International Journal For Technological Research In Engineering
Volume 7, Issue 4, December-2019 *ISSN (Online): 2347 - 4718*

EXPERIMENTAL STUDIES ON GEOPOLYMER CONCRETE WITH METAKAOLIN AND GGBS

Damuluri Devi Dhakshayani
M.Tech Student, Department of Civil Engineering, Usha Rama College of Engineering & Technology, Telaprolu, Krishna District, Andhra Pradesh, India, 521109

ABSTRACT: The global cement industry contributes about 7% of greenhouse gas emission into the earth's atmosphere. Among the greenhouse gases; CO_2 contributes about 65% of global warming. Cement industry is one of the major contributors of CO_2 emission. Consequently, efforts have been made in the concrete industry to use waste materials as partial replacement of coarse or fine aggregates and cement. Construction industry is dominated by new materials which are ecologically violable and feasible solution for ever growing architectural industry. Effort are in progress all over the world to develop environment friendly construction materials which minimizes the utility of natural resources and helps to decrease green house gas emissions in to the atmosphere. The green house gas releases in the atmosphere is increasing day by day due to ordinary Portland cement production. In this connection, Geopolymer is in need, where the binders used in the production of geopolymer concrete is inorganic polymers. Geopolymer concrete will be introduced as an alternative concrete which did not use any cement in its mixture and used Metakaoline and GGBS as alternative cement. NaOH and Na2SiO3 were used as activator solution. The fixed ratio of sodium silicate to sodium hydroxide is 2.5 and the concentration of sodium hydroxide is 8 Molar. The geopolymer concrete specimens are casted and tested in the laboratory for compressive strength, Split Tensile Strength and Flexural Strength for 3 Days, 7 Days and 28 days and cured at ambient temperature. This study helps in gaining knowledge about the morophological composition of geopolymer concrete which might result in path-breaking trends in research and construction industry.
KEYWORDS:Geopolymer Concrete, Alkali Activators, Compressive Strength, Split Tensile Strength, Flexural Strength.

I. INTRODUCTION

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.

Bennet Jose Mathew explained that the demand for cement is increasing with the increase in the development of infrastructure taking place all over the world. The process of producing cement is not only highly internal energy intensive, but is also responsible for large emissions of carbon dioxide (CO2), which is green house gas causing global warming. According to one of the studies in the past the worldwide cement production accounts for almost 7% of the total world CO2 emissions. The control of such green house gas emission is a major issue for sustainable concrete. In addition to this, about 3 billion tons of the raw materials are needed every year for cement manufacturing, which consumes considerable energy and adversely affect the ecology of the planet. At the same time, the ordinary Portland cement concretes are less durable under certain environmental conditions. On this backdrop, there is an urgent need to find an alternate binder to cement in order to make the construction industry eco friendly and sustainable.

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.

In 1978, Davidovits proposed that binders could be produced by a polymeric reaction of alkaline liquids with the silicon and the aluminium in source materials of geological origin or by-product materials such as fly ash and rice husk ash. He termed these binders as geopolymers. Palomo et al suggested that pozzalona such as blast furnace slag might be activated using alkaline liquids to form a binder and hence totally replace the use of OPC in concrete. This concrete is produced by activating different alumino-silicate based waste materials with highly alkaline solution. The curing of freshly prepared Geopolymer concrete is the most crucial aspect and it plays an important role in the entire geopolymerisation process. The proper curing of concrete has a positive effect on the final properties of the Geopolymer concrete. The curing of such concrete is mostly carried out at elevated temperatures; however, curing at ambient temperatures is also carried out at times. At ambient temperatures; the reaction of fly ash-based Geopolymeric materials is very slow and usually shows a slower setting and strength development. It is believed that higher temperatures activate alumino-silicate phases in the fly ash; therefore, they are generally cured at elevated temperatures between 60°C- 90°C.

In India, the Metakaolin and GGBS are the most thriving industrial effects. These contain physical and mechanical properties of fresh and hardened concrete that have been investigated. Slump and air content of fresh concrete and absorption and compressive strength of hardened concrete were also investigated. Test results show that this Metakaolin and GGBS are capable of improving hardened concrete performance up to 10%, Enhancing fresh concrete behavior and can be used in architectural concrete mixtures. The compressive strength of concrete was measured for 3, 7 and 28 days. In order to evaluate the effects of Metakaolin and GGBS on mechanical behavior, many different mortar mixes were tested.

In this work, Metakaolin-GGBS based geopolymer is used as the binder, instead of Portland or other hydraulic cement paste, to produce concrete. The Metakaolin-GGBS based Geopolymer paste binds the loose coarse aggregates, fine aggregates and other un-reacted materials together to form the geopolymer concrete, with or without the presence of admixtures. The manufacture of geopolymer concrete is carried out using the usual concrete technology methods.

II. MATERIALS USED

The materials used in the project are as follows:

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

Metakaolin

Metakaolin is a calcined product of the clay mineral kaolinite. The Particle size of Metakaolin is smaller than cement particles, but not as fine as silica fume. When kaolinite, a layered silicate mineral with a distance of 7,13 A between the layers of SiO_2 and Al_2O_3 is heated, the water contained between the layers is evaporated and the kaolinite is activated for reaction with cement.

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. Chemical formula of Metakaolin is $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$.

Applications of Metakaolin

- High performance, High strength and Lightweight concrete
- Precast Concrete for architectural, Civil, Industrial and structural works
- Fiber cement and Ferro cement products, Glass Fiber Reinforced Concrete.
- Mortars, Repair Material, Pool plasters.
- Manufactured Repetitive Concrete products

Metakaolin can be used in mortars and concrete for:

- Increased Compressive and Flexural Strengths
- Reduced Permeability & Efflorescence
- Increased resistance to Chemical attacks
- Reduced Shrinkage
- Improved finish ability, color and appearance

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.

Figure1. Metakaolin

Figure2. GGBS

Alkaline Solution

The most common alkaline liquid used in geopolymerisation is a combination of sodium hydroxide (NaOH) and sodium silicate (Na2SiO3). 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 SiO2-to-Na2O ratio by mass of approximately 2, i.e., SiO2 = 29.4%, Na2O = 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.

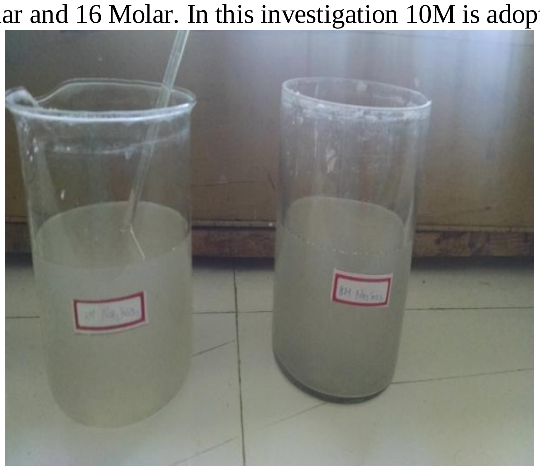


Figure3. Alkaline Solution

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. The binder is prepared with sodium hydroxide and sodium silicate.

PREPARATION OF ALKALINE SOLUTION

400 g (molarity x molecular weight) of sodium hydroxide flakes dissolved in one litre of water to prepare sodium hydroxide solution of 10M. The mass of NaOH solids in a solution vary depending on the concentration of the solution expressed in terms of molar, M. The mass of NaOH solids was measured as 310 g per kg of NaOH solution of 10M concentration. The sodium hydroxide solution is mixed with sodium silicate solution to get the desired alkaline solution one day before making the Geopolymer concrete. After solution is prepared the composition is weighed and mixed in concrete mixture as conventional concrete and transferred into moulds as early as possible as the setting times are very low.

For 10M NaoH:

10M NaoH = 10 x40 = 400 gm/lit.

Total NaoH to be mixed = 400/(sp.gravity of NaoH)
= 400/2.541
= 160 gm/lit

Assume sodium silicate / sodium hydroxide = 2.5

Na2Sio3 = 2.5 x NaoH
= 2.5 x 400 = 1000 gm/lit

Total Na2Sio3 = 1000/(sp.gravity of Na2Sio3)
= 1000/2.7
= 370.37gm/lit

Finally for one litre of water mix:

NaoH = 160gm/lit

Na_2SiO_3 = 370.3gm/lit

For all test specimens, moulds were kept on table vibrator and the concrete was poured into the moulds in three layers by tamping with a tamping rod and the vibration was effected by table vibrator after filling up moulds. After curing the specimens in water for a period of 3 days, 7 days, & 28 days the specimens were taken out and allowed for drying under shade before testing.

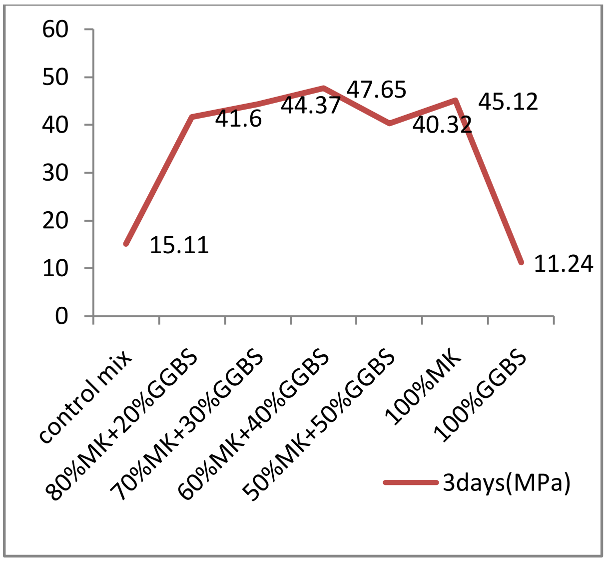
IV. RESULTS AND DISSUSSION

TEST RESULTS:

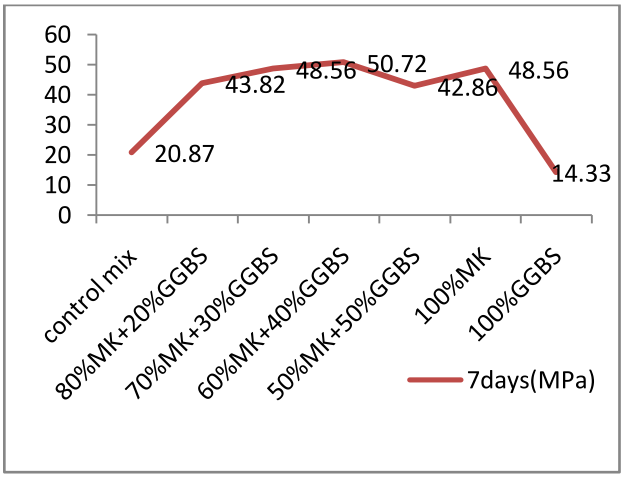
This section provides the results obtained from various tests conducted in this work. The different results obtained from Compressive Strength test for 3 days, 7 days, & 28 days.

Table.Compressive strength with age

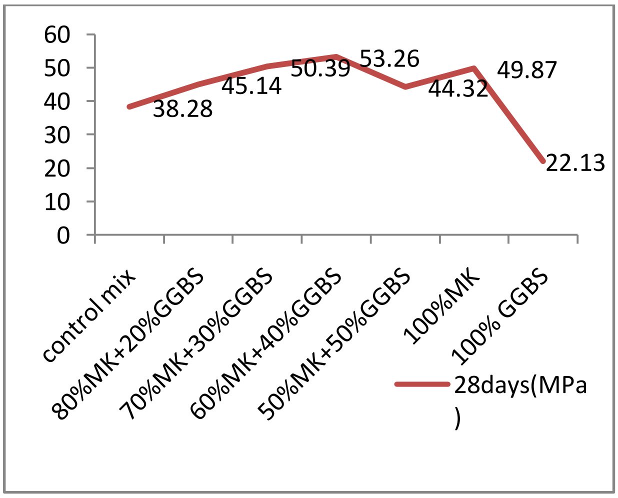
S.NO	Percentage of Metakaolin and GGBS in mixture	3 DAYS N/mm^2	7 DAYS N/mm^2	28 DAYS N/mm^2
1	100% GGBS	11.24	14.33	22.13
2	100% MK	45.12	48.56	49.87
3	80%MK+20%GGBS	41.6	43.82	45.14
4	70%MK+30%GGBS	44.37	48.56	50.39
5	60%MK+40%GGBS	47.65	50.72	53.26
6	50%MK+50%GGBS	40.32	42.86	44.32



(a)



(b)



(c)

Figure 4. (a),(b),(c), Compressive strength of Geopolymer concrete for 3days,7days & 28days respectively.

When 100% GGBS is used 28-day compressive strength reached 22.13 N/mm^2, where as for 100% Metakaolin, its value reached to 49.87 N/mm^2. Out of the combinations of different percentages of GGBS & Metakaolin, 60% Metakaolin+ 40% GGBS found to yield highest strength as 53.26 N/mm^2 which is an excellent out come. However the other aspects of concrete in terms of durability, bond with steel etc must be studied before recommending it as a construction material.

V. CONCLUSIONS

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.
- Alone metakaolin can perform well as it has got 45MPa compressive strength for 3days but GGBS cannot be used alone, 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 much 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.

REFERENCES

[1] A Study On Strength Properties Of Geopolymer Concrete With Addition Of G.G.B.S, Ganapati Naidu. P, A.S.S.N.Prasad, International Journal of Engineering Research and Development eISSN : 2278-067X, pISSN : 2278-800X,Volume 2, Issue 4 (July 2012), PP. 19-28

[2] Strength, Economic And Sustainability Characteristics Of Coal Ash –Ggbs Based Geopolymer Concrete. Mr. Bennet Jose Mathew, Mr. M Sudhakar, International Journal Of Computational Engineering Research (ijceronline.com) Vol. 3 Issue.1 ,2012

[3] A Review On Use Of Metakaolin In Concrete, Aiswarya S, Prince Arulraj G, IRACST – Engineering Science and Technology: An International Journal (ESTIJ), ISSN: 2250-3498,Vol.3, No.3, June 2013

[4] Mechanical Properties Of Geopolymer Concrete With Fly Ash And Ggbs As Source Materials, B. Rajini1, A.V. Narasimha Rao, International Journal of Innovative Research in Science, Engineering and Technology'Vol. 3, Issue 9, September 2014

[5] A Review on Use of Metakaolin in Cement Mortar and Concrete, Dr.K.Srinivasu, M.L.N.Krishna Sai, Venkata Sairam Kumar.N, International Journal of Innovative Research in Science, Engineering and Technology'Vol. 3, Issue 7, September 2014
[6] Effect of Metakaolin Content on the Properties of High StrengthConcrete, P. Dinakar*, Pradosh K. Sahoo, and G. Sriram, International Journal of Concrete Structures and Materials,Vol.7, No.3, pp.215–223, September 2013
[7] A review: The comparison between alkali-activated slag (Si+Ca) and metakaolin (Si+Al) cements,Chao Li a,⁎, Henghu Sun a,b, Longtu Li, Cement and Concrete Research 40 (2010) 1341–1349,elsvier journal.
[8] Experimental study on Geo-Polymer concrete incorporating GGBS,V. Supraja, M. Kanta Rao, International Journal of Electronics, Communication & Soft Computing Science and Engineering ,ISSN: 2277-9477, Volume 2, Issue 2
[9] Geopolymer Concrete, An Earth Friendly Concrete, Very Promising In The Industry,T.V. Srinivas murthy1, dr. Ajeet kumar rai, International journal of civil engineering and technology, volume 5, issue 7, july (2014), pp. 113-122.
[10] Metakaolin- Pozzolanic Material For Cement in High Strength Concrete Sanjay N. Patil, Anil K. Gupta, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) ISSN: 2278-1684, PP: 46-49
[11] Strength Properties of Metakaolin Admixed Concrete,Nova John, International Journal of Scientific and Research Publications, Volume 3, Issue 6, June 2013 1 ISSN 2250-3153
[12] Proceedings of Seventh International Conference on Fly Ash, Silica Fume,Slag and Natural Pozzalonas in Concrete-Vol-II Editor- V.M.Malhotra. The Indian Concrete Journal, Vol.80, June 2006.

