar with M sand as a Partial replacement for natural sand. It was taken that proportion of mortar is 1:2, 1:3 & 1:6 with water cement ratio of 0.5 & 0.55. The replacement levels were taken like 0%, 50% & 100%. Finally it was concluded

that in all the mortar mix proportion with the w/c ratio of 0.5 & 0.55 the 50% replacement level of M-Sand was given higher strength. Krishnan. L, Karthikeyan. S, Nathiya. S, Suganya. K studied the setting time of GC at ambient temperature by the addition of GGBFS into the fly ash based GC. For this 12M Concentration of NaOH & Na2Sio3 were taken. The replacement level of GGBFS was varied like 10%, 20%, 30% & 40%. It was concluded that 40% replacement level of GGBFS given higher compressive strength.

EXPERIMENTAL

Materials

General

In the review of literature various materials and the conclusions were discussed in detail. From the above literatures the materials chosen for the present works are materials used.

- Fly ash – (Class F)
- Chemical
  - Sodium hydroxide.
  - Sodium Silicate.
- Super-plasticizer
- Aggregates
  - Fine aggregate
  - Coarse aggregate

Fly ash

In Geopolymerization process, fly ash is one of the important ingredients in the creation of GC. It is a fine powder of spherical glass particles having pozzolanic properties consists of reactive silicon dioxide (SiO_2), aluminum oxide (Al_2O_3), iron III oxide (Fe_2O_8) and other oxides. It can be obtained by electrostatic (or) mechanical precipitation of dust like particles from the flue gases of power station furnaces fired with pulverized bituminous (or) other hard coal. There are two types of fly ash are exists, that in class C fly ash and class F fly ash having its own unique properties. The Specific gravity of Fly ash 2.13. The chemical composition of fly ash is shown in Table 1.

Table 1: Chemical composition of fly ash

S. No.	Oxides	Percentage
1	SiO_2	58.70
2	Al_2O_3	30.35
3	Fe_2O_3	4.20
4	CaO	1.80
5	Na_2O	0.09
6	MgO	0.82
7	Mn_2O_3	0.09
8	TiO_2	1.88
9	SO_3	0.30
10	Others	2.25
11	LOI	2.03

Alkaline liquids

In Geopolymerization process, an alkaline solution is mainly used to activate the source materials. The main alkaline activate used for the Geopolymerization process are combination of Sodium or potassium hydroxide and sodium or potassium Silicate. Sodium based solutions were selected due to cheaper cost than potassium based solutions.

Chemicals

The alkaline activator solutions are main constituent for the geopolymerization process. Hence Sodium silicate and sodium hydroxide liquids are obtained from local suppliers in Chennai.

Sodium hydroxide

Normally sodium hydroxide (NaOH) is available in solid state either flakes (or) pellets form obtained from local suppliers. According to the purity of NaOH, the cost will be varied. The NaOH solution was prepared by dissolving the pellets in water. Depending upon the concentration of solution, the mass of NaOH solids in a solution varied in terms of molar. For instance sodium hydroxide solution with concentration of 16M consists of 16 x 40 = 640 grams of sodium hydroxide solids (in pellet form) per litre of the solution. Where 40 is the molecular weight of sodium hydroxide.

Sodium silicate

Sodium Silicate (Na_2SiO_3) is also known as water glass or liquid glass available in liquid gel form obtained from local suppliers. The mixture of sodium silicate solution and sodium hydroxide solution forms the alkaline liquid.

Superplasticizer

Generally in fresh state, the GC has a stuff consistency. To achieve the adequacy in the Geopolymer concrete, superplasticizer is added. Depending on the solid content of the mixture a dosage of 1 to 2 percent by weight of fly ash is advisable. In this present investigation a superplasticizer namely MasterGlenium SKY8233 has been added for obtaining workable concrete.

Aggregates

Generally aggregate are the main material in the concrete. Based on aggregates the strength density and other properties of the concrete are varied. Fine aggregate and coarse aggregate are the main important aggregate in the concrete mix.

Fine aggregate

The Fine aggregate which is used for the project is mainly M-Sand with the replacement of river sand obtained from local suppliers. Manufactured sand is defined as a purpose- made crushed fine aggregate produced from a suitable source material. Production generally involves crushing, screening and possibly washing. Separation into discrete fractions, recombining and blending may be necessary. In this M sand was used to replace the river sand like 0%, 20%, 40%, 60%, 80% & 100%. Properties of fine aggregates (M-sand and River sand) are tabulated below in Table 2.

Table 2: Properties of M-Sand and river sand

S. No.	Characteristics	Values (M-Sand)	Values (Natural sand)
1	Type	Crushed	Uncrushed
2	specific gravity	2.57	2.59
3	Bulk density	16571.27 (kg/m3)	1564.64 (kg/m3)
4	Finess modulus	2.47	3.09
5	Grading zone	Zone II	Zone II

Coarse aggregate

Grading of combined coarse aggregates having the sizes of 8mm, 10mm and 20mm were used and obtained from local suppliers. The properties of coarse aggregate are tabulated in Table 3.

Table 3: Properties of coarse aggregate

S. No.	characteristics	Values
1	Type	Crushed
2	specific gravity	2.73
3	Bulk density	1406.62 (kg/m3)

Methodology

The Methodology is the important and easily understandable about the projects using the step by step procedures. The methodology is explained below in Fig. 1.

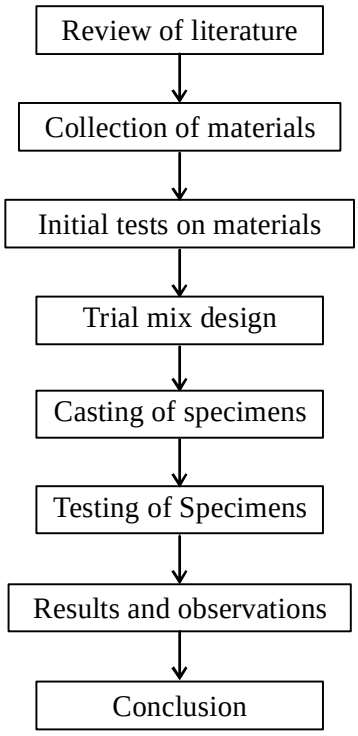

Fig. 1: Methodology of Geopolymer

Experimental investigation

Introduction

The Experimental investigation was carried out on the test specimen based on the mix design and variation of M-Sand to study the strength related properties of Geopolymer concrete. The experimental test for strength properties of concrete are compressive strength and split tensile strength test of concrete

Mix proportion of geopolymer concrete

Anuradha R et al. have studied and given that modified guidelines for Geopolymer concrete. Based on the ratio between alkaline liquid and fly ash have been taken as 0.60, the ratio between Na_2SiO_3 to NaOH have been taken as 2.5 and fly ash content to compressive strength have been taken.

Preparation of alkaline activator solution

The alkaline activator solutions are a combination of sodium hydroxide and sodium silicate solutions. To prepare sodium hydroxide solution of 16 Molarity (16 x 40) 640 g of sodium hydroxide pellets are dissolved in one liter of water. The mass of NaOH solids in the solution varies depending on the concentration requirement. The prepared NaOH solution was added with Na_2SiO_3 solution according to the mix, 24 hrs before casting.

Geopolymer mix design

The aggregates occupy the largest volume by mass in geopolymer concrete. The alkaline activator solution is mainly used to activate the silicon and aluminum in the fly ash. The mix proportion values shown below in Table 4.

Table 4: Mix proportions value

Constituents	Density (kg/m3)
Coarse aggregate	1295
Fine aggregate	555
Fly ash	345
Sodium silicate	146.43
Sodium hydroxide	58.57
Super plasticizer	6.9

In the above trial mix design the fine aggregate of natural river sand has been replaced by M-Sand in the proportions of 0%, 20%, 40%, 60%, 80% & 100%.

RESULTS AND DISCUSSION

The compressive strength and split tensile strength tests have been carried out for the Geopolymer concrete with the replacement of M-Sand.

Test specimens

The test specimens for compressive strength test were carried out in the cubes of having size of 100 mm x 100 mm x 100 mm for each replacement percentage of M-Sand, the three numbers of cubes were cast ,oven dried for 24 hours and tested at 60°C the age of 7 days and 28 days. The test specimens for split tensile strength test were carried out in the cylinders of having a size of 100 mm diameters and 200 mm high cast iron moulds were used. For each replacement percentage of M-Sand, the three number of cylinders were cast, oven dried for 24 hrs @ 60°C and tested at the age of 7 days and 28 days. The details of test specimens are tabulated below in Table 5.

Table 5: Details of test specimens

S. No.	Name of test	Size of specimen (mm)	No. of specimens
1	Compressive strength	100 x 100 x 100	36
2	Split tensile strength	100 x 200	36

Compressive strength test

The variation of compressive strength at the age of 7^{th} and 28^{th} days by varying the percentage of M-sand like 0%, 20%, 40%,60%, 80%,100% for river sand. Results are tabulated below in Table 6.

Table 6: Compressive strength of geopolymer concrete with manufactured sand

Mix	Cube strength (N/mm^2)	
	7 Days	28 Days
M1	21.98	31.28
M2	22.40	31.60

Cont…

Mix	Cube strength (N/mm^2)	
	7 Days	28 Days
M3	22.90	32.50
M4	23.45	33.00
M5	23.92	33.45
M6	25.10	35.25

From the above test results obtained for the compressive strength shows that there is increase in strength when manufactured sand is fully replaced by river sand.

Tensile strength

The variation of Tensile strength at the age of 7th and 28th days by varying the percentage of M-sand like 0%, 20%, 40%,60%, 80%,100% for river sand. Results are tabulated below in Table 7.

Table 7: Tensile strength of Geopolymer concrete with Manufactured sand

Mix	Tensile strength (N/mm^2)	
	7 Days	28 Days
M1	1.37	2.38
M2	1.42	2.48
M3	1.43	2.50
M4	1.48	2.58
M5	1.50	2.62
M6	1.54	2.69

Suggestions for future work

- Flexural strength of the Geopolymer concrete beams shall be studied.
- Durability property of the Geopolymer concrete with M-sand shall be carried out.
- Geopolymer concrete beam, reinforced concrete beams & columns, Reinforced concrete beams and columns wrapped or strengthened by FRP has to be investigated.

CONCLUSION

Based on the experimental investigation the following conclusions are listed below.

From the above test results obtained, the compressive strength and Split tensile strength of the Geopolymer concrete increases when manufactured sand is fully replaced the river sand. Hence it proves that Geopolymer concrete using M-sand is an alternative to Ordinary Portland Cement. Since no cement is used in Geopolymer concrete; a lot of energy can be saved. The waste material of Fly ash helps to reduce the atmospheric pollution.

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