An Experimental Study on Geo-Polymer Concrete Incorporating GGBS And Metakaolin

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***Abstract*— The major problem the world is facing today is the environmental pollution. In the construction industry mainly the production of Portland cement will cause the emission of pollutants results in environmental pollution. We can reduce the pollution effect on environment, by increasing the usage of industrial by-products in our construction industry. Geo-polymer concrete is such a one and in the present study, to produce the geo-polymer concrete the Portland cement is fully replaced with GGBS (Ground granulated blast furnace slag) and Metakaolin and alkaline liquids are used for the binding of materials. The alkaline liquids used in this study for the polymerization are the solutions of Sodium hydroxide (NaOH) and sodium silicate (Na2Sio3) of A53 which consists of SiO2 = 29.4%, Na2O = 14.7%, and water = 55.9% by mass is used. 10Molar Sodium hydroxide is taken for the preparation of different mixes by varying the percentages of GGBS (Ground granulated blast furnace slag) and Metakaolin. The cube specimens are taken of size 150mm x 150mm x 150mm for compression test. The curing was done directly by placing the specimens to direct sunlight. The geo-polymer concrete specimens are tested for their compressive strength at the age of 3, 7 and 28days and compared with conventional concrete. For this study M30 concrete mix was used for experimental work. The result shows that there is an increase in the strength of Geopolymer concrete up to 40%GGBS content and then it is decreasing. Therefore it is preferable to use 40%GGBS with Metakaolin to get high strength. Metakaolin and GGBS can be used as a replacement material for cement gives an excellent result in strength aspect and quality aspect since it is better than the control concrete.**

***Index Terms*— Geopolymer concrete, GGBS, Metakaolin, Alkaline solutions, curing, compressive strength.**

I. INTRODUCTION

The Concrete usage around the world is second only to water. Ordinary Portland cement (OPC) is conventionally used as the primary binder to produce concrete. The environmental issues associated with the production of OPC are well known. The amount of the carbon dioxide released during the manufacture of OPC due to the calcination of limestone and combustion of fossil fuel is in the order of one ton for every ton of OPC produced. In addition, the extent of energy required to produce OPC is only next to steel and aluminum. In the construction industry, mainly the production of Portland cement will cause the emission of pollutants, results in environmental pollution. The need to reduce the global anthropogenic carbon dioxide has encouraged researchers to search for sustainable building materials.

In order to reduce the emissions of carbon dioxide, cement in concrete is replaced by materials like fly ash, GGBS (Ground granulated blast-furnace slag) and metakaolin is considered as a more eco- friendly alternative to Ordinary Portland Cement (OPC) based concrete. It is termed as Geopolymer concrete. The advancement of concrete technology can reduce the consumption of natural resources and energy sources and lessen the burden of pollutants on environment. Presently large amounts of Metakaolin, a dehydroxylated form of the clay mineral kaolinite came into existence. This project describes the feasibility of using GGBS (Ground granulated blast-furnace slag) and metakaolin in concrete production as replacement of cement.

Geopolymer materials represent an innovative technology that is generating considerable interest in the construction industry, particularly in light of the ongoing emphasis on sustainability. In contrast to the Portland cement, the most Geopolymer systems rely on minimally processed natural materials or industrial byproducts to provide the binding agents. Since Portland cement is responsible for upward of 85 percent of the energy and 90 percent of the carbon dioxide (CO_2) attributed to a typical ready-mixed concrete, the savings of the potential energy and carbon dioxide through the use of Geopolymer can be considerable. Consequently, there is growing interest in Geopolymer application in construction industry.

II. LITERATURE REVIEW

The trading of carbon dioxide (CO_2) emissions is a critical factor for the industries, including the cement industries, as the greenhouse effect created by the emissions is considered to produce an increase in the global temperature that may result in climate changes. The tradeable emissions‟ refers to the economic mechanisms that are expected to help the countries worldwide to meet the emission reduction targets established by the 1997 Kyoto Protocol. Speculation has arisen that one ton of emissions can have a trading value about US$10 (Malhotra 1999; Malhotra 2014).

Recently, Alloucher et al. (2021) studied the self-curing properties of geopolymer concrete. The study shows that the temperature generated is dependent upon the amount of concrete mixed. The strength of GPC was found to increase with curing period. The modulus of elasticity and Poisson‟s ratio corresponding to 28 days‟ curing were found to be within acceptable range for typical concrete used in a structural application.

Mustfa et al. (2022) based on the experimental work concluded that the $Na_2SiO_3/NaOH$ ratios and NaOH molarities the compressive strength of the fly ash based geopolymer concrete. The $Na_2SiO_3/NaOH$ ratio of 2.5 contributed to the high compressive strength of 57Mpa. The highest NaOH molarity did not necessarily give the highest compressive strength. The geopolymer with 12 M NaOH showed excellent results including a high compressive strength of up to 94.59 MPa corresponding to 7 days‟ curing.

III. MATERIALS

The materials used in the project are as follows:

- Cement
- Fine aggregate
- Coarse aggregate
- Water
- Metakaolin
- Ground granulated blast furnace slag (GGBS)
- Alkaline solution

Cement: Ordinary Portland Cement of “BHARATHI” brand 53 GRADE confirming to Indian standards is used in the present investigation. The cement is tested for its various properties as per IS: 4031-1988 and found to be confirming to the requirements as per IS: 8122-1989.

Fine aggregate: The sand obtained from Krishna River near Vijayawada is used as fine aggregate in this project investigation. The sand is free from clayey matter, silt and organic impurities etc. The sand is tested for specific gravity, in accordance with IS: 2386-1963 and it is 2.719, whereas its fineness modulus is 2.31. The sieve analysis results are presented in table. The sand confirms to zone-II

Coarse aggregate: Machine crushed angular Basalt metal used as coarse aggregate. The coarse aggregate is free from clayey matter, silt and organic impurities etc. The coarse aggregate is also tested for specific gravity and it is 2.68. Fineness modulus of coarse aggregate is 4.20. Aggregate of nominal size 20mm and 10mm is used in the experimental work, which is acceptable according to IS: 383-1970.

Water: The locally available potable water, which is free from concentration of acid and organic substances, is used for mixing the concrete.

Metakaolin: is obtained from the Kaomine industries PVT LTD at Vadodara on Gujarat state. The specific gravity of Metakaolin is 2.6 and the size of particle is less than 90 microns. The colour of metakaolin is pink.

Metakaolin

Ground granulated blast furnace slag (GGBS): is obtained from jindal steel and power ltd.,Vijayawada office . The specific gravity of GGBS is 2.9. Bulk density is 1200 kg/m3 and Fineness is >350m2/kg. The colour of GGBS is off-white.

Ground granulated blast furnace slag

Alkaline Solution: The most common alkaline liquid used in geopolymerisation is a combination of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3). It is recommended that the alkaline liquid is prepared by mixing both the solutions together at least 24 hours prior to use. The sodium silicate solution is commercially available in different grades. The sodium silicate solutionA53 with SiO_2-to-Na_2O ratio by mass of approximately 2, i.e., SiO_2 = 29.4%, Na_2O = 14.7%, and water = 55.9% by mass is used. The sodium hydroxide with 97-98% purity, in flake or pellet form, is commercially available. The solids must be dissolved in water to make a solution with the required concentration. The concentration of sodium hydroxide solution can vary in the range between 8 Molar and 16 Molar. In this investigation 10M is adopted.

Alkaline Solution

III. METHODOLOGY

A concrete mix of M30 grade is designed based on IS:10262-1984 and cubes are casted for the conventional mix. Geopolymer concrete mixes of varying percentages of GGBS and METAKAOLIN are laid with alkaline binders.

Maximum nominal size of aggregate = 20mm

Value of slump = 50mm

Zone of aggregate = zone ll

Specific gravity of cement = 3.15

Specific gravity of coarse aggregate = 2.8

Specific gravity of fine aggregate = 2.6

Target Mean Strength of Concrete

$F'_{ck} = f_{ck} + (t \times s)$

$F'_{ck} = 30 + (1.65 \text{ X } 4)$

$F'_{ck} = 36.6$ Mpa

Water	Cement	F.A	C.A
186	413	660	1166
0.45	1	1.59	2.82

The different percentages of GGBS and Metakaolin based Geopolymer concrete are as follows:

- 80%MK+ 20% GGBS
- 70%MK+ 30% GGBS
- 60%MK+ 40% GGBS
- 50%MK+ 50% GGBS
- 100%MK
- 100% GGBS

IV. TESTS AND RESULTS

Tests on Cement:

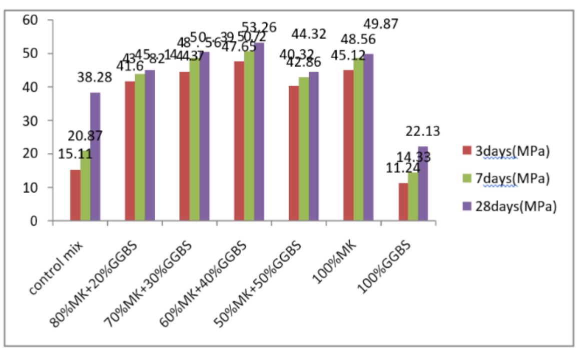
S.NO	PHYSICAL TESTS	OBTAINED RESULTS	REQUIREMENTS AS PER IS CODES
1	Fineness	2.6%	Not>10% as per IS 4031 part 1
2	Standard Consistency	27.5%	IS 4031 part 4
2	Initial Setting time	47min11sec	Not less than 30 minds as per IS 4031 part 5
3	Final setting time	498 min	Not more than 600 minutes as per IS 4031 part 5
4	Soundness	5mm	Not>10mm as per IS 4031 part 3
5	Specific gravity	3.01	IS 2720 part 3(3.15isgeneral value)

Tests on Aggregate:

Sl. No	Physical Tests	Obtained results	Requirements as per IS 383
1	Crushing Test	38%	Not more than 45% (otherthan wearing surfaces)
2	Impact Test	32.95%	Not more than 45% (otherthan wearing surfaces)
3	Los Angeles AbrasionTest	28.5%	Not more than 50% (otherthan wearing surfaces)
4	Flakiness Index	20.12%	Not > 35% as per MORTH
5	Specific gravity		
	a) Coarse Aggregates	2.8	
	b) Fine Aggregates	2.6	
6	Water absorption		Not>2%as per IS:2386-Part 3
	a) Coarse Aggregates	0.2%	
	b) Fine Aggregates	0.5%	

Compressive Strength:

S. NO	% of Metakaolinand GGBS in mixture	3DAYS N/mm2	7DAYS N/mm2	28DAYS N/mm2
1	100% GGBS	11.24	14.33	22.13
2	100% MK	45.12	48.56	49.87
3	80%MK+20%GGBS	41.6	43.82	45.14
4	70%MK+30%GGBS	44.37	48.56	50.39
5	60%MK+40%GGBS	47.65	50.72	53.26
6	50%MK+50%GGBS	40.32	42.86	44.32



V. CONCLUSION

Based on limited experimental investigations conducted on concrete the following conclusions are drawn

- From the above results it is apparent that Geopolymer concrete based on GGBS and metakaolin has got more compressive Strength than conventional concrete.
- The strength of the Geopolymer concrete increases with the increase in GGBS content upto 50% and then reduces, so it is recommended to use GGBS up to 50% in the GPC mixes.
- The strength of the Geopolymer concrete increases with 2%-4% from 3 to 7 days and 2% - 5% from 7 to 28 days that means there is no much increase in the strength after 7days.
- Alone metakaolin can perform well as it has got 45MPa compressive strength for 3days but GGBS cannot be used as the compressive strength of it is less than control mix of M30.
- The results showed that the substitution of 60% Metakaolin and 40% GGBS content induced higher compressive strength.
- From the above all tests, it is concluded that the Metakaolin and GGBS can be used as a replacement material for cement gives an excellent result in strength aspect and quality aspect since it is better than the control concrete.
- By using the Metakaolin and GGBS as a filler or replacement in GPC concrete will reduce environmental pollution as they are reason for getting turned the agricultural land to barren land when they are disposed as wastes

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