NOVATEUR PUBLICATIONS
JournalNX- A Multidisciplinary Peer Reviewed Journal
ISSN No: 2581 - 4230
VOLUME 9, ISSUE 5, May -2023

GGBS BASED GEOPOLYMER CONCRETE

M.B.Latke[1],
Prof. A. A. Waghmare[2]
Dr. V.V.P College of Engineering, Savitribai Phule Pune University, Ahmednagar, Maharashtra, India
[2]PG Guide, Department of Civil Engineering,Dr. V.V.P College of Engineering

Abstract

In an attempt to improve the sustainability of construction and reduce portland cement, the use of supplementary cementitious materials, such as ground granulated blast-furnace slag (GGBS), has become a common practice. Concrete is one of the most widely used construction materials which are usually associated with Portland cement as the main ingredient for making concrete. The global warming is caused by the emission of greenhouse gases such as CO2 into the atmosphere by human activities. Among the greenhouse gases, CO2 contributes about 65% of global warming.A geopolymer or alkali-activated cement is an inorganic, alumino-silicate based material. The strengths of geopolymer mortar and concrete are of the same order as those made with normal Portland cement. A wide range of materials is being used for Geopolymerization including materials rich in Si(e.g. fly ash, GGBS and rice husk) and materials rich in Al (e.g. clays like kaolin, betonies, and burned clays). Because of its availability, fly ash is considered among the important sources of geopolymer. As per IS 3812 (Part II): 2013, fly Ash is defined as pulverized fuel ash extracted from flue gases by any suitable process such as by cyclone separator or electro-static precipitator'. It is a byproduct of thermal power plants which is facing the problems of its disposal. Government of India has taken initiative through 'Fly Ash Utilization Programme' to increase utilization of fly ash in concrete, brick, agriculture etc. It is expected that such program will help to meet the reduction of CO2 emission.

Keywords: greenhouse gases, GGBS, molarity, Sodium hydroxide, sodium silicate, Geopolymerization.

I. INTRODUCTION

The production of Portland cement is an energy-intensive process that emits a very large amount of greenhouse gas into the atmosphere. Therefore, efforts have been made to promote the use of pozzolans to partially replace Portland cement in concrete production. Other efforts seek to totally replace Portland cement with other forms of cementations materials such as geopolymer. A geopolymer or alkali-activated cement is an inorganic, alumino-silicate based material. The strengths of geopolymer mortar and concrete are of the same order as those made with normal Portland cement. The texture and appearance of geopolymer cement is similar as that of Portland cement. Furthermore, it is known that geopolymer possess good mechanical properties as well as fire and acid resistance. A wide range of materials is being used for Geopolymerization including materials rich in Si (e.g. fly ash, GGBS and rice husk) and materials rich in Al (e.g. clays like kaolin, betonies, and burned clays). Because of its availability, fly ash is considered among the important sources of geopolymer. Although low-calcium fly ash produced by burning bituminous coal is commonly used in fly ash based geopolymer and high-calcium fly ash produced by burning lignite and/or sub bituminous coal has also been investigated in regard to its use in geopolymer production. As per IS 3812 (Part II): 2013, fly Ash is defined as 'pulverized fuel ash extracted from flue gases by any suitable process such as by cyclone separator or electro-static precipitator'. It is a byproduct of thermal power plants which is facing the problems of its disposal. Government of India has taken initiative through 'Fly Ash Utilization Programme' to increase utilization of fly ash in concrete, brick, agriculture etc. It is expected that such program will help to meet the reduction of CO2 emission. On the other side, the availability of fly ash gives opportunity to use as partial replacement for OPC. Fly ash is not having any binding property but when it reacts with calcium hydroxide during the hydration process, it forms C-S-H gel. Use of fly ash in PPC is restricted up to 25 % by IS 1489 (part I) 1991 code. In practice, highest replacements of OPC by 60 to 68 % of fly ash in high volume fly ash concrete were achieved. Fly ash replacement is not achievable up to 100 %. Granulated Blast Furnace Slag is obtained by rapidly chilling (quenching) the molten ash from the furnace with the help of water. During this process, the slag gets fragmented and transformed into amorphous granules (glass), meeting the requirement of IS 12089:1987 (manufacturing specification for granulated slag used in Portland Slag Cement). The granulated slag is ground to desired fineness for producing GGBS. But research was going on since 1930 for complete replacement of cement as binder material. Due to presence of SiO2 and Al2O3 in fly ash, it is very useful in making of special cement. In general terms fly ash is divided into two categories first one is low calcium fly ash Class F and second is high calcium fly ash Class C. It has been shown that low-calcium fly ash-based geopolymer concretes (LCGC) have similar mechanical properties to concretes produced with PC. In Thailand, approximately three million tons of fly ash is produced from lignite coal-fired Mae Moh power station in Lampang province. This fly ash contains relatively high calcium oxide content, typically around 12–25% by weight. According to previous researches, geopolymer paste and mortar produced from high-calcium fly ash exhibited good strength and durability.

Ground Granulated Blast Furnace Slag is a by-product from blast furnaces, used to make Iron. Blast furnaces are fed with controlled mixture of iron ore, coke and lime stone and operated at a temperature of about 1500oC. When iron ore, coke and lime stone melt in the blast furnace, two products are produced i.e., molten iron and molten slag. The molten slag comprises mostly Silicates and Alumina from the original iron ore, combined with some oxides from lime stone. Using high pressure water jets, this rapidly quenches the slag and forms granular particles, generally not bigger than 5 mm in size. The rapid cooling prevents the formation of larger crystals and the resulting granular material comprises of around 95% non-crystalline Calcium Alumino Silicates. The granulated slag is further processed by drying and then grinding in a vertical roller mill or rotating ball mill into very fine powder, GGBS.

GGBS blended concrete has been successfully in concrete for many years in many countries throughout the world. From all the available technical literature it is suggested that there are potentially many technical benefits to be gained from using GGBS, when structure have to be design for durability requirements in very aggressive environment, GGBS blend mixes are recommended in standards of most develop and developing countries. Many countries have accepted the benefit and have recommended its use in their national standards. Once the user is making aware of the properties of toe material and has understood the benefit to be gained there is no reason why it should not continue to be used successfully and more often in existing and future projects. plants for water and sewage and chimneys partially.

II. LITERATURE REVIEW

The effect of sodium hydroxide concentration on the fresh properties and compressive strength of self-compacting geopolymer concrete (SCGC) was presented by **Memon et al (2013).** The experiments were conducted by varying the concentration of sodium hydroxide from 8 M to 14 M. Test methods such as Slump, flow; V-Funnel, L-box and J Ring were used to assess the workability characteristics of SCGC. The test specimens were cured at 70°C for a period of 48 hours and then kept in room temperature until the day of testing. Compressive strength test was carried out at the ages of 1, 3, 7 and 28 days. Test results indicate that concentration variation of sodium hydroxide had least effect on the fresh properties of SCGC. With the increase in sodium hydroxide concentration, the workability of fresh concrete was slightly reduced; however, the corresponding compressive strength was increased. Concrete samples with sodium hydroxide concentration of 12 M produced maximum compressive strength.

The experimental work was conducted by **Voraa and Dave (2013)**, casting 20 geopolymer concrete mixes to evaluate the effect of various parameters affecting its compressive strength in order to enhance its overall performance. Various parameters i.e. ratio of alkaline liquid to fly ash, concentration of sodium hydroxide, ratio of sodium silicate to sodium hydroxide, curing time, curing temperature, dosage of superplasticiser, rest period and additional water content in the mix have been investigated. The test results show that compressive strength increases with increase in the curing time, curing temperature, rest period, concentration of sodium hydroxide solution and decreases with increase in the ratio of water to geopolymer solids by mass 10 & admixture dosage respectively. The addition of naphthalene based superplasticiser improves the workability of fresh geopolymer concrete. It was further observed that the water content in the geopolymer concrete mix plays significant role in achieving the desired compressive strength.

The effect of partial replacement and full replacement of cement by low calcium fly ash was studied by **Patankar and Jamkar (2012**) in two phases. It was found that the compressive strength decreases with increases in replacement of cement by fly ash. Up to 40% replacement of cement, initial strength is less but strength at 60 days of curing is more or less similar to that of conventional concrete at 28 days of curing. Beyond 40% replacement of cement, workability and strength has been reduced and setting time increased. Beyond 60% replacement of cement, increases the water 11 demand, difficulty in mixing, more time required for demoulding of cubes and rate of gain of strength is observed.

The mechanical properties of geopolymer concrete composite (GPCC) which contain fly ash, alkaline liquid and glass fiber are determined by **Satish Kumar et al (2012).** They found that the density of geopolymer concrete composite was found approximately equivalent to that of conventional concrete. In geopolymer concrete composite there is increase in compressive strength, flexural strength, and split tensile strength up to fiber percentage of 0.02% by volume of concrete with respect to geopolymer concrete.The factors that influence the early age compressive strength of geopolymer concrete such as molarities of sodium hydroxide are presented by Bhosale and Shinde (2012). The mechanism of activation of fly ash with alkaline solution is also described. Alkaline activator was used as sodium hydroxide and sodium silicate solution. The comparison of ratio Na_2SiO_3 and NaOH at the values 0.39 and 2.5 were studied test were conducted to check mechanical properties of geopolymer concrete such as compressive strength, split tensile strength, flexural strength, rebound hammer test, acid resistant test for ambient temperature and oven dry temperature. From test result it was observed that compressive strength was more for oven dry temperature as compare to ambient temperature. Also it was observed that compressive strength increases as increase in molarities of sodium hydroxide.

The effect of water-to-geopolymer binder ratio on production of fly ash based geopolymer concrete was studied by **Patankar et al (2012)**. In this study authors changes the quantity of water in mixture without disturbing the mix proportion and tested the mechanical properties of fresh concrete and hard concrete. It is observed that the flow of geopolymer concrete increases with increase in water-to-geopolymer binder ratio by maintaining other parameters constant. Means higher ratio gives segregated mixture while lower ratio gives viscous and dry mixture. Also it is observed that compressive strength of geopolymer concrete decreases as ratio of water-to-geopolymer binder increases. And it is reported that the suitable range of water-to-geopolymer binder ratio was in between 0.24 to 0.35.

By reducing the mean particle size of the fly ashes from 30 μm to below 10 μm, substantial improvement in the flow and strength properties of mortars and concrete are achieved by Chaterjee (2010) but the enhancement of properties corresponding to further reduction of fly ash particle size to even 3-5 μm is either incommensurate or inconsistent.

III OBJECTIVES OF INVESTIGATION

1. To study the effect of various percentages of GGBS on GGBS based geopolymer concrete .
2. To study the different mechanical properties of GGBS based geopolymer concrete.
3. To study the effect of 12 molarity and 16 molarity NaOH solution on GGBS based geopolymer concrete.

IV. MATERIALS

1. Fly Ash: In the present experimental work, low calcium Class F (American Society for Testing and Materials 2001) dry fly ash obtained from the dirk India pvt.Ltd. was used as the base material. Fly ash (Pozzocrete 60) is a high efficiency class F pozzolanic material confirming to BS 3892 obtained by selection and processing of power station fly ashes resulting from the combustion of pulverized coal. Pozzocrete 60 is subjected to strict quality control. The general information of class F low calcium fly ash is shown in table 3.1. Also table 3.2 gives information about chemical composition of Pozzocrete 60 as obtained from Dirk India Pvt. Ltd.

2.Ground Granulated Blast Furnace Slag (GGBS): GGBS is a byproduct from manufacturing of iron and steel-making. Blast furnace slag is formed in the processes of iron manufacture from iron ore, combustion residue of coke, and fluxes such as limestone or serpentine and other materials. If the molten slag is rapidly chilled by immersion in water, a vitreous Ca–Al–Mg silicate fine grain glass is formed with a highly cementitious in nature. Due to presence of SiO2 and Al2O3 in GGBS it can be used in geopolymer as a base material. A typical chemical composition of GGBS is shown in Table. The GGBS was finely crushed in the laboratory for this study as the available GGBS was in larger size (around 20mm).

3. Water-to-Geopolymer binder ratio: The ratio of total water (i.e. water present in solution and extra water if required) to material involve in polymerization process (i.e. fly ash and sodium silicate and sodium hydroxide solutions) plays an important role in the activation process

4. Solution to fly ash ratio : As solution (i.e. sodium silicate + sodium hydroxide) to fly ash ratio increases,
strength also increases. But the rate of gain of strength is not much significant beyond solution to fly ash ratio of 0.35. Similarly, the mix was more and more viscous with higher ratios and unit cost is also increases. So, in the present mix design method, solution-to-fly ash ratio was maintained at 0.35.

5. Preparation of Geopolymer Concrete Mixes: Preparation of geopolymer concrete is similar to that of cement concrete. Two types of coarse aggregates, sand and fly ash were mixed in dry state. Then add prepared mixture solution of sodium hydroxide and sodium silicate along with extra water based on water-to-geopolymer binder ratio and mix thoroughly for 3–4 min so as to give homogeneous mix. It was found that the fresh fly ash based geopolymer concrete was viscous, cohesive and dark in color. After making the homogeneous mix, workability of fresh geopolymer concrete was measured by flow table apparatus as per IS 5512-1983 and IS 1727-1967. Concrete cubes of side 150 mm are casted in three layers. Each layer is well compacted by tamping rod of diameter 16 mm. All cubes were placed on table vibrator and vibrated for 2 min for proper compaction of concrete. After compaction of concrete, the top surface was leveled by using trowel. After 24 h of casting, all cubes were demoulded and then placed in an oven for thermal curing (heating). To avoid the sudden variation in temperature, the concrete cubes were allowed to cool down up to room temperature in an oven. Three cubes were casted and tested for compressive strength for each curing period.

V. TESTING PROGRAM

Compressive Strength Test: (IS 516:1959) :A cube compression test was performed on standard cubes of GPC of size 150mm x 150mm x 150 mm after 7 days, 14 days and 28 days after oven curing for one day. Results are shown in Table No. 4.1 . Graphical presentation between compressive strength and various parameters such as molarity is shown in figures for 7 days, 14 days and 28 days respectively.
The compressive strength of specimen was calculated by the following formula: fcu $fcu = \frac{pc}{A}$……… (3.1)

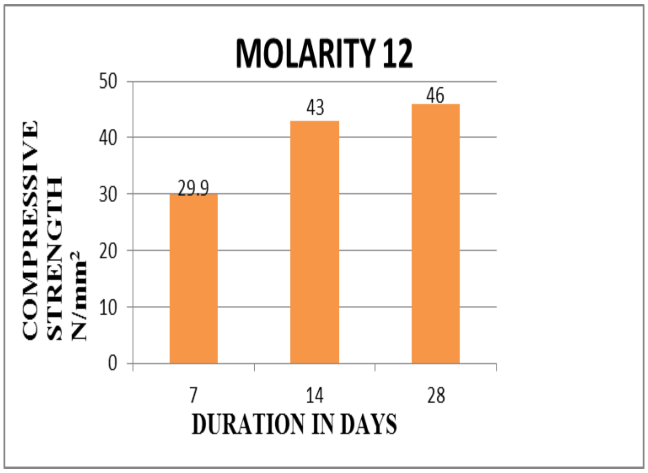
Where Pc = Failure load in compression in N
A = Loaded area of cube in mm^2

fcu **=** Compressive strength in N/mm^2

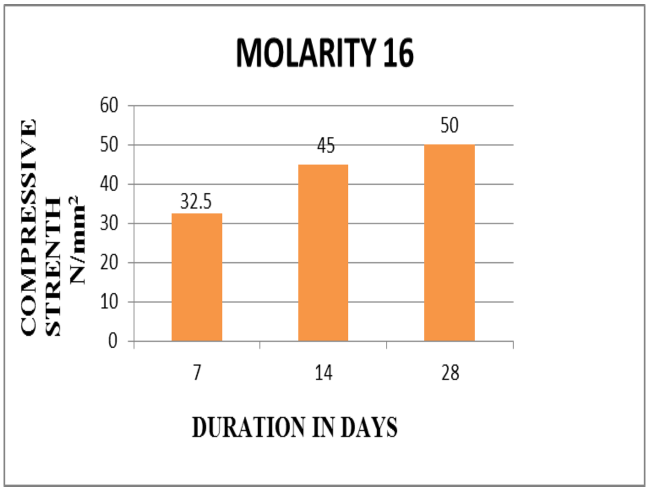
Fig. 4 - Compression test on Specimens

Table: Compressive strength results for cubes of GGBS based geopolymer concrete

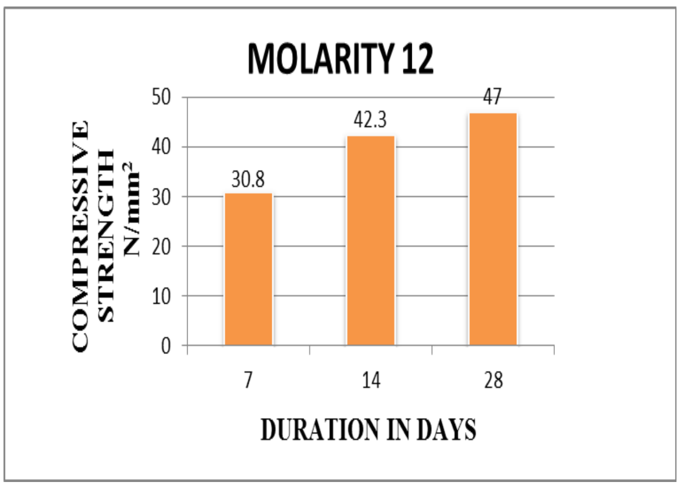
TRIAL	MOLARITY of NaOH	FLY ASH IN %	GGBS IN %	RESULT COMPRESSIVE STRENGTH IN N/mm^2		
				7	14	28
1	12	100	0	29.9	43	46
2	16	100	0	32.5	45	50
3	12	80	20	30.8	42.3	47
4	16	80	20	33.8	46.9	52
5	12	60	40	31.2	43.2	48
6	16	60	40	33.1	48.5	54
7	12	50	50	30	41.4	48
8	16	50	50	33.18	46	51



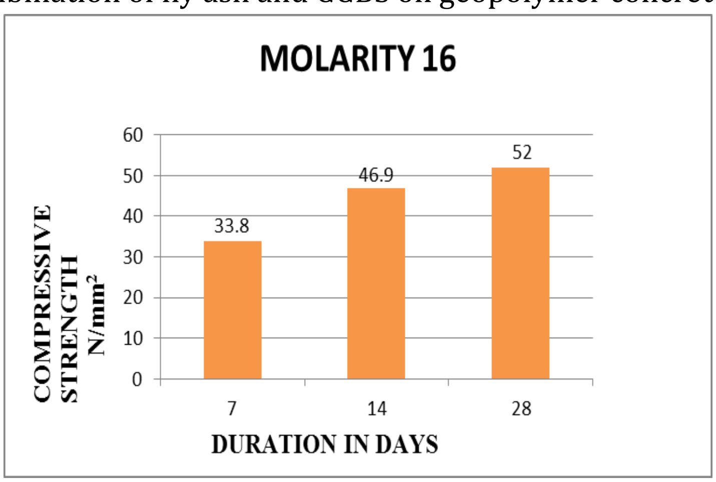
Graph:Effect of combination of fly ash and GGBS on geopolymer concrete for 12M for trial 1.



Graph: Effect of combination of fly ash and GGBS on geopolymer concrete for 16M for trial 2.

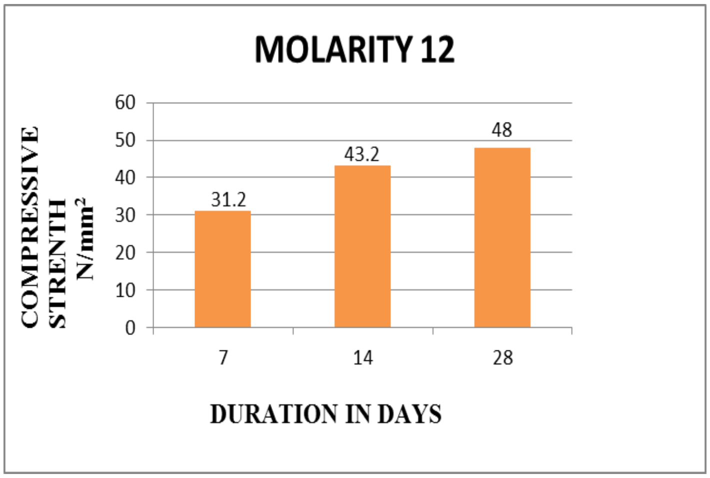


Graph: Effect of combination of fly ash and GGBS on geopolymer concrete for 12M for trial 3.

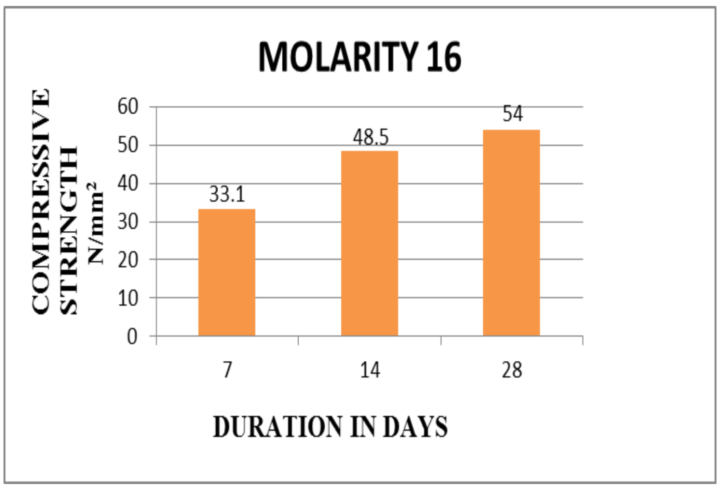


Graph: Effect of combination of fly ash and GGBS on geopolymer concrete for 16M for trial 4.

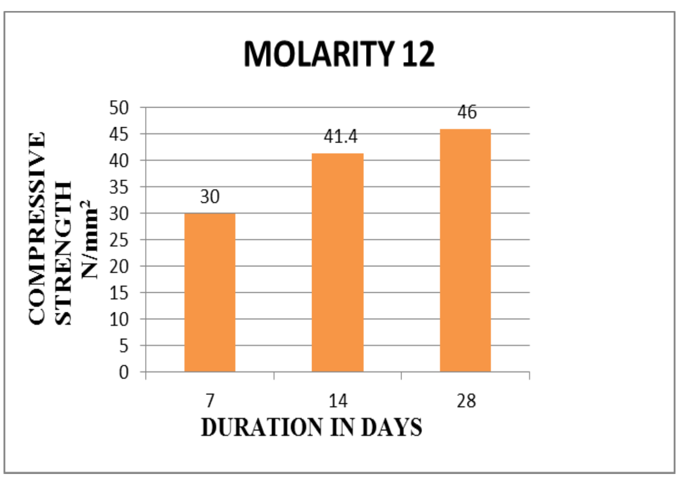
NOVATEUR PUBLICATIONS
JournalNX- A Multidisciplinary Peer Reviewed Journal
ISSN No: 2581 - 4230
VOLUME 9, ISSUE 5, May -2023



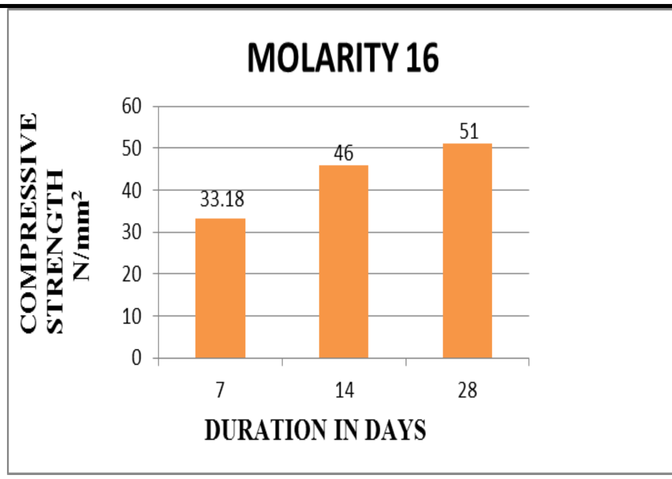
Graph: Effect of combination of fly ash and GGBS on geopolymer concrete for 12M for trial 5.



Graph: Effect of combination of fly ash and GGBS on geopolymer concrete for 16M for trial 6.



Graph: Effect of combination of fly ash and GGBS on geopolymer concrete for 12M for trial 7.



Graph: Effect of combination of fly ash and GGBS on geopolymer concrete for 16M for trial 8.

VII. CONCLUSIONS

- Workability of Geopolymer concrete was found to be very stiff before addition of extra water. When extra water was added to the Geopolymer concrete mix, it was workable. When extra water was added to the solution, it ultimately reduces the concentration of sodium silicate and sodium hydroxide solutions and increases the workability of Geopolymer concrete mix. As alkaline solutions are viscous (i.e. offers resistance to flow) in behavior, addition of extra water to it reduces viscosity of Geopolymer concrete mix. As the time increases workability of Geopolymer concrete mix also increases after wet mixing of ingredients.
- As conventional concrete requires external curing due to heat of hydration reaction but there is expulsion of water in the polymerization process of Geopolymer concrete so no extra curing is required.
- Compressive strength of geopolymer concrete increases with increase in percentage of replacement of fly ash with GGBS. Fly ash was replaced by GGBS up to 40%, beyond that fast setting was observed.

VIII. ACKNOWLEDGEMENT

This project is providing us a great opportunity to learn. The discussion has been successfully completed as result of knowledge, skills, logic and also those who guide us. I also wish to express our sincere thanks with deep sense of gratitude to Prof.A.A.Waghmare, Department of Structural Engineering. Dr. Vithalrao Vikhe Patil College of Engineering, Ahmednagar, for his constant support and for providing me with all possible facilities in the department, for his encouraging and keen personal interest during the course of this project work. It gives us immense pleasure to express my sincere thanks and deep sense of gratitude to Dr. Kawade U.R, Head of Civil Department for his valuable guidance, encouragement and keen personal interest during the course of this project. Finally, I thanks to our Principal Dr. Naik U.P for leading us and for inspiring us. I would also like to thank all the Staff members of Structural Engineering Department and my friends who directly or indirectly helped me in completing project successfully.

IX. REFERENCES

1. Sundeep and Megha Sharma (2016)," Ground Granulated Blast Furnace Slag (GGBS) and Rice Husk Ash (RHA) Uses in the Production of Geopolymer Concrete", Dept. of Civil Engineering, The Univ. of Texas at El Paso, El Paso, TX 79902.

2. Patankar Subhash V., Ghugal Yuwaraj M and Jamkar Sanjay S. (2015) "Mix Design of Fly Ash Based Geopolymer Concrete" Springer India.

3. Naidu Ganapati. Prasad A.S.S. N, Adiseshu S., Satayanarayana P.V.V (July 2014), "A study on strength properties of geopolymer concrete with addition of G.G.B.S" International journal of engineering research and development, volume 2, Page No. 19-28.

4. Memon Fareed Ahmed, Nuruddin Muhd Fadhil, Khan Sadaqatullah, Nassir Shafer, Tehmina Ayub (2013), "Effect of sodium hydroxide concentration on fresh properties and compressive strength of self-compacting geopolymer concrete," Journal of Engineering Science and technology, Vol. 8, Page No. 44 – 56.

5. Anuradha R., Sreevidya V., Venkatasubramani R., and Rangan B.V. (2012), "Modified guidelines for geopolymer concrete mix design using Indian standards," Asian journal of Civil Engineering, vol. 13, pp. 353–364.

6. Joseph, B., and Mathew, G. (2012). "Influence of aggregate content on the behaviour of fly ash based geopolymer concrete." Sci. Iran., 19(5), 1188–1194.

7. Patankar S. V., Jamkar S. S., and Ghugal Y. M. (2012), "The effect of partial replacement and full replacement of cement by low calcium fly ash," Journal of structural Engineering, vol. 39, no. 1, pp. 7–12.

8. Chindaprasirt P., Chareera T., Hatanaka S. & Cao T. (2011) "High strength geopolymer using fine high calcium fly ash" American Society of Civil Engineers .

9. Chaterjee Anjan K. (28-30 JUN 2010 Italy), "Indian fly ashes, their characteristics, and potential for mechano-chemical activation for enhanced usability".

10. Loyd N. A, and Rangan B.V. (25 –27 August 2010), "Geopolymer concrete: A review of development and opportunities," 35th conference on our world in concrete and structure, Singapore.

11. IS 10262:2009, "Indian Standard, recommended guidelines for concrete mix designs", Bureau of Indian Standard, New Delhi

12. Rangan B. V., (2008) "Mix design and production of fly ash based geopolymer concrete," Indian Concrete Journal, vol. 82, no. 5, pp. 7–15.

13. ASTM. (2008a). "Standard specification for coal fly ash and raw or calcined natural pozzolan for use in cement." C618, West Conshohocken, PA.

14. ASTM. (2008b). "Standard test methods for time of setting of hydraulic cement mortar by modified vicat needle." C807, West Conshohocken, PA.