Geopolymer Concrete

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Abstract **- Cement and concrete are widely used in building and construction practices throughout the world. The use of Ordinary Portland Cement (OPC) requires use of additional energy and poses environmental damage. The objective of this project is to provide a green alternative construction material to OPC by Geopolymerization of industrial wastes. This study made an effort to develop a low-cost working recipe that utilizes a combination of fly ash (FA) and Ground Granulated Blast Furnace Slag (GGBS) with different additives such as NaOH & Na2SiO3 to create a geopolymer with comparable or better performance to OPC. The effectiveness of the methodology was tested by evaluating the synthesis factors and testing the unconfined compressive strength.**

Index Terms **- Introduction, Review of Literature, Methods and Methodology, Result and Discussion, References.**

1.INTRODUCTION

Cement and concrete have been widely used as construction materials; however, many have not considered the environmental impacts of its widespread use. Currently, the world annual consumption of Ordinary Portland Cement (OPC) is about 1.56 billion tons.

The production of OPC is a high temperature, energy consuming and heavily polluting process; every ton of OPC produced releases 800 kilograms of CO2.

A new building material being researched is geopolymer cement. While OPC is a ceramic material, geopolymers are materials bonded by polymerization. A major advantage of using geopolymers over OPC is that the raw materials are industrial waste products and the manufacturing process is more environmental friendly. Fly ash is a byproduct resulting from coal burning, which provides the alumina silicate needed for geopolymerization. This is combined with Ground granulated blast furnace slag (GGBS) a by-product of iron &steel making, GGBS is highly cementitious and high in CSH (calcium silicate hydrates) which is a strength enhancing compound which improves the strength, durability and appearance of the concrete. As a result, both ingredients that are currently wasted and costly to store will be able to serve as a sufficient basis for the geopolymer. These two waste materials are combined with sodium silicates (Na2SiO3) and Sodium hydroxide (NaOH) in order to begin the polymerization process. This production produces significantly less CO2 than its OPC counterpart. The material is also known to be significantly more resistant to degradation. The emissions are reduced to around 15 to 20% of the amount produced by OPC. The developments of geopolymers are becoming increasingly focused on as the negative effects of OPC are becoming more apparent.

2. REVIEW OF LITERATURE

Mechanism of Geopolymerization:

Geopolymerization is an exothermic process that is carried out through oligomers which are the fundamental unit structures for the three-dimensional macromolecular edifice. Davidovits also stated that geopolymerization could be regarded as the analogue of synthesis of zeolite. In other words, the chemistry involved in geopolymerization is close to that in synthesis of zeolite, although the geopolymer microstructure is amorphous to semi-crystalline rather than crystalline. In general, geopolymerization involves a number of processes including dissolution, reorientation, and solidification.

During the dissolution step, both Si and Al species are produced when Si-Al raw materials come in contact with alkaline solution. Xu stated that the extent of generation of both Si and Al were contingent upon the following aspects: concentration of the alkaline solution, alkali metal cation (e.g., Na+, K+) in alkaline solution, mixing rate and time, and intrinsic properties

(e.g., structure and composition) of Si-Al raw materials. It is believed that, of all these stated factors, the concentration of alkaline solutions and the intrinsic properties of the Si-Al raw materials are dominant. Throughout the reorientation step, the dissolved Si and Al species (e.g., Al3+, Si4+) are diffused into the oligomers. Plus, the oligomers in the aqueous phase form relatively large networks by condensation, resulting in the formation of a gel. Meanwhile, the further leaching of reactive Al and Si species from the raw materials is occurring when the dissolved Al3+ and Si4+ on the surface of source Si-Al materials are removed. According to Xu, the time and intensity of stirring are main factors for this step. Longer leaching period and a more intense stirring can maximally remove the dissolved Si and Al species from the surface of raw materials and kinetically break the barrier between the Si-Al particle surface and the gel phase so as to accelerate the reorientation of both Al and Si species. At the step of solidification, the gelation system continues to rearrange and reorganize, as the connectivity of the gel network increases, resulting in the amorphous or semi-crystalline three-dimensional aluminosilicate network commonly attributed to geopolymer. At this stage, temperature and air circulation are two major factors determining the properties of the final geopolymeric products. It needs to be pointed out that there is no specific order for these 3 major steps. In other words, they occur simultaneously. For instance, during the step of solidification, both dissolution and reorientation are happening as well.

Material for Geopolymer:

Fly ash:

Fly ash is a result of burning finely ground coal inside a boiler for the purpose of producing electricity. This byproduct is removed from the plant exhaust gases through electrostatic precipitators and scrubber systems. Fly ash is a fine, powdery material, composed mostly of silica where nearly all particles are spherical in shape. It is usually light tan in color and consists of silt and clay-sized glassy

GGBS:

Ground-granulated blast-furnace slag (GGBS) is obtained by quenching molten iron slag (a by-product of iron and steelmaking) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. Ground-granulated blast furnace slag is highly cementitious and high in CSH (calcium silicate hydrates) which is a strength enhancing compound which improves the strength, durability and appearance of the concrete.

Alkaline Solution (NaOH & Na2SIO3):

Binding solution used in geopolymerization process is an alkaline solution comprising of mixture of NaOH and Na2SiO3 in varying proportions. As explained in the mechanism this alkaline solution dissolves the binder to get alumino-silicate products which have the cementing property. According to Petermen the activation of the selected pozzolanic material is the most significant factor in producing a mechanically-sound cementitious material via the geopolymerization process. The initial mechanism of reaction is driven by the ability of the alkaline solution to dissolve the pozzolanic material and release reactive silicon and aluminum into solution. The activators prompt the precipitation and crystallization of the siliceous and aluminous species present in the solution. OH- acts as a catalyst for reactivity, and the metal cation serves to form a structural element and balance the negative framework carried by the tetrahedral aluminum.

Aggregate:

Aggregate is a broad category of Coarse to medium-grained particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geosynthetic aggregates. Aggregates are the most mined materials in the world. Aggregates are a component of composite material such as concrete and asphalt concrete; the aggregate serves as reinforcement to add strength to the overall composite material.

3. METHODS AND METHODOLOGY

Methods of curing for geopolymer concrete

Oven curing

In the geopolymerization process of geopolymer concrete, water is given out during the chemical reaction and this water tends to vaporize as the specimens were subjected to heat during the curing process (Hardjito and Rangan, 2005). Similarly, the drying shrinkage becomes negligible due to the small quantity of water in the pores of the rigid specimens.

Several efforts (Perera et al., 2007; Kani and Allahverdi, 2009; Rovnanik, 2010; Heah et al., 2011) were carried out for determining the influence of curing conditions on the physical and mechanical properties geopolymer paste and concrete. For near perfect geopolymerization the curing temperatures were observed between 40°C to 85°C. Singh et al. (2015) reported that for an alkaline activated fly ash, curing temperature is very vital for achieving higher strength, specimens subjected to higher curing temperature exhibited higher mechanical strength than those of lower temperature this finding is in agreement with that of (Nuruddin et al., 2016). They also observed that longer duration of curing results in better strength, but the increase of strength is negligible when curing time was extended beyond 24 hours. Rovnanik (2010) reported that curing temperature has an important influence on hardening and geopolymerization of rock-based geopolymer Adam and Horianto (2014) reported duration and temperature of curing influence on the strength of fly ash geopolymer paste. They found that the state of curing plays a vital role on the strength development and micro-structural system of fly ash based geopolymer. The best heat curing zone obtained was 120°C for 20 hours of curing. However, they considered only mortar paste but its behavior in concrete was not cited. In another development, Kong and Sanjayan (2010) reported that temperature has great influence on strength development of geopolymer concrete and it relied upon the size of geopolymer paste and aggregates. Similarly, the frequency at which aggregate expanded when subjected to higher temperature is influential in the performance of geopolymer concrete at elevated temperature. The investigation reveals that aggregate and specimen dimensions as the primary factors that control the behavior of geopolymer concrete at advanced temperatures of about 800°C. In all, proper curing of geopolymeric materials is demanded to produce geopolymer concrete with best properties for sustaining their structural integrity (Van Jaarsveld et al., 2002). Yewale et al. (2016) studied on the evaluation of efficient type of curing geopolymer concrete. In their work geopolymer concrete was manufactured with class F fly ash and it is activated by solutions of sodium hydroxide and sodium silicate.

Ambient curing:

Nath and Sarker (2015) studied have focused on producing geopolymer Concrete that will be applicable for on-site constructions. In their work Fly ash of low calcium content was blended with small quantity of OPC to speed up the curing process of geopolymer concrete specimens at ambient condition in place of using heat for curing. They found that blending small amount OPC with fly ash causes quick setting time and slight decrease in workability. The strength gained at early-age has also improved significantly up to 28 days. Moreover, the microstructural analysis revealed a part of calcium-alumina-silicate gel hydrate (CASH) which is due to the presence of calcium ions in the OPC. Similarly, Nath and Sarker (2014) reported that blending Fly ash and slag in producing geopolymer concrete affected the setting time, workability, and initial strength behavior of geopolymer concrete cured in ambient state and the values obtained are similar to that of OPC concrete. They found that GGBS contributed in producing internal heat in the mixture which aid the geopolymerisation process at ambient curing and yield positive strength development at an early age. Similarly, the strength gain tends to follow the same pattern with that in 0 5 10 15 20 25 3 6 12 16.73 17.56 19.34 18.16 19.23 21.8 19.73 21.35 24.75 Compressive strength (N/mm2) Curing days GPC-1 GPC-2 GPC-3 OPC concrete under the same curing condition. This considered being a new development for on-site utilization. However, optimum percentage of slag (GGBS) used was not being reported and other mechanical properties at this temperature were not analyzed. Yewale et al. (2016) stated that the mechanical strength result of geopolymer concrete cured at room temperature is promising compared to water curing. Similarly, Kumaravel (2014) worked on various curing conditions of geopolymer concrete for cast in place applications. The geopolymer concrete was produced using low calcium fly ash and blast furnace slag as the binder material and reacted with alkaline solutions and aggregate to form the concrete. The hardened concrete specimens were subjected to three various modes of curing. He found that the rate of strength development for ambient cured geopolymer concrete resembles that of OPC Concrete and therefore be used for onsite constructions. Similarly, Nuruddin et al. (2011) found that the weight of fly ash geopolymer concrete correspond to that of OPC concrete. Analysis of microstructural properties

of the specimens was shown in Fig. 4. From the Fig. 4; the geopolymer paste was slightly covered by the ITZ zone and contributed to better compressive strength formation of the geopolymer concrete samples. Appreciable bonding was observed between the aggregate and the paste which helps in improving the compressive strength.

Mix design procedure for geopolymer concrete with fly ash:

A few mix design methodologies have been proposed earlier for GPC. Of them all, Lloyd and Rangan (2010) were the first to propose a mix design methodology for fly ash based geopolymer concrete. According to this method, density of GPC has been assumed as 2400 kg/m3 and the total aggregates content was fixed at 80%. By deducting the total aggregates content from the assumed density of 2400 kg/m3, the total mass of fly ash and alkaline activator solution was obtained. Consequently, the fly ash content was determined based on the activator solution to fly ash ratio. Further, individual sodium silicate and sodium hydroxide content were determined from the Na2SiO3/NaOH ratio employed. Finally, the designed compressive strength and workability was determined by using water to geopolymer solid ratios. The main thing lacking in this method is that it doesn't take into consideration the specific gravity of materials used. Anuradha (2012) suggested a design procedure for different grade of GPC by using Indian standards. In this method, fly ash content and activator solution to fly ash ratio was selected based on the strength required and by keeping fine aggregate percentage as constant. Later, correction to fine aggregate percentage was performed based on its zone. The activator solution content employed was observed to be excess for the corresponding strength reported. Ferdous (2013) proposed a mix design for fly ash-based GPC by considering the concrete density variability, specific gravity of the materials, air content, workability, and the strength requirement. The significant issue that arises in their design process could be the selection of activator solution to fly ash ratio, and also in determining the exact activator solution content with respect to the fly ash content.

Test on Aggregate:
Sieve Analysis (IS 2386 Part I)
Moisture Content of aggregates (IS 2386 Part III)
Silt content of fine aggregate (IS 2386 Part I)
Specific gravity (IS 2386 Part III)
water absorption (IS 2386 Part III)
Impact test on aggregate (IS 2386 Part IV)
Bulk Density of Aggregate (IS 2386 Part III)

Test on Fly ash:
Fineness of Fly ash (IS 3812 Part I)

Mix Design:

In this paper, attempt has been made to propose mix design methodology for fly ash-based GPC in a rational way. As said earlier, the activator solution is the costliest among the raw materials involved in the production of GPC, and by fixing the activator content the cost of the final GPC product can be considerably brought down. Also, by doing this, flexibility in the design mixes both on the strength requirement and desired activator solution point of view can be rendered. The essential features of the proposed method are the flexibility to select activator solution to fly ash ratio required for specific strength and to estimate the probable strength that can be achieved for certain activator solution to fly ash ratio. Binder content is calculated based on the relationship between activator solution content and activator solution to fly ash ratio. In the proposed mix design methodology, the materials volume and its specific gravity is also taken into account. Volume of total aggregates is determined by using absolute volume method; it considers the specific gravity of all the ingredients used. Then the individual aggregate content is established from combined aggregate grading curve. Provision is also made for enhancing the workability of GPC. the step-by-step procedure is summarized as follows;

1. Fix the alkaline activator solution (AAS) content:

In the mix proportioning of normal concrete, water content is fixed based on the maximum size of the aggregate (IS 10262: 2009), and the same procedure can be adopted in the case of GPC also for fixing the AAS content. By following this method, the total water content in the mix can be kept within the maximum water content limits as prescribed in table;

Maximum nominal size of aggregate in mm	Maximum water content in kg/m3
10	208
20	186
40	165

2. Determination of activators content:

From the literature, NaOH and Na2SiO3 were found to be the commonly used alkali activators (Lloyd and Rangan, 2010). Therefore, in the present study NaOH and Na2SiO3 were chosen as the activators. Let; Na2SiO3 to NaOH = R

Then; Mass of AAS =Mass of (Na2SiO3 + NaOH)
= Mass of (R NaOH + NaOH)
= Mass of NaOH (R + 1)

Mass of NaOH (MNaOH) = Mass of AAS/ (R + 1)

Mass of Na2SiO3 (MNa2SiO3) = RxMNaOH

From the above relation, individual mass of NaOH and Na2SiO3 can be determined

3. Calculation of water content in AAS:

Water to geopolymer solid ratio is an important parameter which assist in the design of fly ash-based GPC mixtures (Heah et al., 2012). The total water present in the AAS should be determined to calculate the water to geopolymer solid ratio and the sum of the mass of the water present in the NaOH solution and Na2SiO3 solutions gives the total mass of water or water content of alkaline activator solution. Let,

SNaOH and SNa2SiO3 be the percentage of solids in NaOH and Na2SiO3, respectively,

then the water content is determined as follows;

Water Content (Wc)
= Mass of water in (NaOH + Na2SiO3)

Mass of water in NaOH
= MNaOH - (SNaOH x MNaOH)
= MNaOH (1- SNaOH)

Mass of water in Na2SiO3
= MNa2SiO3 –(SNa2SiO3xMNa2SiO3)
= MNa2SiO3 (1- MNa2SiO3)

4. Determination of total aggregates:

The total aggregates content was determined as per the absolute volume method. The volume of total aggregates includes all the aggregates used in the study i.e. fine aggregate passing 4.75 mm and coarse aggregates passing 20 mm, 10 mm.

Let, the total volume of concrete is Vc,

volume of total aggregates is VTA, volume of binder is VB, volume of NaOH is VNaOH, volume of Na2SiO3 is VNa2SiO3, and volume of entrapped air be Va, then;

Volume of Concrete (Vc)
= VTA + VB + VNaOH + VNa2SiO3 + Va

Where, VB = Bc/GB;
VNaOH = MNaOH/GNaOH;
VNa2SiO3 = MNa2SiO3 / GNa2SiO3;
Va assumed as 2%

GB, GNaOH, and GNa2SiO3 are the specific gravities of binder,

NaOH, and Na2SiO3 respectively.

Let us consider 1cubic metre concrete, then;

0:98 = VTA + VB + VNaOH + VNa2SiO3

VTA = 0:98 –[{(Bc/GB) +(MNaOH/GNaOH) + (MNa2SiO3/ GNa2SiO3)}x {1/1000}]

5. Calculation of fine and coarse aggregate content:

The fine and coarse aggregate content was determined according to combined aggregate grading as recommended by DIN 1045 standards (1988). Let the percentage of fine aggregate in the total aggregate be x% and that of the coarse aggregate be y%. Various sizes of coarse aggregates are used and are categorized as CA1, CA2.

Let percentage of CA1 mm size of aggregate be y1%, CA2 mm size of aggregate be y2%. Then,

Mass of fine aggregate (MFA)
= (x% VA) x GFA 1000

Mass of CA1 aggregate (MCA1)
= (y1% VA) x GCA1 x1000

Mass of CA2 aggregate (MCA2)
= (y2% VA) x GCA2x1000

where, GFA is the specific gravity of fine aggregate; GCA1, GCA2 are the specific gravity of CA1 mm, CA2 mm aggregate respectively.

6. Use of superplasticizer (SP):

Alkaline solution has the higher viscosity than the potable water. The alkaline solution when used for making concrete (GPC) it was found to inhibit the concrete's workability, whereas when equal amount of water was used in ordinary concrete better workability was observed. Therefore, attempts were made to improve the workability of GPC by adding some extra water, and it was noticed that the addition of extra water has detrimental effect on the strength and also

bulging phenomenon in the specimens was observed. To avoid the addition of extra water, Naphthalene based SP was used to improve the workability of GPC, and it was found that SP has the profound impact on the behavior of fresh GPC without affecting much the strength and other properties. Further, care has been taken to reduce the water demand by using aggregates in their saturated surface dry (SSD) condition.

Final Mix Design: -

- Stipulations for proportioning: -

1. Grade designation: - M30
2. Type of Cement: - OPC 43 Grade
3. Maximum nominal size of aggregate: - 20mm
4. Exposure Condition: - moderate
5. Workability: - 75mm(slump)
6. Method of concrete placing: - chute (non pumpable)
7. Degree of site control: - Good
8. Type of aggregate: - crushed angular aggregate
9. Chemical admixture type: - Superplasticizer – CAC H4

- Test data for materials: -

1. Specific gravity of fly ash: - 2.2
2. Specific gravity of GGBS: - 2.75
3. Specific gravity of NaOH: - 1.4506
4. Specific gravity of Na2SiO3: - 1.35
5. Specific gravity of CA: - 2.83
6. Specific gravity of FA: - 2.80
7. Specific gravity of SP: - 1.145
8. Water absorption
   a. 20mm Coarse aggregate: - 1.22
   b. 10mm Coarse aggregate: - 1.75
   c. Crushed Sand: - 3.09
9. Free moisture
   a. Coarse aggregate: - Nil
   b. Fine aggregate: - Nil

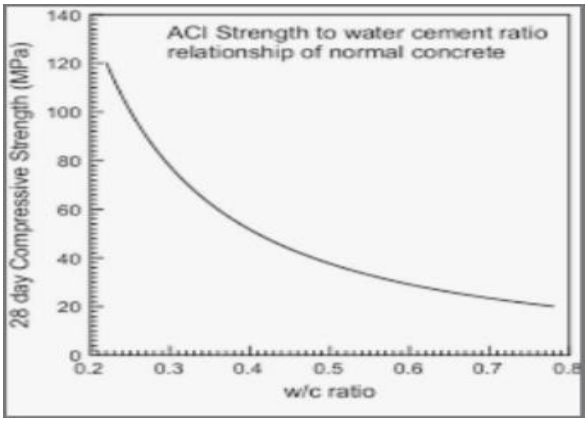
STEP 1: Fix the Alkaline Activator Solution (AAS) Content:

From the trials carried out in the laboratory it was found that at an AAS content of 200 kg/m3 GPC can be developed effectively with better strength, workability and economy. Moreover, at AAS content of 200 kg/m3, the water content present in the AAS found to be within the maximum water content limits given in Table 11 for 20 mm maximum aggregate size case.

Thus, AAS Content = 200 kg/m3

STEP 2: Determination of Strength: -

From Fig. 10, for AAS/FA ratio of 0.5, the minimum 28-day compressive strength that has to be obtained is 38 MPa.



STEP 3: Calculation of Binder Content:

Binder content (BC) = AAS content/(AAS/FA)

BC= 200/0.5

= 400 kg/m3

We have considered 70% fly ash and 30% GGBS in mix Design

Thus, fly ash = 70% of 400 = 280kg/m3

GGBS = 30% of 400 = 120 kg/m3

STEP 4: Calculation of individual activator solution contents:

For all the mixes the Na2SiO3 and NaOH ratio employed was 1.5, and R shall be taken as 1.5.

Mass of AAS = Mass of NaOH (1.5 + 1)

Mass of NaOH (MNaOH) = Mass of AAS/2.5

= 200/2.5 = 80 kg/m3

Mass of Na2SiO3 (MNa2SiO3) = 1.5x MNaOH

= 1.5x80 = 120 kg/m3

STEP 5: Calculation of Water Content in AAS:

Mass of water in NaOH = MNaOH (1 – NaOH)

= 80 (1- 0.45)

= 80 (0.55)

= 44 kg/m3

Mass of water in Na2SiO3=

MNa2SiO3 (1-SNa2SiO3)

= 120 (1-0.50)

= 120 (0.50)

= 60 kg/m3

Total Water Content (Wc) in the mix = Mass of water in (NaOH + Na2SiO3)

= 44 + 60 = 104 kg/m3

From the above calculations, NaOH solutions prepared for the mix consists of 36 kg solids dissolved in 44 kg of water, and the sodium silicate gel used in the mix consists of 60 kg of water out of 120 kg solution. The total water content in the mix is thus found to be 104 kg per cubic metre of concrete. The total solid content which includes the fly ash, solids in NaOH, and Na2SiO3 in the mix contains 496 kg per cubic metre of concrete. Thus, the water to geopolymer solid ratio is obtained as 0.21

Here we are not getting desired content of solids in chemicals due to this geopolymer solid ratio comes out as 0.21 which is less than the actual design assumption hence to adjust that some additional water, we added that is 25kg/m3 hence due to this we obtained geopolymer solid ratio of 0.26

STEP 6: Determination of Total Aggregates:

The volume of total aggregates (VTA) is obtained by using the absolute volume method as follows:

VTA=0.99–[{(Bc/GB)+(MNaOH/GNaOH)+ (MNa2SiO3 / MNa2SiO3)} x {1/1000}]

=0.99-[{(280/2.2)+(120/2.75)+(80/1.4506)+ (120/1.35)} x {1/1000}]

= 0.99-0.315 = 0.675 m3

STEP 7: Calculation of Fine and Coarse Aggregate Content:

Mass of fine aggregate (MFA) = (40%xVTA) x GFAx1000

(40%) = (40%x0.675)x2.80x1000 = 756 kg/m3

Mass of coarse aggregate

(MCA)=(60%xVTA) xGCAx1000

(60%) = (60%x0.675) x2.83x1000 = 1146.15kg/m3

Thus, Mass of 20mm aggregate (60%)

= 60% of mass of coarse aggregate

= 0.60 x 1146.15 =687.69 kg/m3

Similarly, Mass of 10mm aggregate (40%)

=0.40 x 1146.15 = 458.46 kg/m3

STEP 8: Superplasticizer (SP) Dosage:

Based on the experimental observations in the laboratory, SP dosage of 1% of binder content is found to be suitable to improve the workability and the same has been followed in this case.

SP Dosage = 1.3% x 400 = 5.20 kg/m3

Mix proportion:

Fly ash = 280 kg/m3

GGBS = 120 kg/m3

Mass of NaOH = 80 kg/m3

Mass of Na2SiO3 = 120 kg/m3

Fine aggregate = 756 kg/m3

Coarse aggregate (20 mm) = 687.69 kg/m3

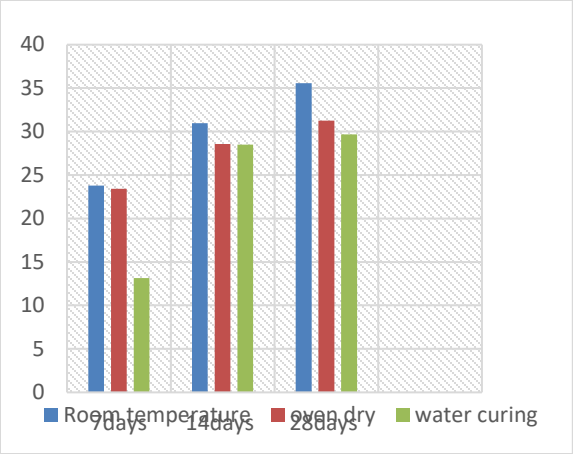
Coarse aggregate (10mm) = 458.46 kg/m3

SP = 5.20 kg/m3

4. RESULTS AND DISCUSSION

From all the set of cubes kept at room temperature, oven dry and water curing each cube is tested at 7days, 14days and 28days and the strength is compared to know which curing gives us the higher strength. The testing is carried out by compression testing machine. The results are as follows:

Test samples	Weight (gm)	Density (gm/cm3)	Load (KN)	Strength (N/mm2)	Strength in %
7 Days					
Room temperature	7915	2.34	535	23.78	79.27
Oven dry	7840	2.32	527	23.42	78.07
Water curing	8210	2.43	296	13.16	43.87
14 Days					
Room temperature	7930	2.35	697	30.98	103.27
Oven dry	7890	2.34	643	28.58	95.27
Water curing	8230	2.44	641	28.48	94.93
28 Days					
Room temperature	7940	2.35	800.50	35.58	118.60
Oven dry	7950	2.36	703.57	31.27	104.23
Water curing	8280	2.45	667.74	29.68	98.93



From the chart above we can easily make that the cube which are kept at room temperature acquires higher strength and also the cube which are kept for over drying achieve the target strength but the cubes which are kept for water curing fails to achieve target strength.

Hence water curing should not be adopted for geopolymer concrete.

REFERENCES

[1] Ukesh Praveen P and Srinivasan K (2017) "Self-Compacting Geopolymer Concrete-A Review", IOP Conf. Ser.: Mater. Sci. Eng. 263 032024: Materials Science and Engineering

[2] Manimaran E and Mohankumar G (2017) "Influence of Sodium Hydroxide Concentration on the Strengthof Fly ash Based GPC", International Journal of Engineering Sciences & ResearchTechnology

[3] Patankar S.V, Ghugal Y.Mand Jamkar S.S, "Effect of Concentration of Sodium Hydroxide and Degree of Heat Curing on Fly ash Based Geopolymer Mortar," Indian journal of materials science, vol. 2014, pp. 1–6, 2014.

[4] Deepa Balakrishnan S, Thomas John V and Job Thomas (2013) "Properties of Fly ash Based Geo-Polymer Concrete",American Journal of Engineering Research (AJER) e-ISSN: 2320-0847 p-ISSN: 2320-0936 Volume-2 pp-21-25.

[5] Satpute Manesh B, Wakchaure Madhukar R and Patankar Subhash V (2012) "Effect of Duration and Temperature of Curing on Compressive Strength of Geopolymer Concrete", International Journal of Engineering and Innovative Technology (IJEIT) Volume 1, Issue 5, May 2012

[6] B. V. Rangan (2008), Fly Ash Based Geopolymer Concrete, Research Report GC 4 Engineering Faculty, Curtin University of Technology, Perth, Australia.

[7] Sandeep L.Hake, Dr R. M. Damgir and Dr S.V. Patankar, "State of Art- Investigation of Method of Curing on Geopolymer Concrete," IOSR Journal of Mechanical and Civil engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 12, Issue 3 Ver. II (May. - Jun. 2015),

[8] Phoo-ngernkham T, Hanjitsuwan S, Damrongwiriyanupap N, and Chindaprasirt P, "Effect of Sodium Hydroxide and Sodium Silicate Solutions on Strengths of Alkali Activated High Calcium Fly ash Containing Portland Cement," KSCE Journal of Civil Engineering, vol. 21, no. 6, pp. 2202–2210, Oct. 2016.

[9] Adam A. A, Amiri N.H, Suarnita I.W, and Rupang N, "The Effect of Lime Addition on the Setting Time and Strength of Ambient Cured Fly Ash Based Geopolymer Binder,"MATEC Web of Conferences, vol. 47, p. 01015, 2016.

[10] Albitar M,Mohamed Ali M.S, Visintin P, and Drechsler M, "Durability Evaluation of Geopolymer and Conventional Concretes," Construction and Building Materials, vol. 136, pp. 374–385, Apr. 2017

[11] Al-Majidi M.H, Lampropoulos A, Cundy A, and Meikle S, "Development of Geopolymer Mortar Under Ambient Temperature for in Situ Applications," Construction and Building Materials, vol. 120, pp. 198–211, Sep. 2016.