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Effect of Replacement of Natural Sand With M-Sand in Geopolymer Mortar

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Abstract: ***Geopolymer mortar manufactured with sand and M-sand, which is composed by the base materials containing affluent aluminium and silicon that was activated by adopting alkaline solution to serve as a binder. Alkaline solution was prepared by using a combination of sodium hydroxide and sodium silicate. The product of ground granulated blast furnace slag (GGBS) based geopolymer mortar was studied by using 8 M, 10 M, 12 M, 14 M and 16 M concentrations of NaOH; and by 50% and 100% partial replacement of natural sand by M-Sand. The compressive strength of geopolymer mortar cubes is tested at 3days, 7days and 28 days after casting. The test results were compared with normal cubes of geopolymer mortar with same concentrations of NaOH.***

Keyword: geopolymer, aluminium, alkaline solution, sodium hydroxide, sodium silicate, GGBS.

I. INTRODUCTION

Cement is most widely used materials all over the world ranking in second place after water. Cement acts as a binding material to produce the mortar and it plays a major role in Construction field [2]. The demand of concrete is believed to rise exponentially in future driven by the infrastructural development taking all over the world [14]. The production of OPC not only consume significant amount of resources but also emits about 7% of the global carbon dioxide i.e. about 2.8 billion tons of greenhouse gas emission annually. Manufacturing of 1 ton of cement releases 1 ton of Co_2 [15]. Development of construction industries, there is a need of alternative binder which is having less carbon content for replacement of cement to reduce the growth of serious threats in near future [2].

II. GEOPOLYMER

In 1998 Davidovits proposed a geopolymer technology as an alternative to the Ordinary Portland cement (OPC) binder which is majorly being used in construction industries.

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Geopolymer are chain of mineral molecules linked with covalent bonds. In this technology, the material which is rich in silica (Si) and alumina (Al) is reacted with high alkaline solution by the process of geopolymerisation for the production of binding material [2].The alkaline solution act as activator for Geopolymerization which involves fast chemical reaction under highly alkaline condition on Si-Ai minerals that results in a three-dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds. The main significance of geopolymer technology lays primilinary in its ability to produce high performance binder from materials such as fly-ash or GGBS which are rich in Silica and Alumina content [4].The use of Geopolymer concrete in ready mix designs are increasing, also its applications in precast connections using accelerated curing is observed. Geopolymer mortar is emerging as environment friendly construction material for sustainable development as there are number of benefits linked with it [14]. Geopolymer mortar not only reduces the Co_2 release from OPC and utilises industrial waste by products such as fly ash, ground granulated blast furnace slag etc effectively. As a source material which are activated by alkaline solution act as binder [15]. Co_2 emission to the atmosphere caused by cement and aggregate industries can be reduced by 80% with the help of geopolymer technology. Hence it can be said that the geopolymer mortar shows considerable promise for the application in concrete industry as an alternative binder to OPC and is relatively new area for research that can leads to use of geopolymer environmentally friendly mortar eventually[2].

III. POLYMERIZATION

Polymerization is a producer of responding monomer particles together in a substance response to shape polymer chains or three-dimensional systems. In substance mixes, polymerization happen by means of an assortment of response instruments that change in multifaceted nature because of practical gatherings introduce in responding compound sand their inalienable steric impacts [12].

Polymerization, any procedure in which generally little particles called monomers. Consolidate chemically to deliver a vast chain like atom called a polymer. As a rule, not less than 100 monomer atoms must be consolidated to make an item that has certain remarkable physical properties for examples, versatility, high rigidity or the capacity to frame filaments that separate polymers from substances made from littler and easier particles frequently, a large number of monomer units are joined in a single molecule of a polymer [12].

Geopolymerization involves a substantially fast chemical reaction under alkaline conditions on silica - alumina minerals that shows in a 3D polymeric chain and ring structure.

Although the mechanism of polymerization is yet to be fully understood, a critical feature is that water is not involving in chemical reaction and water only present to facilitate workability and does not become a part of the resulting geopolymer structure [19].

IV. OBJECTIVES

The objectives of the present study are

- To study the properties and importance of manufacturing sand (M-Sand).
- To reduce the usage of ordinary Portland cement (OPC) by using GGBS in geopolymer mortar.
- To study the compressive strength of geopolymer mortar with different concentrations of NaOH with M-Sand.
- The compressive strength results of geopolymer mortar cubes with M-Sand are compared with geopolymer mortar cubes with normal sand (N-Sand).

V. MATERIALS

A. *Ground granular blast furnace slag (GGBS)*

Ground granular blast furnace slag (GGBS) is a cementious material whose main use in concrete and is a by-product from the blast furnace used to make iron. GGBS is incorporated through the path towards dousing. It is unclear in nature and surrounding as an outcome of slag dousing from effect warmer. It can be seen as helper thing in the midst of formation of steel which can help in strong advancement. Because of exponential developing in urbanization and industrialization, side effect from venture is turning into an expanding sympathy towards reusing and waste administration. GGBS is exceptionally valuable in the plan and advancement of high-quality cement mortar and cement [20 - 32].

B. *Fine Aggregate*

Fine aggregate are filler materials in construction. Particles of the fine aggregate ranges from 4.75 mm to 0.075 mm sieve. River sand, crushed stone sand, crushed gravel sand are the major sources of fine aggregate.

C. *Alkaline solution*

a. *Sodium hydroxide*

Sodium hydroxide is a pure whitish solid, flakes, sold in pellets, and granular form, as well as in solution. It has lower solubility in ethanol and methanol, but it is highly soluble in water, but is insoluble in ether and other non-polar solvent [4].

b. *Sodium Silicate*

Sodium silicate is the common name for compounds with an elemental formula Na_2SiO_3.

Sodium silicate is also the technical and common name for a mixture of such compounds, chiefly the metasilicate, also called water glass, or liquid glass, sodium silicate is available in liquid form and solid form [12].

$$\mathbf{Na_2CO_3+SiO_2 \rightarrow Na_2SiO_3+CO}$$

VI. EXPERIMENTAL INVESTIGATION

a. *Sieve Analysis*

In olden days only manual sieving is used where no electricity supply is available, for on-site random checking of maximum size and minimum size manual sieving is done. It is used only for explanation purpose. . In the laboratory the differentiation is made between throw-action sieve shakers and horizontal sieve shakers. The natural sand and M-Sand is sieved as per the procedure given in IS: 383 – 1970.

b. *Normal Consistency*

By taking the geopolymer material GGBS proportion and adding the alkali solution bit by bit starting from 30% proposed material. The Geopolymer was taken as 26% of total. The thickness of Geopolymer bond is taken 1242 kg/m^3. The workability and nature of mortar are affected by properties of materials that make Geopolymer mortar cubes. The mixing is done with 1:3[9].

Fig. 1: Consistency Test Apparatus

c. *Procedure for Mortar Cubes*

This test shall be conducted at a temperature of 27°C. The required amount material is weighed for each cube separately. The quantity of GGBS, M-sand, sodium hydroxide and sodium silicate required for each cube are as follows

GGBS = 200gms, M-Sand = 600gms, 2mm to 1mm – 200gms ,1mm to 500 micron -200gms, 500 microns to 90 micron – 200gms which are taken from IS 650:1991. Water = (P/4+3) percentage of combined mass of GGBS and M-sand. Place the materials on tray, a mixture of GGBS and M-Sand. Mix when it is dry with trowel for one minute until the mixture gets uniform colour. After that add alkaline solution to the sample and mix thoroughly. The time of mixing shall not exceed 3 minutes and should get uniform colour within 4 minutes. Assemble the moulds which are required for casting, fix the joints of the mould tightly. After 24 hours De-mould the specimen and then do the ambient curing for a period of 3 days, 7 days and 28 days to gain the strength. Compressive test is carried out to know the compressive strength at 3,7,28 days.

d. *Mixing*

The dissolvable activator plan is set up before 24 hours of tossing. At the start with, every single dry material was mixed properly for 3 minutes. Solvent activator course of action is added bit by bit to the mix. Mixing is refined for 5 minutes to get uniform mix. [33 - 45].

e. *Casting*

The sizes of the moulds used for mortar cubes are (70.6 mm X 70.6 mm X 70.6 mm).

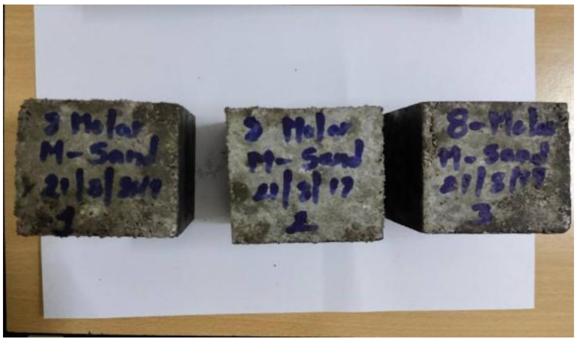


Fig. 2: Mortar Cubes

f. *Ambient Curing*

Geopolymer mortar good at reduction of greenhouse gases compared to ordinary Portland cement. Many researches on fly ash based geopolymer shows that by heat curing it gains more strength. Considering the in-situ applications we are going for ambient curing under room temperatures. After demoulding geopolymer mortar cubes are kept in air at room temperatures 27-30^{0}C.in this type of curing cubes gain strength without use of water. But these cubes gain more strength over time [19].

g. *Compressive Strength of Mortar Cubes*

The strength of geopolymer mortar is determined by doing compressive strength test on 70.6*70.6*70.6 mm cubes, made with M-sand, mixed manually and compacted by using a standard vibrating machine. The equipment required for this experiment are standard compression testing machine and geopolymer specimens. This test is carried out by placing the specimen in testing machine firmly in position. Load is applied on the specimen at the rate of 140 kg/cm^2. Maximum capacity of loading for compressive testing machine is 2000 KN. The figure-3 shows the compressive testing machine diagram.

Fig. 3: Compression testing machine

VII.EXPERMENTAL RESULTS

Table I. 8 Molar 100% M-Sand, 50% M-sand + 50% N-Sand & 100% N-Sand for 3, 7 & 28 days

Compressive strength (MPa)	Trails	100%M-Sand	50%M-Sand, 50% N- Sand	100% Sand
3 days	Trail-1	27.55	24.4	26.4
	Trail-2	25.48	28.52	28.52
	Trail-3	29.36	24.4	32.59
	Avg.	**27.46**	**25.77**	**29.17**
7 days	Trail-1	31.49	34.63	38.7
	Trail-2	35.42	30.55	36.67
	Trail-3	39.63	34.63	36.67
	Avg.	**35.51**	**33.27**	**37.34**
28 days	Trail-1	48.89	42.78	38.7
	Trail-2	44.74	46.85	42.78
	Trail-3	40.74	38.7	40.74
	Avg.	**44.81**	**42.77**	**40.74**

Table II. 10 Molar 100% M-sand, 50% M-sand + 50% N-Sand & 100% N-Sand for 3, 7 & 28 days

Compressive strength (MPa)	Trail	100% M-Sand	50% M-Sand, 50% N-Sand	100% Sand
3 days	Trail-1	30.55	28.52	28.52
	Trail-2	32.59	26.4	36.67
	Trail-3	28.52	30.55	32.59
	Avg.	**30.55**	**28.49**	**32.59**
7 days	Trail-1	34.63	34.63	43.44
	Trail-2	38.7	36.67	34.63
	Trail-3	36.67	32.59	38.7
	Avg.	**36.66**	**34.63**	**38.92**
28 days	Trail-1	44.82	38.7	38.7
	Trail-2	50.93	44.82	44.82
	Trail-3	46.82	46.85	42.78
	Avg.	**47.52**	**43.45**	**42.1**

Table III. 12 Molar 100% M-sand, 50% M-sand + 50% N-Sand & 100% N-Sand for 3, 7 & 28 days.

Compressive strength (MPa)	Trail	100% M-Sand	50% M-Sand, 50% N-Sand	100% Sand
3 days	Trail-1	26.4	24.44	34.63
	Trail-2	32.59	32.59	30.55
	Trail-3	34.63	32.59	34.63
	Avg.	**31.20**	**29.87**	**33.27**
7 days	Trail-1	38.7	36.67	40.27
	Trail-2	36.67	36.67	41.76
	Trail-3	38.7	34.63	39.54
	Avg.	**38.02**	**35.99**	**40.51**
28 days	Trail-1	50.93	50.93	48.89
	Trail-2	48.89	44.8	44.82
	Trail-3	55	46.85	40.74
	Avg.	**51.60**	**47.52**	**44.81**

Table IV. 14 Molar 100% M-Sand, 50% M-Sand + 50% N-Sand & 100% N-Sand for 3, 7 & 28 days.

Compressive strength (MPa)	Trail	100% M-Sand	50% M-Sand, 50% N-Sand	100% Sand
3 days	Trail-1	30.55	28.52	36.67
	Trail-2	36.64	34.63	36.67
	Trail-3	34.63	30.55	34.63
	Avg.	**33.94**	**31.23**	**35.99**
7 days	Trail-1	38.7	43.44	38.7
	Trail-2	40.74	34.63	44.84
	Trail-3	42.78	38.7	42.78
	Avg.	**40.74**	**38.92**	**42.10**
28 days	Trail-1	48.89	50.93	55
	Trail-2	55	55	59.08
	Trail-3	61.1	50.93	50.93
	Avg.	**54.99**	**52.28**	**55.00**

Table V. 16 Molar 100% M-sand, 50% M-sand + 50% N-Sand & 100% N-Sand for 3, 7 & 28 days.

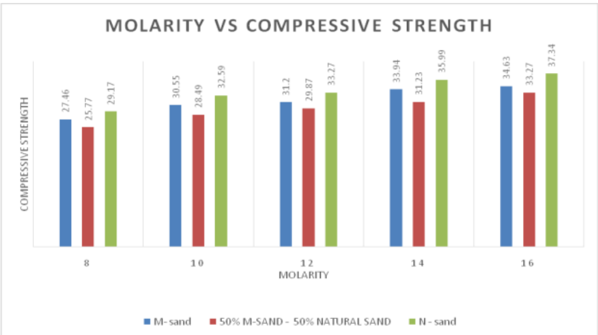
Compressive strength (MPa)	Trail	100% M-Sand	50% M-Sand, 50% N-Sand	100% Sand
3 days	Trail-1	34.63	32.59	38.7
	Trail-2	36.67	32.59	36.67
	Trail-3	32.59	34.63	36.67
	Avg.	**34.63**	**33.27**	**37.34**
7 days	Trail-1	45.64	42.78	45.64
	Trail-2	44.74	41.76	44.74
	Trail-3	40.74	39.54	46.84
	Avg.	**43.70**	**41.36**	**45.74**
28 days	Trail-1	59.08	59.08	59.08
	Trail-2	55	57.04	50.93
	Trail-3	59.08	61.11	48.89
	Avg.	**57.72**	**59.07**	**52.96**

Table VI. Average Compressive Strength for 3 days.

S.No	Molarity	Average compressive strength for 3 days (MPa)		
		M-Sand	50% M-Sand, 50% N-Sand	N-Sand
1	8	27.46	25.77	29.17
2	10	30.55	28.49	32.59
3	12	31.2	29.87	33.27
4	14	33.94	31.23	35.99
5	16	34.63	33.27	37.34

For 3 days polymerisation reaction in M-sand mortar cubes is low compared to natural sand mortar cubes.so the compressive strength results in M-sand mortar cubes is low compared to natural sand mortar cubes.

Graph 1: Average compressive strength for 3 days



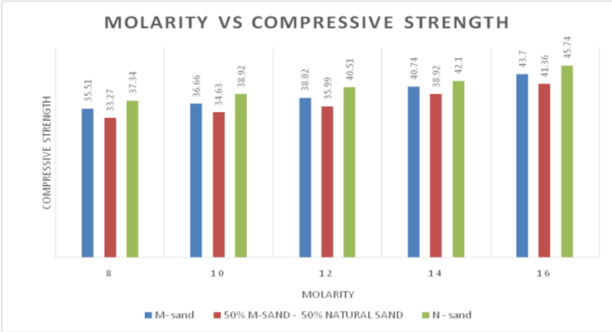
This graph shows the compressive strength results for M-sand, 50% M-sand – 50% natural sand, 100% natural sand for 3 days.

Table VII. Average compressive strength for 7 days

S.no	Molarity	Average compressive strength for 7 days (MPa)		
		M-Sand	50% M-Sand, 50%N-Sand	N- Sand
1	8	35.51	33.27	37.34
2	10	36.66	34.63	38.92
3	12	38.02	35.99	40.51
4	14	40.74	38.92	42.1
5	16	43.7	41.36	45.74

For 7 days polymerisation reaction in M-sand mortar cubes is low compared to natural sand mortar cubes. So the compressive strength results in M-Sand mortar cubes is low compared to natural sand mortar cubes.

Graph 2. Average compressive strength for 7 days



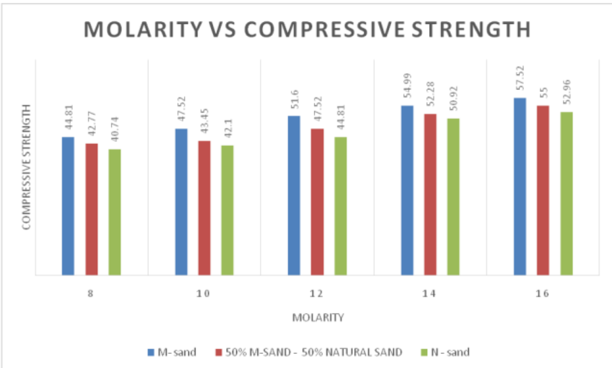
This graph shows the compressive strength results for M-sand, 50% M-sand – 50% natural sand, 100% natural sand for 7 days.

Table VIII. Average compressive strength for 28 days.

S.no	Molarity	Average compressive strength for 28 days (MPa)		
		M-Sand	50% M-Sand, 50% N-Sand	N- Sand
1	8	44.81	42.77	40.74
2	10	47.52	43.45	42.1
3	12	51.6	47.52	44.81
4	14	54.99	52.28	50.92
5	16	57.52	55	52.96

For 28 days polymerisation reaction in M-sand mortar cubes is high compared to natural sand mortar cubes.so the compressive strength results in M-sand mortar cubes is high compared to natural sand mortar cubes.

Graph 3: Average compressive strength for 28 days



This graph shows the compressive strength results for M-sand, 50% M-sand – 50% natural sand, 100% natural sand for 28 days.

VIII. CONCLUSION

The study of geopolymer mortar is done at room temperature. From the experimental results reported the following conclusions are drawn:

a) Higher concentration of sodium hydroxide solution results in a higher compressive strength of geopolymer mortar;
b) By replacing cement with GGBS the emission of CO_2 is reduced considerably which in turn reduces the effect of global warming;

c) As like earlier studies the GGBS based geo-polymer mortar with M-Sand gains more strength on time. Thus, the Geo-polymer mix with M-Sand has a higher compressive strength than Geo-polymer mix with Natural Sand.

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