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AN EXPERIMENTAL STUDY ON DURABILITY OF GEOPOLYMER CONCRETE BY REPLACEMENT OF SAND WITH M-SAND.

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Abstract*— *Concrete is the most common material for construction all over the world. The demand for concrete as a construction material leads to the increase of demand for Portland cement. Geo-polymer is an eco-friendly binding material alternative to ordinary Portland cement. Geo-polymer concrete is obtained by mixing the ingredients such as sodium hydroxide solution, sodium silicate solution (NaOH and Na2SiO3),or potassium hydroxide, potassium silicate solutions (KOH and K2Sio3)fly ash, grounded granulated blast furnace slag(GGBS) and, fine aggregate and coarse aggregate and cured suitably. The blend of sodium hydroxide solution and sodium silicate solution is termed as alkaline liquid. This study presents an investigation deals with Geo-polymer concrete by replacing of fine aggregate material witch using the M-Sand. Complete 100% replacement of natural sand witch M-Sand and compare the results witch GPC natural sand and GPC witch M-Sand and its durability. When exposed to sulphate, and acidic environment and comparison were made with normal Ordinary Portland Cement (OPC) concrete. In total four tests were conducted to determine acid and sulphate resistance of geo-polymer concrete witch M-Sand. The tests involved immersion for a period of 30 to 60 days into 5% solution of sodium sulphate, 5% solution of magnesium sulphate, 5% solution of sulphuric acid and 5% solution of phosphoric acid. The evolution of weight loss and compressive strength loss were studied. The most significant degradation of compressive strength and weight were determined in 5% of acid solution. The least strengths variation and weight loss were found in the 5% of sulphate solution. The OPC concrete more deteriorated in acid as well as in sulphate solution in compared with geo-polymer concrete, thus geo-polymer concrete is more durable than the OPC concrete.*

Keywords: Binding material, GPC, M-Sand, degradation, deteriorated

I. INTRODUCTION

Concrete is the most versatile material of construction over the world .The usage of concrete is rapidly increasing day by day. The second largest producer of the greenhouse gas effect is the cement industry. Large amount of greenhouse gases like Carbon dioxide are emitted into atmosphere during manufacturing process of cement. Concrete is the material of choice for a variety of application of different types of Structures such as housing, bridges, highway pavements, industrial structures, water-carrying and retaining structures, etc.

Concrete is one of the most widely used materials in the world. Ordinary Portland cement (OPC) is conventionally used as the primary binder to produce concrete. The amount of the carbon dioxide released during the manufacture of OPC due to the calcinations of limestone and combustion of fossil fuel is in the order of one ton for every ton of OPC produced.

Fly ash is by-product of coal used in thermal power plants to produce power, GGBS is by-product of manufacture of iron. Fly ash and GGBS were used as binding materials to make concrete as a substitute for Ordinary Portland cement. The silicon and the aluminium in the fly ash reacted with an alkaline liquid that is a combination of sodium silicate and sodium hydroxide solutions to form the Geo-polymer paste that binds the aggregates and other un- reacted materials. As the demand for natural river sand is exceeding the availability, it has resulted in fast diminution of natural sand sources. Hence, river sand is replaced by manufactured sand to overcome the demand. The durability of concrete plays a major role in the view of life time of concrete as it should have ability to resist in different weathering conditions.

OBJECTIVE OF THE STUDY:

1. To develop the proper mix proportion for Geo-Polymer concrete and replacement of natural sand with M-Sand in Geo-Polymer concrete.
2. To study the behaviour of GPC and to know compressive strength and split tensile strength GPC made with M-Sand
3. Concrete cubes, cylinders specimens made with Fly ash and GGBS
4. To evaluate the different strength and durability properties of geo-polymer concrete mixture replaced with Manufactured sand
5. Different Types of Durability tests were to be done and compare with OPC.

SCOPE OF THE STUDY:

1. To reduce the green house gas emission.
2. Use the industrial by-product materials such as fly ash, GGBS (which are base materials to make geo-polymer concrete)
3. To construct building in economy and to increase the durability of the building.
4. The technology and the equipment currently used to manufacture OPC concrete were use to make the Geo-Polymer concrete.

II. LITERATURE REVIEW

Kothapalli Sindhu Rani1 et al(2016)[3] Experimental Study Of Geo-Polymer Concrete By Using Glass Fibers-by, International Journal Of Professional Engineering Studies. Temperature plays very important role in setting time of geo-polymer paste and there was very little time interval was observed between initial setting and final setting time Moreover, the durability of the fly ash-based geo-polymer is better than OPC when exposed to an aggressive environment

Veerendra Kumar et al(2016)[1]Studies on Mix Design of Sustainable Geo-Polymer Concrete BY-.M Research scholar, International Journal of Innovative Research in Engineering & Management About 60% of M-sand and 40% of pond ash as sand replacement is found to be the optimum amount in order to get a favourable strength. Compressive strength of concrete increases with increasing the concentration of sodium hydroxide

Ganapati Naidu et al on (2015)[3] studies the Strength Properties of Geo-polymer Concrete With Addition of G.G.B.S (International Journal Of Engineering Research And Development In this paper an attempt is made to study strength properties of geo-polymer concrete using low calcium fly ash replacing with slag in 5 different percentages. Higher concentrations of G.G.B.S (Slag) result in higher compressive strength of geo-polymer concrete. Compressive strength of geo-polymer concrete increases with increase in percentage of replacement of fly ash with GGBS.A maximum of 25% loss in compressive strength was observed when geo-polymer concrete exposed to a temperature of 500^{o}C for two hours. 90% of compressive strength was achieved in 14 days.

III. METHODOLOGY

DEATILED MIX DESIGN FOR GEOPOLYMER CONCRETE

The process of mix design starts with the calculation of the quantity of the aggregates based on the percentage of total aggregates in the whole mix. Once the quantities of the aggregates are arrived, the quantity of the alkaline liquid and binder content can be found out based on the ratio of alkaline liquid to binder content chosen arbitrarily based on the previous trials. The measure of sodium silicate and sodium hydroxide are calculated based on the ratio between the sodium silicate and sodium hydroxide. First the value of sodium silicate is found, the quantity of NaOH and water can be found based on constant percentage of n the molarity chosen. On completion of this cycle helps us arrive at a trial mix. The correctness of the mix can be checked by finding the absolute weight of the materials, using their specific Title and Author Details

IV. MATERIALS USED

1. FLY ASH (class-F)
2. GGBS (ground granulated blast-furnace slag)
3. ALKALINE SOLUTION
4. MANUFACTURE SAND
5. COARSE AGGREGATE
6. FINE AGGREGATE
7. SUPER PLASTICIZER (Conplast SP-430)
8. WATER

FINAL MIX PROPORTION

Table.1 Final mix proportion

Cement kg/m^3	F.A kg/m^3	C.A kg/m^3	Water lit/m^3
480 kg/m3	610	1070	155 lit
1	1.2	2.23	0.3

V. MOULDS

Test specimens in the form of 150x150x150 mm cubes and 150 x 300 mm cylinders and 100x500x100 mm Prisms were made. Initially, the mixing is attempted in a manual method.

Fig.1 Moulds used for casting

VI. PREPARATION OF ALKALINE SOLUTION

Prior to the day of mixing, a sodium hydroxide solution was prepared by dissolving sodium hydroxide flakes in distilled water. Fig.3.6 shows the alkaline solution prepared for this study. According to the concentration, solution was prepared 8 molar. For 1 kg of 8 molar solutions consisted of 320 grams of flakes. Calculation was made to take into account the impurity percentage of flakes. Then it was completely mixed with a sodium silicate solution and extra water if needed. 10 to 24 hours needed to complete the reaction. On the day of mixing, the required amount of super- plasticizer was poured in the activator liquids mixing and was mixed thoroughly with the solution.

Fig.2 Preparation on alkaline solution

VII. WORKABILITY OF CONCRETE

The workability of fresh Geo-polymer concrete was studied using slump cone test as per IS Code 1199-1959.Workability is an important property of fresh concrete, which shows the behaviour of concrete from mixing to till finishing. The flow diameter was measured immediately after completion of mixing of Geo-Polymer concrete by hand mix. The workability of mix was determined by measuring diameter of concrete flow on flow table in two perpendicular directions. The target mix was assumed to be of the slump between 50 to 75mm.The following test were indicates good workability of Geo-polymer mix. It could be easily placed in the mould for casting the Geo-polymer specimens. However, based on the flow diameter the workability of mix may be classified.

Figure.3 Slump Cone Test for Workability of GPC

VIII. DURABILITY TEST

1. Alkaline resistance test: - Acid resistance was tested on 15×15×15 cm size cube specimens made of ge1opolymer concrete by using M-Sand. The cube specimens were weighed and immersed in 5% NaOH solution of sodium hydroxide for 28, 60 and 90 days respectively. Then the specimens were taken out from the acid solutions and the surfaces of specimens were cleaned and the weight and compressive strength of specimens were found out and thus the average loss of weight and compressive strength were calculated.

Fig.4 Cubes in alkaline solution

2. Sulphate resistance: The sulphate attack testing procedure was conducted on 150×150×150 mm size cube specimens of geo-polymer concrete by using M-Sand. Then, they were cured in 5% sodium sulphate solution and 5% magnesium sulphate solution for 30 and 60 days respectively .This type of testing represent an accelerated testing procedure, which indicates the performance of particular concrete mixes to sulphate attack on Geo-Polymer concrete. The degree of sulphate attack was evaluated by measuring the weight losses and compressive strength loss of the specimens at 28, 60 and 90 days respectively.

Fig.5 Cubes in Sulphate attack test

3. Chloride attack test: The chloride attack testing procedure was conducted on 150×150×150 mm size cube specimens of geo-polymer concrete by using M-Sand. Then, they were cured in 5% sodium chloride solution and cured for 30 and 60 days respectively. This is accelerated curing in this process GPC cubes react with chloride solution which is called chloride attack test. The weight loss of the specimen was happened in this test. The degree of chloride attack was evaluated by measuring the weight losses and compressive strength loss of the specimens at 28, 60 and 90 days respectively.

Fig.6 Cubes in Chloride solution

4. Acid resistance: Acid resistance was tested on 15×15×15 cm size cube specimens made of Geo-Polymer concrete by using M-Sand. The cube specimens were weighed and immersed in 5% solution of sulphuric acid and 5% solution of phosphoric acid for 28, 60 and 90 days respectively. Then the specimens were taken out from the acid solutions and the surfaces of specimens were cleaned and the weight and compressive strength of specimens were found out and thus the average loss of weight and compressive strength were calculated

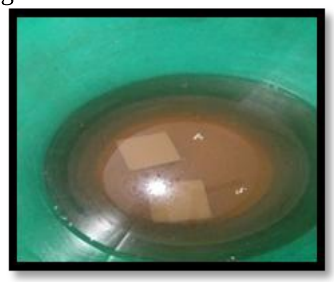

Fig.7 Cubes in acid test

IX. COST ANALYSIS

Cement has a very effective hauling and transportation system in our country which makes its transportation cost less. GGBS and coal ash currently doesn't have such a system. To normalize this effect, the transportation of these materials is assumed to be in the same manner as cement. Standard freight charge from Indian Railway website is considered for this analysis. Local market price for NaOH and aggregates were considered in this study. The cost per quantity and total cost is mentioned in Table 3.10. Only fly ash-GGBS based concrete are used for this study.

TABLE 2 Cost Analysis

Material	Cost(Rs/kg)
GGBS	2.2
Fly Ash	1
Coarse Aggregate 0.43	0.68
Fine Aggregate	1.55
Water	0.1
NaOH	90
Sodium Silicate	10

The total cost of geo-polymer concrete (Rs 4238.38) for cubic meter. The cost of OPC concrete were taken from ready mix plant cost because now a days for commercial or domestic construction were made by using RMC plants. It is easy and 20% less than OPC based concrete (Rs 3420). This reduced cost is mainly due to the assumptions made for the transportation of coal ash, GGBS and sodium silicate. If we are not considering the ready mix cost and if we taken versine material means it costs around (Rs 5500.00) based up on distance the cost of materials were changed. The transportation cost plays a major roll.

X. ANALYSIS OF TEST RESULTS

1. RESULTS FOR GPC (8MOLAR)

Table 3 Compressive strength of GPC 8M

Mix Design	Molarity	Compressive strength (MPa)			
		3 days	7 days	14 days	28 days
M40	8M	22.76	28.55	37.65	48.57

Table .4 Split tensile strength of GPC 8M

Mix Design	Molarity	Split tensile strength (MPa)			
		3 days	7 days	14 days	28 days
M40	8M	2.786	2.91	3.03	3.2

Table.5 Flexural strength of 8M GPC

Mix Design	Molarity	Flexural strength (MPa)			
		3 days	7 days	14 days	28 days
M40	8M	3.95	4.23	4.92	5.34

2. RESULTS FOR GPC MANUFACTURING SAND (8 MOLARITY)

Table 6 Compressive strength of GPC of 8M for M-Sand

Mix Design	Molarity	Compressive strength (MPa)			
			7 days	14days	28 days
M40	8M	23.46	29.54	42.44	49.63

TABLE 7 SPLIT TENSILE STRENGTH OF GPC 8M FOR M SAND

Mix Design	Molarity	Split tensile strength (MPa)			
		3 days	7 days	14 days	28 days
M40	8M	2.9	3.18	3.31	3.67

Table 8 Flexural strength of GPC 8M for M sand

Mix Design	Molarity	Flexural strength (MPa)			
		3 days	7 days	14 days	28 days
M40	8M	4.1	4.7	5.1	5.77

XI. GRAPH RESULTS FOR GPC

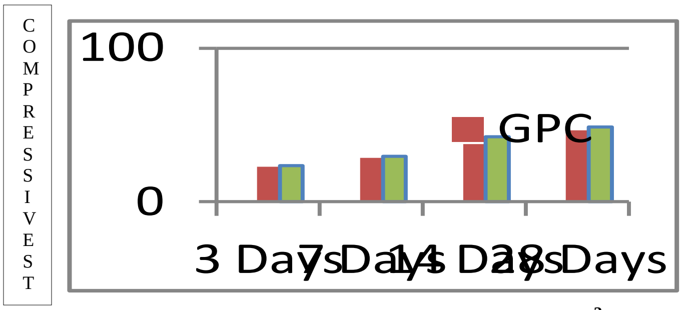

Fig .8 Comparison of compressive strength (N/mm^2)

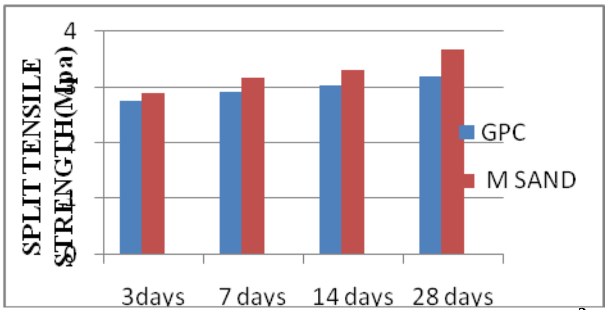

Fig 9 Comparison of split tensile strength (N/mm^2)

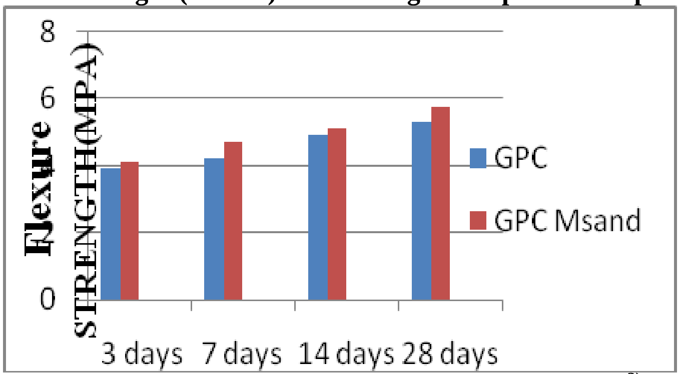

FIG 10 COMPARISON OF FLEXURAL STRENGTH (N/MM^{2})

XII. DURABILITY RESULTS

1. **Results Resistance to Alkaline test:**

Table.9 weight loss (in %) due to 5% solution of NaOH

No. of Days	OPC concrete (%)	Geo-Polymer concrete (%)
28 days	2.1	1.23
60 days	3.6	2.46
90 days	4.1	3.8

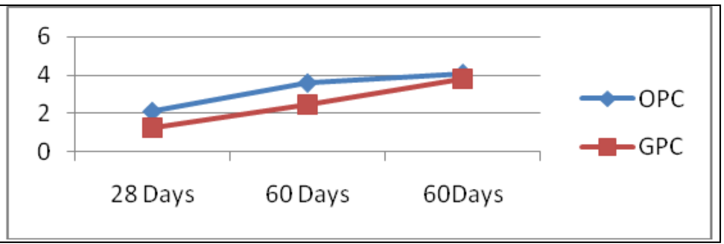

Fig .11 of Weight loss (in %) of OPC Concrete and GPC

2. Results Resistance to sulphate attack test:

Table.10 Weight loss (in %) due to 5% solution of $MgSO_4$and Na_2SO_4

No. Of Days	OPC concrete (%)	Geo-Polymer concrete (%)
28 days	3.1	2.6
60 days	4.3	3.1
90 days	4.8	3.9

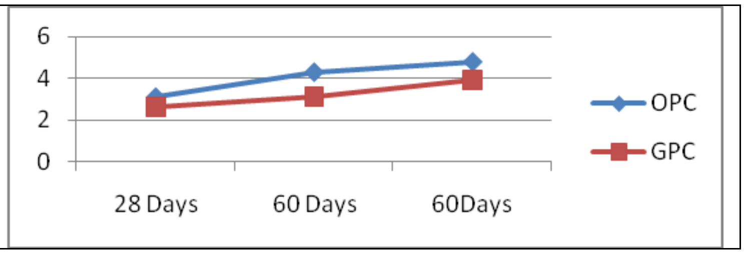

Fig.12 Comparison of Weight loss (in %) of OPC Concrete and GPC

3. Results Resistance to chloride attack test:

Table. 11 Weight loss (in %) due to 5% solution of Nacl

No. of Days	OPC concrete (%)	Geo-Polymer concrete (%)
28 days	2.5	1.83
60 days	4.1	2.22
90 days	4.8	3.78

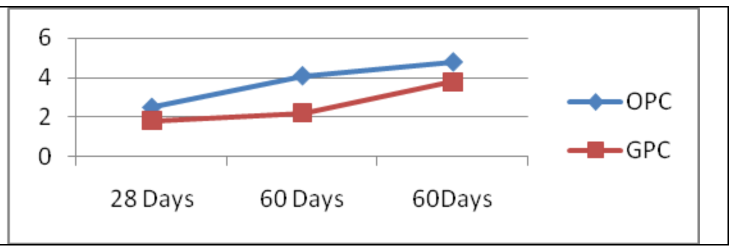

Fig.13Comparison of Weight loss (in %) of OPC Concrete and GPC

4. **Results Resistance to acid attack test:**

TABLE 12 WEIGHT LOSS (IN %) DUE TO 5% SULPHURIC AND 5% PHOSPHORIC ACID

No. of Days	OPC concrete (%)	Geo-Polymer concrete (%)
28 days	3.50	2.41
60 days	4.76	3.56
90 days	5.6	5.8

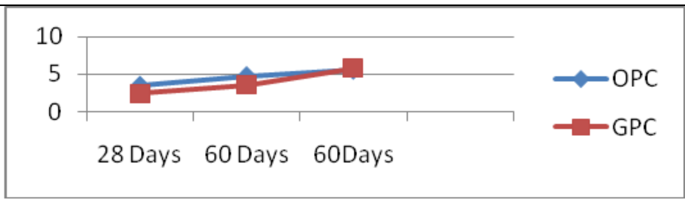

Fig.14 Comparison of Weight loss (in %) of OPC Concrete and GPC

5. Compressive Strength

Table 13 Compressive strength after Alkaline test

No. of Days	OPC concrete (%)	Geo-Polymer concrete (%)
28 days	41.3	64.7
60 days	35.3	61.2
90 days	31.6	56.3

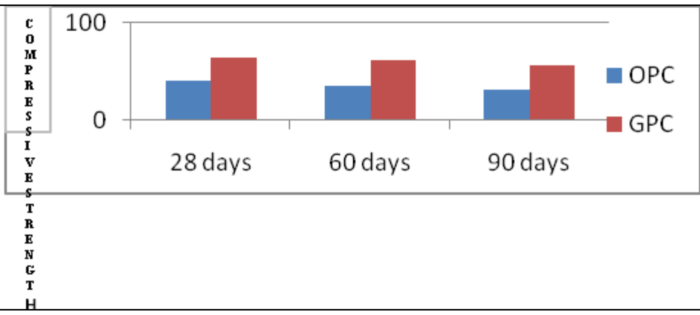

Fig.15 Comparison of Compressive strength of OPC concrete with GPC due to 5% solution of NaOH (N/mm^2)

6. Table 14 Compressive strength after Sulphate attack test

No. of Days	OPC concrete (%)	Geo-Polymer concrete (%)
28 days	43.4	65.48
60 days	36.3	60.3
90 days	31.1	58.07

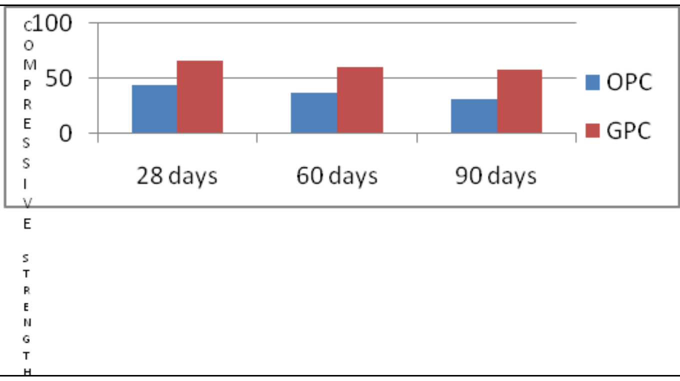

Fig.16 Comparison of Compressive strength of OPC concrete with GPC due to 5% solution of $NaSO_4$ and $MgSO_4$ (N/mm^2

7. Table 15 Compressive strength after chloride attack test

No. of Days	OPC concrete (%)	Geo-Polymer concrete (%)
28 days	42.34	66.2
60 days	32.13	59.6
90 days	30.6	57.3

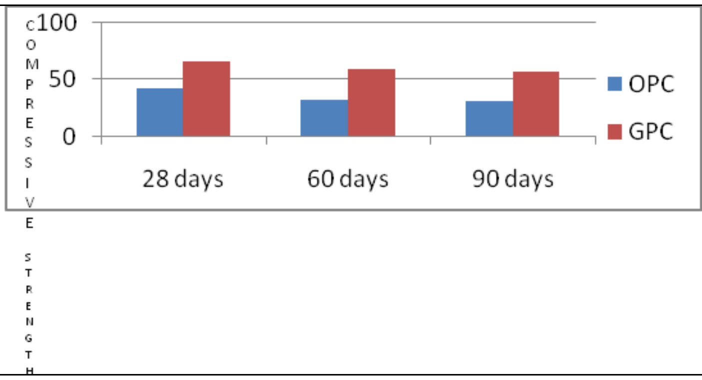

Fig.17 Comparison of Compressive strength of OPC concrete with GPC due to 5% solution of NaOH (N/mm^2)

8. Table 16 Compressive strength after Acid resistance test

No. of Days	OPC concrete (%)	Geo-Polymer concrete (%)
28 days	42.7	63.1
60 days	34.6	58.3
90 days	30.8	55.3

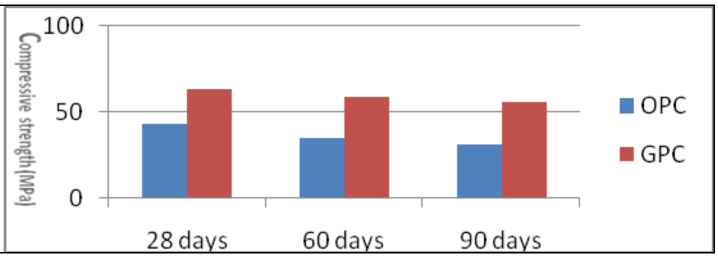

Fig.18Comparison of Compressive strength of OPC concrete with GPC due to 5% solution of HCL and H_3PO_4 (N/mm^2)

XIII. CONCLUSION

The major conclusions drawn from this research are presented below:

1. The fly ash Based and GGBS Based Geo Polymer concrete in structural applications has led to the total elimination of cement from concrete, which ultimately becomes "Green Concrete" and eco friendly to the atmosphere.
2. The fly ash a by product of burning Coal and GGBS a by product of Manufacture Iron once considered as waste material, has found useful through Geo-Polymer concrete in construction industries and become a valuable material.
3. The increase in the concentration of sodium hydroxide and Sodium Silicate which acts as a Alkaline solution to the Geopolymer Concrete from 8 M to 12M increased the viscosity and reduced the fresh properties of SCC mix.
4. The compressive strength of SCGC was incresed with increasing the amount of NaOH molarity.
5. The cost of the concrete was reduced by replacement of natural sand with M-sand. It also increases the properties of concrete like strength and durability.
6. The voids in concrete were reduced by replacement of natural sand with M-sand as it contains dust particles and also it overcomes the deficiencies like segregation, honeycombing in concrete.
7. Energy absorbtion capacity increases in the cylinders and beams with M-Sand compared to natural sand.
8. Its resistance against sulphate and acid attack makes it suitable to be used for construction in abrasive soils where ground water contains considerable amount of sulphate salts
9. The compressive strength increased up to 25% for the durability.

FUTURE SCOPE OF WORK

1. Investigations on the effect of varying percentage of fly ash and reduce the economy of Geo-Polymer concrete.
2. Study on the addition of various fibres and different fine aggregate in Geo-Polymer concrete and their effect on enhancement of strengths.
3. Achieving ultra high strength Geo-Polymer concrete by the addition of granite slag, quartz sand and quartz powder
4. This work can also be extended by using recycle aggregates and other materials.
5. By increasing the different molarities and mix designs to prepare 100% fly ash concrete.

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