International Journal of Latest Technology in Engineering, Management & Applied Science (IJLTEMAS)
Volume VII, Issue XII, December 2018 | ISSN 2278-2540

Calorific Studies and Its Influene on Alkali Activated Fly Ash Based Concrete Composites

K. Mythili[1], C. G. Deepanraj[2], Dr. V. Rajkumar[3]
PG Student[1], Assistant Professor[2], Associate Professor[3]
Government College of Engineering, Salem, Tamil Nadu, India

***Abstract*–The paper presents a study on thermal behaviour of geopolymer concrete, also the effect of core temperature with applied heat on surfaces which influences the phase polymerization. Geopolymer concrete is made with source material fly ash and alkaline activator made of Sodium Silicate with Sodium hydroxide solution made of 12 molar concentration. Ingredients are mixed thoroughly and cast into cube of size 150mm x 150mm x 150 mm. Two methods of curing were adopted; ambient and steam curing. Both the temperature based specimens were compared in thermal aspect. Density of the specimens were calculated in reference to calories. Percentage of weight attained at regular intervals are observed. Cubes were kept in steam accelerated chamber at the temperatue of 80 ℃ and the rest were kept at ambient curing. The variations in their internal temperature with respect to time was recorded. It was observed that the weight of the specimen increases as the time increases.**

I. INTRODUCTION

The geopolymer concrete is synthesised from the by-product materials such as flyash that are rich in silica and aluminium. The previous studies have showed that the geopolymer concrete consumes more time in attaining strength by curing at the room temperature. The application of heat fastens the process of setting, therefore the geopolymer concrete can be hardened by using accelerated steam curing or hot air oven curing.

The specimens should be cured minimum for a period of 24 hrs in the steam accelerating chamber at 80 ℃. The application of heat play a major role in polymerization process. It is not only the external heat, the heat which is induced within the specimen also has a major part to play. In the polymerization process monomer molecules react together in a chemical reaction to form polymer chains or three-dimensional networks. Basic chemical reaction leads to an intermediate product called geopolymer precursor. This precursor inturn undergoes further polymerization to form geopolymer backbone. The polymerization process also take place at the room temperature but the formation of the geopolymer backbone attains after a long time. The inner temperature will be induced within the specimen at the ambient temperature. The heat plays a major role in the polymerization process therefore the effect of heat on the geopolymer concrete has to be studied. The success of an innovative material lies in the development of its applications. Geopolymer concrete is not only nature friendly but it also possess excellent mechanical and durability properties. Geopolymer concrete can be used for high temperature applications.

II. MATERIALS USED

The main constituents used in the manufacture of the geopolymer concrete were fly ash, alkaline solution and aggregates. The flyash used in the production of the geopolymer concrete was class F which were sourced from the mettur thermal power plant. The class F flyash was characterized by high silicon and aluminium contents and low calcium content. Sodium based alkaline solutions were used which on reaction with flyash acts as a geopolymeric binder. Sodium hydroxide solution was prepared by dissolving sodium hydroxide pellets in water. Sodium silicate solution was mixed along with the sodium hydroxide solution to get the alkaline solution. The coarse aggregate of nominal size 10 mm were used. Well graded river sand of zone II which was obtained from the local supplier was used as fine aggregate.

III. METHODOLOGY

The source materials such as the fly ash, fine aggregate, coarse aggregate and alkaline solution were mixed together along with the optimum fibre fraction of polypropylene. From the results obtained on the testing of durability and mechanical properties of GPC with different fractions of the polypropylene fibres, the fibre fraction of 1% proved to have the optimum results. Two types of mixes of geopolymer concrete one with polypropylene fibres and other without polypropylene fibres were mixed. Fresh geopolymer concrete was found to be highly viscous and with high workability. Fresh concrete mixture was cast in 150mm x 150mm x 150 mm steel moulds and they are compacted by using table vibrator. After casting, the specimen should be given a minimum rest period of 2 days before placing the specimen for curing. The specimens were tested under both ambient curing and the accelerated steam curing conditions.

3.1 Temperature Variations In Alkaline Activator Solution

The alkali solution used here is a mixture of sodium hydroxide and sodium silicate. Increase in molarity of the alkaline solution increases the strength of GPC. A molarity of 12M was adopted to produce the sodium hydroxide solution, based on literatures. Sodium hydroxide which was available in the form of pellets was dissolved in the calculated quantity of water in order to achieve the 12M. Sodium silicate to sodium hydroxide ratio was maintained at a value of 2.5 in order to obtain higher compressive strength. When sodium hydroxide dissolved in water evolves a large quantity of heat since it was an exothermic reaction. These solution must be prepared 24 hours prior to the mixing of the concrete. The heat that was liberated in the solution was recorded at an interval of about 15 minutes with the help of a digital probe type thermometer as shown in the figure 1 (a). The temperature of the solution got gradually decreased and it attained the normal room temperature.

(a)

(b)

Figure 1: (a) Temperature measurement of Alkaline Solution (b) Fresh concrete

3.2 Internal Temperature Variation of Specimen at Ambient Curing

Geopolymer concrete cured at room temperature increased its suitability and application to concrete based structures. Three common types of geopolymer are the polysialate Al-O-Si chain, polysialate siloxo Al-O-Si-Si chain, polysialate disiloxo Al-O-Si-Si-Si chain. After casting the specimens it was allowed to remain at the room temperature in ambient curing condition. The figure 1(b) showed that the sample remains fresh and the progress of the polymerization process is also found to be slow. The geopolymers produced in ambient curing achieved lower strength in their early days, but the compressive strength increased as the age of the concrete increases. Also the internal core temperature was found to be high in comparison to that of the ambient temperature. The internal temperature of the specimen was observed at regular intervals till the concrete hardened.

3.3 Internal Temperature Variation of Specimen at Accelerated Steam Curing

The polymerization process was accelerated at a higher temperature when compared to that of the ambient curing. The high temperature can applied by two methods either by using hot air oven or with the accelerated steam curing chamber. The figure 2 (a) shows the accelerated steam curing chamber which was used. The specimens were kept at the rest period for 2 days and the curing process was started. Figure 2 (b) shows the specimens inside the accelerated steam curing chamber. The curing temperature was maintained at a temperature of about 80^{o} C inside the chamber. The curing was applied for a period of about 24 hrs. Applied external temperature increased the inner core temperature and the temperature was recorded at regular intervals with the help of thermometer.

(a)

(b)

Figure 2: (a) Steam curing chamber (b) Steam curing of GPC

3.4 Measurement of Density of the Specimen

Density of concrete was the measure of compactness of a substance. The density of concrete depends upon the quantity of aggregate, the amount of entrained air, fly ash and content of the alkaline solution. The density of conventional concrete was found to be 2400 Kg/m^3.Density of GPC was low in comparison to that of the conventional concrete but the value seems to be nearly equal. Initially when the concrete was mixed the wet weight of the concrete was noted. The concrete was weighted at regular intervals till it was hardened as shown in the figure 3. The same procedure was repeated for both the normal GPC and fibre reinforced GPC. Then the density of the specimen was calculated and the readings were tabulated. The fresh concrete will be less denser and lower in weight as compared to that of the hardened concrete. It was observed that the weight of the concrete was found to increase gradually as the concrete hardened. This weight of the concrete was due to the geopolymerization process that took place within the concrete. It result in the formation of a structure harder similar to that of the zeolite structure.

Figure 3: Weight measurement

IV. RESULTS AND DISCUSSION

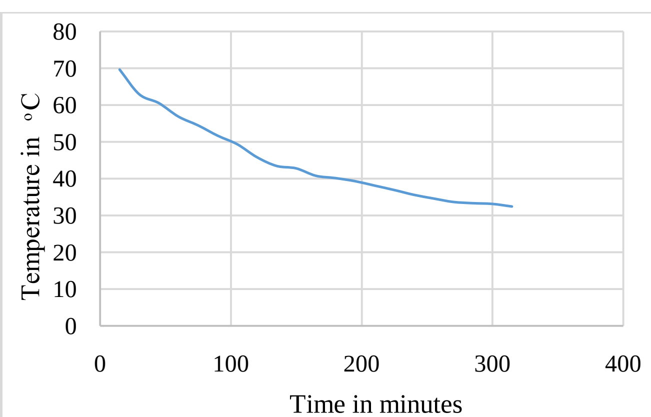

Figure 4: Chart indicating time versus temperature of alkaline solution

A graph has been drawn with time in minutes along the X axis and temperature along the Y axis as shown in the figure 4. The temperature of the alkaline activator solution was observed. The sodium hydroxide solution only liberated heat on addition of water to sodium hydroxide pellets. Even after the mixing of sodium silicate solution and sodium hydroxide solution the exothermic reaction took place. The heat liberated was very high initially for a temperature of 69.6 °C and it got reduced as the time passes. It was found that the temperature varied linearly with time and it reached the ambient temperature within 6 hrs from mixing. This indicate there was an influence of heat in the geopolymerization process right from the time of mixing the alkaline solution.

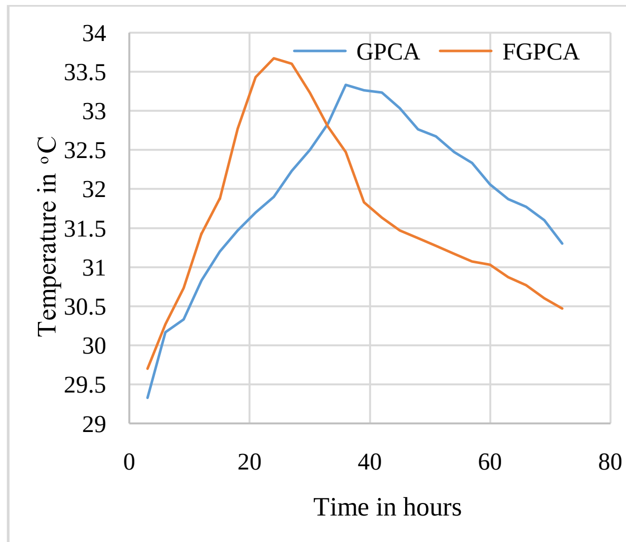

Figure 5: Chart indicating variation of time versus temperature GPC_A in & $FGPC_A$

In the ambient curing no external temperature was applied to the specimen. Instead the specimen was allowed to cure by itself. The core temperature of the specimen was high when compared to the room temperature. It was also found to be increasing non-linearly as the polymerization process took place. Figure 5 shows that the polymerization process took place at a peak internal temperature of 33.67 °C. The peak internal temperature of normal GPC was lower than that of the polypropylene fibre based GPC. In fibre based geopolymer concrete the core temperature increased within 27 hrs. The internal temperature was high for only a shorter phase and it began to drop rapidly. Then the polymerization process continue with a lower internal temperature. In normal GPC the temperature reach a peak at 33.33 °C, then the polymerization took place at a nearly steady rate with a lower reduction in the temperature. After the concrete was completely hardened the temperature reaches a steady state.

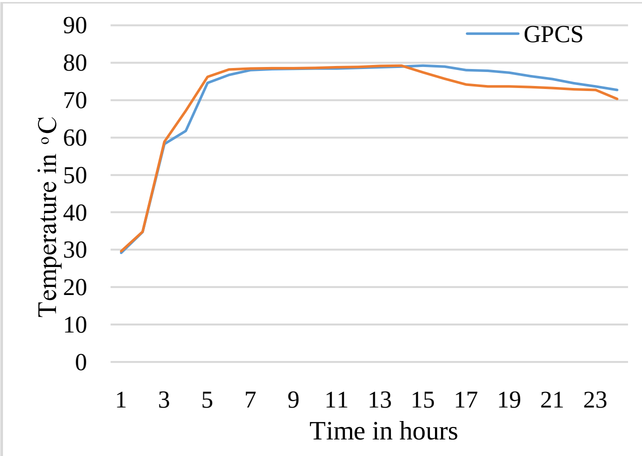

Figure 6: Chart indicating variation of time versus temperature for GPC_S & $FGPC_S$

The temperature that were externally applied by means of accelerated steam curing chamber and the rate of polymerization reaction was higher. Temperature of 80° C is applied, it produced an internal temperature in the range as denoted by the graph as shown in the figure 6. This temperature was higher than the internal core temperature in the ambient curing. This high temperature speeded up the process of polymerization. Thus the quick gain in the strength was achieved in the specimens in case of steam curing. The fibre reinforced geopolymer concrete specimens gain strength rapidly due to the presence of fibres. Thus the addition of fibres further speeds up the geopolymerization process. The GPC retain heat for a prolonged period of time whereas once the polymerization process was completed the fibre reinforced geopolymer concrete hold lesser internal heat with the hardening of the concrete. The heat was maintained constant externally but the within the specimen the temperature seemed to be varying. The loss in temperature was high in the polypropylene fibre reinforced specimens. This showed that fibre reinforced was well suited for high temperature based applications.

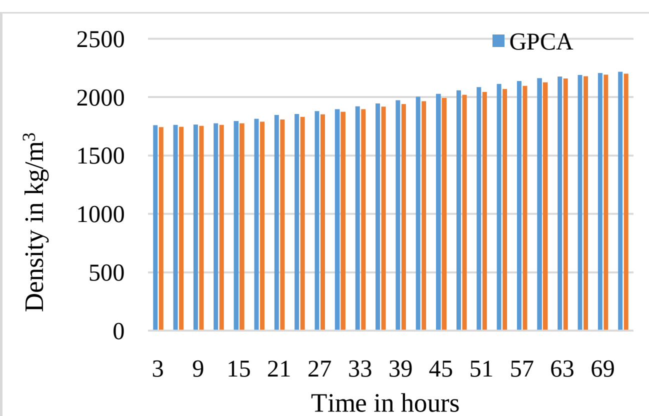

Figure 7: Chart indicating variation of time versus density for GPC_A & $FGPC_A$

After the mixing of the concrete the specimen remained wet for a few days. This period was called as the rest period of the specimen. After the rest period the concrete specimen start to harden with the minimum internal temperature. The weight of the specimen increased very slowly at the initial stage. From figure 7 it was observed that the weight of the specimen showed a growth phase during the final stage of the hardening process. The density of the polypropylene fibre reinforced specimen was lower than that of normal geopolymer concrete specimen. This was due to the fact that the density of the polypropylene fibres was very low and polypropylene fibres were light in weight. Finally the hardening process gets completed nearly within duration of 72 hrs. The variations in the density of the specimens are lower after this phase.

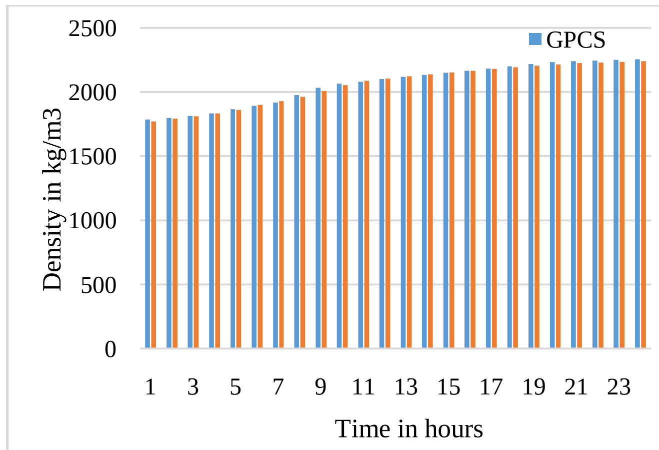

Figure 8: Chart indicating variation of time versus density for GPC_S & $FGPC_S$

After the rest period the specimens were kept in the accelerated steam curing chamber for a period of 24 hrs. Heat was an important parameter in influencing the geopolymerization process. The external temperature was maintained by the chamber at 80° C for the entire curing period. Internal temperature is initiated inside the specimen. The applied external temperature will induce an internal temperature higher than that in the ambient curing. This temperature had greater influence in the polymerization process which activate the process and helps in the completion of the process in a very short duration. The density of the normal GPC was higher than the polypropylene fibre reinforced geopolymer concrete. In case of normal GPC the rate of absorption of temperature was little bit slower in comparison to that of the polypropylene fibre reinforced GPC. The figure 8 shows that fibre helps in retaining the temperature and speeds up the polymerization process. After the completion of the polymerization process the temperature inside polypropylene fibrere inforced geopolymer concrete start to reduce. But the normal GPC does not loss the core temperature very soon as compared to the polypropylene fibre reinforced GPC. This showed that the fibres that were used as the reinforcement plays a major role in increasing its thermal resistance and it also helps in the gaining of the strength quicker.

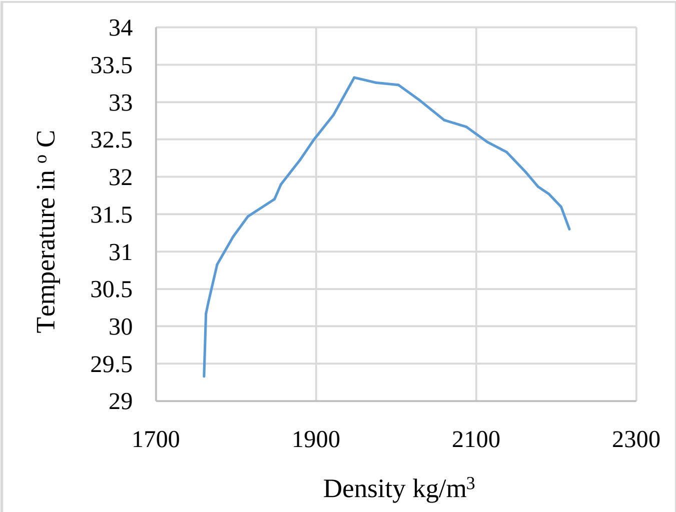

Figure 9: Chart indicating variation of density versus temperature for GPC_A

From figure 9it was observed that ambient curing without fibre showed an increase in density after the optimum temperature of the specimen was reached. Till that the increase in the density of the specimen was lower. This was because in the ambient curing the core temperature was low even it was higher the normal room temperature.

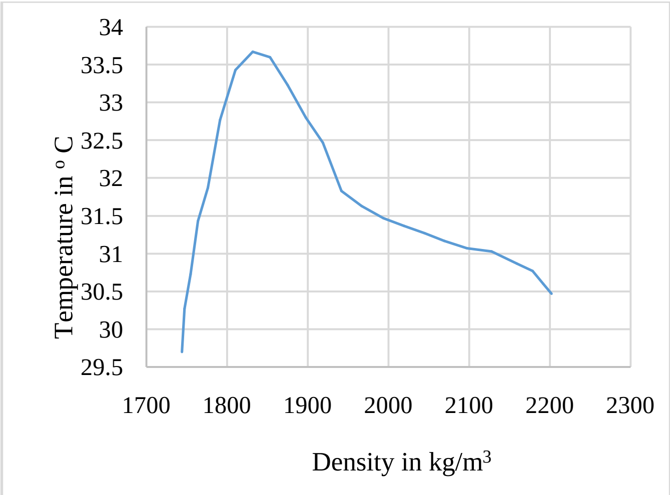

Figure 10: Chart indicating variation of density versus temperature for $FGPC_A$

Figure 10 shows that rate of increase in density was higher only after the optimum temperature was reached. The presence of fibres help in reaching the optimum temperature within a short interval of time. The fibres absorbed heat more efficiently and helped in attaining the optimum temperature faster. The high temperature activated the geopolymerization process. This proved that only after the full geopolymerization the rate of increase in density was higher. Once the density reached the saturated level then there was only small change in the density of the specimens.

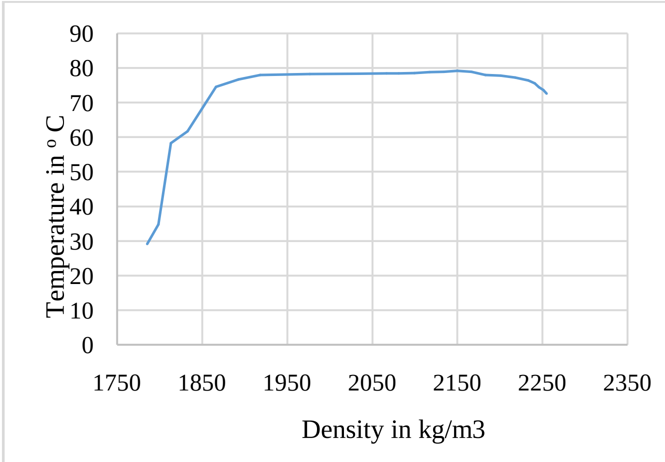

Figure 11: Chart indicating variation of density versus temperature for GPC_S

Figure 11 shows that in steam curing the rate of attainment of density was higher than the ambient mode. Steam curing helped in gaining weight at a rapid rate during the initial stage of curing itself. Thus it proved that temperature plays a major role in achieving density. With increase in temperature the density also increases reaching the optimum temperature of 79.2° C with a density of 2149.926 kg/m^3. The specimen showed a drop in temperature and the core temperature started decreasing. After this the increase in density was at a much lower rate. The maximum value of density attained was 2254.815kg/m^3.

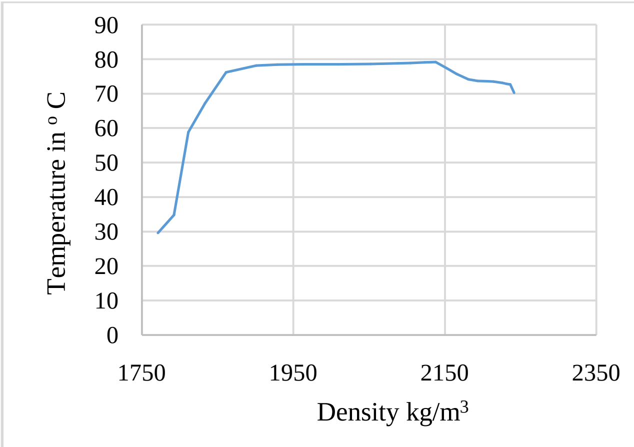

Figure 12: Chart indicating variation of density versus temperature for $FGPC_S$

The specimens were provided with polypropylene fibres and fibres played a vital role in increasing the density of the specimen. These fibres helped in absorbing the externally applied heat quickly. Figure 12 shows that increased internal core temperature helped in attaining a density of 2137.78 kg/m^3 at the optimum temperature of 79.2 °C. After this phase we could observe only a slow increase in density till it reached the maximum value. At the maximum density of 2241.185 kg/m^3 the temperature of the specimen was observed to be 70.3 °C. This specimen showed a decrease in temperature at a rapid rate due to the presence of fibres.

Table 1: Acceleration and Deceleration rates under different modes of curing

Designation	Acceleration rate	Deceleration rate
GPC_A	46.889	132.38
$FGPC_A$	22.09	115.740
GPC_S	7.007	19.206
$FGPC_S$	7.390	11.610

Table 1 showed the acceleration and the deceleration rate for the different modes of curing for both normal and polypropylene fibre reinforced geopolymer concrete. In the ambient mode the acceleration rate was 46.889 for the GPC_A specimens. The deceleration rate showed the highest value in the $FGPC_A$ specimens with a value of 115.740. Thus the loss of heat after attaining optimum temperature was much higher in the fibre reinforced geopolymer concrete specimens at the ambient mode. In mode of steam curing the acceleration rate was 7.390 for $FGPC_S$ specimen, which showed that the increase in density was much faster in the initial stage. The deceleration rate is high for GPC_S specimen with the values of 19.206. In GPC_S specimen the loss of heat with respect to increase in density was high.

V. CONCLUSION

The above test results lead us to the following conclusion

1. The alkaline activator solution liberates a maximum heat of 69.6 °C immediately after mixing due to the exothermic reaction.
2. Under ambient curing condition the polymerization process takes with an optimum temperature of 33.67 °C for $FGPC_A$
3. The optimum temperature reaches a value 79.2 °C for $FGPC_S$at accelerated steam curing condition
4. The maximum density of 2216.296kg/m^{3}is achieved at 72 hrs for GPCA specimen
5. In the accelerated steam curing condition the maximum density achieved is 2254.814kg/m^3 at 24 hrs for GPC_S specimen.

REFERENCES

[1]. Chithra S, et.al, June 2014 "Effect of hot water curing and hot air oven curing on admixed concrete", International Journal of ChemTech Research
[2]. Girawale .M. S, August, 2015 "Effect's of alkaline solution on geopolymer concrete" International Journal of Engineering Research and General Science
[3]. Hardjito .D, et.al,May 2014 "Brief review on the development of geopolymer concrete",Invited Paper, George Hoff Symposium, American Concrete Institute
[4]. James aldred, et.al, August 2012 "Is geopolymer concrete a suitable alternative to traditional concrete?" 37th Conference on Our World in Concrete & Structures
[5]. Joshi .S. V, et.al, October 2012 "Role of alkaline activator in development of eco-friendly fly ash based geo polymer concrete", International Journal of Environmental Science and Development
[6]. Kolli.Ramujee,August 2013 "Strength properties of polypropylene fiber reinforced concrete" International Journal of Innovative Research in Science Engineering and Technology
[7]. Kumaravel. S, April 2014 "Development of various curing effect of nominal strength Geopolymer concrete", Jestr Journal of Engineering Science and Technology
[8]. Manoj Kumar Rajak, et.al, "A systematic review on polypropylene fiber reinforced geopolymer concrete"International Journal of Advanced Research in Engineering and Applied Science
[9]. Patil S. S, et.al,August 2015 "Properties of Polypropylene Fiber Reinforced Geopolymer Concrete" International Journal of Current Engineering and Technology
[10]. Vijai .K, et.al,August 2010"Effect of types of curing on strength of geopolymer concrete", International Journal of the Physical Sciences