Effect of ferrocement wrapping system on strength and behaviour of geopolymer concrete beam

Vaddeswaram Sangeetha¹, B Sarath Chandra Kumar² and Y Himath Kumar³
¹ M. Tech Student, Department of Civil Engineering, Koneru Lakshmaiah Education Foundation, Andhra Pradesh, India-522502.
² Associate Professor, Department of Civil Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, A. P., India-522502.
³ Assistant Professor, Department of Civil Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, A. P., India-522502.

Email: sangeethav115@gmail.com, sarath.9b@gmail.com, himathkumar007@kluniversity.in

Abstract. Geopolymer concrete is an innovative construction material that is environmentally friendly. Geopolymer concrete (GPC) is made by mixing ground granulated blast furnace slag, fine aggregate, coarse aggregate, and alkaline activator solution. Ground Granulated Blast furnace Slag (GGBS) is a Steel Industry by-product. An alkaline activator is a mixture of sodium hydroxide and sodium silicate is adopted with a ratio of 1:2.5. The sodium hydroxide solutions having the molarities of 8M and 10M are used. Beams of size 1500x150x150mm are cast and cured for 28 and 56 days at ambient temperature. Both Conventional and Geopolymer concrete beams are wrapped with Ferrocement. This experimental study primarily aims to compare the flexural behaviour of reinforced cement concrete beams and Geopolymer concrete beams with ferrocement applications to enhance the strength property. Specimens are cast for compressive strength, split tensile strength and bending strength and tested for 7, 28 & 56 days. The obtained results were then plotted in a graph and the feasibility of using the mesh was identified.

1. Introduction
To study the ground granulated blast furnace slag based on the geopolymer concrete. It is very high for the growth rate is reflected by the rate of concrete production. It is a large amount of non-renewable resources of the world to use the concrete. In geopolymer concrete waste materials like fly ash, silica fume, metakaolin, and GGBS, etc. are less pollution to improve the concrete. It reduces the carbon dioxide release from produces the ordinary Portland cement [1]. It is utilizing the industrial wastage by-product of the material to causes the carbon dioxide emission in a binding material and its atmosphere causes the cement and aggregates.

Alkali-solution consists of a sodium hydroxide (or) caustic soda and sodium silicate (or) alkali-silica in the ratio of 2.5 in a material [2]. In 3D of the ring and polymeric chain consists of Si-O-Al-O bonds. It is the inorganic molecule of the reaction between alkali activator solution in ambient curing temperature is taken in hardens of geopolimerization. It is involved in a chemical reaction that is total amorphous aluminosilicate in 3D polymerization network and it is the exothermic reaction of the
geopolymerization. They have three reactions that take place at any time of point and the kinetic reaction of a standpoint was proposed in the geopolymerization model mechanism [3].

In reducing the environmental impacts and waste product of the geopolymer concrete is transport, recuse, fabrication, etc. are the source material of the building industries. It increases the strength of the concrete is used with an alkali solution. They have acid resistance, universal strength, shrinkage, and creep are the properties are shown [4]. The lower energy consumption and reduce carbon dioxide emissions. In geopolymer concrete is an alternative material for the ordinary Portland cement and by-product of the blending cement material.

The range of industrial wastage and by-product of the material are available they produced by the geopolymers. They have silica and alumina are the react materials are suitable in geopolymerization. It is suitable to form sodium hydroxide (or) caustic soda and alkali silicate (or) alkali-silica solutions of the material in geopolymer concrete [5]. It is referring to the product of the calcium reaction to alkali-activator cement is the presence. The combination of both reactions is taking place in a sodium hydroxide (or) caustic soda and alkali silicate (or) alkali-silica in the alkali-activator solution of the geopolymerization in the alkali medium [6].

The most developed geopolymer concrete by using alternate binder material and it is manufacture by alkaline activation solution [5]. The moisture is removing from the material is based on the cement of the change in volume cement paste by removing the absorb water from gel pores [6]. Concrete is a very important material is using the construction which as the same properties are like stiffness, durability, environmental factors and high compressive strength. It is applying for resistance with the concrete mix and the same on other materials [7].

Ground Granulated Blast Furnace Slag is a byproduct of the steel material and reacts with water and cement paste of the part of an OPC Slag it can refine the microstructure of the GGBS. It is large to diffuse the forty percent of the high age co-efficient [8]. It is a cement nous material and strength into an increase in the concrete. The manufacture of the concrete batch plant with aggregate and water the mix design unchanged of the GGBS [9].

\[
n(Si_2O_5,Al_2O_2)+2nSiO_2+4nH_2O \rightarrow n(OH)_3-Si-O-Al^{(3)-}O-Si-(OH)_3
\]

\[
(OH)_2
\]

(Geopolymer Precursor)

\[
n(OH)_3-Si-O-Al^{(3)-}O-Si-(OH)_3 \rightarrow (Na^+,K^+)-(Si-O-Al^{(3)-}O-Si-O-)+4nH_2O
\]

\[
(OH)_2\quad O\quad O\quad O
\]

(Geopolymer Backbone)

**Figure 1.** Formation of Geopolymer Concrete [10].

1.1. History of Geopolymer Concrete

Joseph Davidovits in the year 1978, invented a material that is used as a binder form. In construction, the most used in concrete material [11]. Davidovits (1988; 1994) propose the alkali activator solution it reacts with (Si) and (Al) to the source material are the geologic origin and byproduct of the material such as GGBS and metakaolin to producing the binding material shown in figure 1 [12].

2. Literature Review

Chandru et al, the binder materials are used in slag when compared to the OPC with different proportions. The slag percentages are 30%, 40%, 60%, and 100% conventional concrete and foundry sand is 30%. The physical properties are tested in fly ash; slag; sand and aggregates. To fresh concrete tests in workability conducted with slump and is 0.15X0.15X0.15m are casting and cylinder size is
0.15m diameter and 0.30m diameter are the mechanical properties and water curing at 7, 14, 28 days are test in a specimen. In compressive strength is a 27.5% increase with the 40% of cement replace of slag and 30% of foundry sand and 6% decrease the cement replace of 60% slag and 30% foundry sand [13].

Himath Kumar et al. is conducted to study on the strength and durability of the geopolymer concrete, in which geopolymer concrete is made by 100% slag alkaline solution is taken in 12 and 14 molarity. For this experimental study standard size of cubes, cylinders and prisms were cast and these specimens were cured under room temperatures and were tested after 3, 7, 28 days. The mechanical properties are conducted, and the durability test was conducted after thirty days of ambient curing on 12 and 14 molarity. The results are observed in strength increase the 14 molarity than 12 molarity. To increase the molarity to increase strength [14].

Matthew et al. has described the deformation behavior of the reinforcement geopolymer concrete flexural elements, this research work gives an outline of the reinforced geopolymer concrete beams and slabs. The binder material is taken in the proportion of FA- seventy percent and GGBS- thirty percent. The specimen was reinforced with steel bars and steel fibers of two types are used, crimped steel fibers and polyester fibers. The steel fibers are taken in 1.5 percent of binder weight and polyester fiber in 0.5 percent of binder weight. In this experimental investigation, NaOH is taken in 8 molarity. The size of the beam is 1750mm x 150mm x 210mm with varying reinforcement details and slab dimensions are 1000mm x 1000mm x 60mm, 8mm bars were used in the slab reinforcement. The specimen was cured under room temperature and tested after 28 days. The type of load applied on the beam is 2-point loading and on slabs the loading type is UDL. The load vs deflection relations at the center bottom of slabs and beams are studied. By this test, the first cracking load, ultimate load, and deflection of the specimen are identified [15].

Ratna Srinivas et al. defined traditional concrete beams and geopolymer concrete beams as being the strength characteristics of the GPC higher than the OPC and the GPC’s load deflection behavior is higher than the OPC beams [16].

Srinivasa Rao et al. defined that the compressive strength of geopolymer concrete produced with steel fibers is greater than that of geopolymer concrete produced without steel fibers. It was clear that, as the concentration of NaOH increases, so does the compressive force. The load vs deflection with steel fiber on 8 M and 10 M beam is more than the beam with no steel fibers [17].

3. Materials

3.1. Ground Granulated Blast Furnace Slag
It is non-metallic shown in figure 2 and consists of a silicate and alumina silicate of Ca develop a molten with an iron into a slag is a ground material is a form to a rapid fine ground powder. Slag into alternate binder materials is taken alkali activator ratio proportion of 1:2.5 by mass [18]. The fineness of GGBS is 1.2, standard consistency of GGBS is 33, initial and final setting of GGBS is 24 and 170, specific gravity of slag is 2.9 are properties of GGBS.

![Figure 2. GGBS.](image)

3.2. Ordinary Portland Cement
It is in figure 3 mostly adopting the world because the abundance of less cost produces it. OPC 53 grade is the strength of 53MPa in 28 days of setting. It is used for fast placed construction were initial strength is rapidly [19]. The fineness OPC is 1.67, standard consistency of OPC is 35, initial and final set of OPC is 28 and 244, the specific gravity of OPC is 3.14 are the properties of OPC.
3.3. **Coarse Aggregate**

It is used for max size 20mm and minimum size 10mm. The Coarse Aggregate is Basalt rock crushed in compliance with IS 383 as shown in the figure 4. They range is 9.5mm to 37.5mm in dia. It can be a hard, strong, durable, etc. the gravel aggregate is almost the same as that of sand [20-22]. In this project 20mm, 12.5mm and 10mm are used. Properties given in table 1 and 2.

![Figure 4. Coarse Aggregate (20, 12.5 & 10mm).](image)

| Table 1. Physical properties of Gravel. | Table 2. Physical properties of Gravel. |
|----------------------------------------|----------------------------------------|
| **20mm**                               | **12.5mm**                             |
| Water Absorption                       | Impact Test                            |
| Specific Gravity                       | 12%                                    |
| Flakiness                              | Flakiness                              |
| Bulk Density (kg/m³)                   | Specific Gravity                       |
| Elongation                             | Elongation                             |
| Impact Test                            | Water Absorption                       |
|                                        | Bulk Density (kg/m³)                   |
| 0.36%                                  | 15.3%                                  |
| 2.72                                   | 2.8                                    |
| 8.89%                                  | 16.2%                                  |
| 1662                                   | 0.49%                                  |
| 10.1%                                  | 1666(kg/m³)                            |
| 27.3%                                  |                                        |

3.4. **Fine Aggregate**

The natural marine environment is ground sand shown in figure 5. To render silica in granular form. It is generally consisting of crushed stone to its particles of passing through the 9.5mm sieve and retaining on 75 microns IS sieve 650. Properties in table 3.

![Figure 5. Fine Aggregate River.](image)
Table 3. Normal Sand physical properties.

|                        | Normal Sand          |
|------------------------|----------------------|
| Modulus of Fineness    | 2.7                  |
| Specific Gravity       | 2.64                 |
| Bulk Density           | 1625(Kg/m³)          |
| Bulking of Sand        | 23%                  |
| Silt Content           | 0.25%                |
| Zone                   | II                   |

3.5. Super Plasticizer
It reduces the water and additive to increase the strength of concrete shown in figure 6. It absorbs a particle to form sheets to prevent the hydration. It is both the development of the workability specific gravity of superplasticizer is 1.06.

![Figure 6. Super Plasticiser.](image)

3.6. Alkaline Liquid

3.6.1. Sodium Hydroxide: NaOH solution a possible in pellets is a form to 95% to 97% purity in the market. NaOH solution should be made and complicated shown in figure 7

3.6.2. Alkali-Silica: It is also referred to as refracting. The gel-type can be sold in the markets. Na₂SiO₃ is 24 hours before casting and mixing the solution NaOH and Na₂SiO₃

![Figure 7. Sodium Silicate and Sodium Hydroxide.](image)

4. Mix Proportions

4.1. Alkaline Liquid
In this experimental study, the sodium hydroxide concentration was 8 M to 16 M for the preparation of the alkaline activator solution. For all molarities, the ratio of sodium hydroxide and sodium silicate was taken as 1:2.5. For the preparation of one molar concentration of caustic soda, Forty grams of caustic soda dissolved in one litre of mineral water. The characteristic strength of Mix proportions is 40Mpa.
4.2. Prepare of Geo-polymer Concrete

Davidovits (2002) suggested the method of preparing, casting and curing geopolymer concrete, the type of curing used in this study was ambient curing and suggested that solutions for sodium hydroxide and sodium silicate should be mixed at least 24 hours before adding the solution to the solid particles. Geopolymer concrete can be prepared by following the same techniques that have been followed for the preparation of normal concrete. The aggregate and GGBS were blended for 4 minutes, and now the alkaline solution was applied to the dry mix. For workability, 10% of extra distilled water was added. And all the moulds were lubricated to avoid sticking of mix to the moulds after demould, the fresh concrete which was placed in the moulds were compacted by using table vibrator shown in figure 8 to 11. Normal concrete made with cement was prepared, cast and cured by conventional methods in table 4 and 5 [23-24].

![Figure 8. Preparation of Geopolymer Concrete.](image)

![Figure 9. Geopolymer Concrete Mix.](image)

![Figure 10. Casting of Cubes.](image)

![Figure 11. Casting of Specimen.](image)
Table 4. Geopolymer Concrete Mix Proportions.

| Materials     | Quantity (kg/m³) |
|---------------|------------------|
| GGBS          | 414              |
| Fine-Grained  |                  |
| River Sand    | 330              |
| M-Sand        | 330              |
| Gravels       |                  |
| 20mm          | 681.6            |
| 12.5mm        | 227.2            |
| 10mm          | 227.2            |
| NaOH          | 53               |
| Na₂SiO₃       | 133              |
| Water         | 10%              |

Table 5. OPC Mixing Proportions.

| Materials                  | M40 Quantity (kg/m³) |
|----------------------------|----------------------|
| Cement (OPC 53 Grade)      | 420                  |
| Fine aggregate River Sand  | 765                  |
| Coarse aggregate 20mm      | 840.81               |
| aggregate 12.5mm           | 561.5                |
| Water                      | 151lit/m³            |
| Superplasticizer           | 1.89 kg/m³           |

5. Strength Characteristics

5.1. Compression Test

After completing of curing period, the cube specimens are testing in CTM to get compression strength values of cubes. The compressive strength of concrete specimen was determined by casting of cube having dimensions of 0.15mx0.15mx0.15m. After casting geopolymer concrete and normal concrete cubes they were left under curing condition for 7, 28 & 56 days. The producer was followed as per IS 516: 1959. Cube specimen were placed in the test machine in such a way that the specimen is placed centrally at bottom plate of the test machine, and movable part is adjusted so that it touches the cube's top surface shown in figure 12 to 14. Gradually the load applied without any shock application until the specimen failed, and then the value is noted.

Figure 12. Testing of Specimen.

Figure 13. Compressive Strength (GPC).

Figure 14. Compressive Strength (OPC).
5.2. Split Tensile Test
After completing of curing period, the cylinder specimens are testing in CTM to get tensile strength values of specimens shown in figure 15 to 17. There was no direct method for knowing the tensile strength of concrete, for determining the tensile strength of geopolymer and normal concrete cylinders were cast of 0.15m diameter and 0.30m large cylinder were casted with same molarity (i.e., 8Molarity, 10Molarity) and normal concrete. The test specimens were placed in the compressive strength machine in horizontal direction. The load was applied gradually until cylinder splits in two parts. The test was performed as per IS 5816: 1999.

![Figure 15. Testing of Specimen.](image1)

![Figure 16. Split Tensile Strength (GPC).](image2)

![Figure 17. Split Tensile Strength (OPC).](image3)

5.3. Flexural Strength
After completing of curing period, the prism specimens are testing in flexural testing machine to get flexural strength values of specimens shown in figure 18 to 20. It is finding a concrete strength to subject into the prism beam of a lateral compressive force. The size of 0.15x0.15x0.70 m was casted with same molarity (i.e., 8Molarity, 10Molarity) and normal concrete. After casting geopolymer concrete and normal concrete cubes they were left under curing condition for 7, 28 & 56 days. Cube specimen were placed in the test machine in such a way that the specimen is placed centrally at bottom plate of the test machine, and movable part is adjusted so it touches the top of the cu. The load applied gradually without any shock application until the specimen was failed then value is noted.
6. Experimental Programme
The testing method consists of casting six beams and curing them. The scale of the 1500 X 150 X 150 mm beams, two of which are concrete beams of control cement, two are concrete beams of 8M geopolymer and two are concrete beams of 10M geopolymer. The beams were designed as reinforced pieces under. Use 8 mm diameter stirrups @ 150 mm c/c, it is reinforced with 2-10 # at the bottom, 2-10 # above. The cement concrete control beams cast use M 40 grade (1:1.2:1.5 with a water-cement ratio of 0.45) and steel grade Fe500. Ordinary Portland cement, natural river sand, and max. 20 mm, 12.5 mm, and 10 mm crushed granite are used for conventional concrete. And cast beams of geopolymer concrete. The geopolymer concrete is developed by using the same techniques used in the development of Ordinary Portland cement concrete. GPC is used in the form of GGBS, fine aggregates, coarse aggregates, sodium hydroxide (NaOH), and sodium silicate (Na₂SiO₃).

6.1. Casting of Beams
Firstly, all the six beams are needed to be cast as per the design consideration. The next step of the process, after material procurement, is to weigh the materials of the necessary quantity per meter cube. The volume of the beam is obtained as 0.26 m³, since from Table I we can observe the concrete mix proportions per meter cube. So, it is necessary to measure the required volume of material quantities before cast of beams. After weighing of materials as per the required quantities, now all the coarse aggregates, fine aggregates and cement are need to be mix thoroughly by adding of water content after providing of steel reinforcement in Figure 21.
After placing the beam reinforcement cage into the beam box, the concrete mix which is mixed thoroughly need to be poured into the beam box in the form of layers. After the first two layers have been filled, the vibrator must be put inside the concrete to prevent air voids. And after the next layer of concrete mixture is filled again it is necessary to keep the vibrator to avoid the air voids. At last we need to level the top surface of the beam with the help of a trowel. The beams are needed to be demoulded within 24 hours of cast as shown in Figure 21. And after demould all the control beams need to be covered with the help of gunny bags in order to perform curing up to 28 and 56 days. And GPC beams curing at ambient temperature up to 28 and 56 days.

After curing period completed the beams were cleaned thoroughly using a wire brush. Galvanized iron of two layers hexagonal wire mesh of 1/2 inch ×22-gage were carefully wrapped tightly over the required length using iron winding wire. Plastering was carried out with cement sand mortar having a weight ratio of 1:2. Cement used complies with the IS specifications of 53 grade Ordinary Portland Cement, 8112–1989 and Zone II sand as per IS:383–1970. The ratio of water cement to use was 0.45 by weight. The mortar was applied in such a way that thickness did not exceed 15 mm. The finished specimen was cured for 28 and 56 days using wet gunny bags wrapped on the specimen.

6.2. Testing Procedure
To know the ultimate load carrying capacity, the conventional and GPC beams were tested at a bending load of four points. The hinge support was placed at a distance of 100 mm from the left edge of the beam and at a distance of 100 mm from the right edge of the beam. The conditions of support for all specimens examined are the same as shown in figure 23. The test frame capacity is 200 tons at
the Koneru Lakshmaiah Education Foundation (Deemed to University) Structural Engineering Laboratory.

![Image of beams being tested]

**Figure 23. Testing of Beams.**

The system that was used to test managed and GPC beams. With the aid of crane, the beams are raised and put on the section supports. In addition, it is compulsory to provide the top plate and then the mortar is provided to level the surface and avoid the eccentricity. There were two points of loading similarly distant in the solid steel billets form. To record load values the cell loading was mounted above the sectional girder. The LVDT has to be established at the bottom middle surface of the beam to calculate the mid displacement [26-28].

7. Results and Discussions

7.1. Load-Deflection Relationship:
This test is done on the beams casted with specific molarity and concrete beam grade M40. The load is applied to the beam, and the deflection in the middle of the beam is noted. The load carrying capacity of the ferrocement geopolymer concrete beams is higher than the ferrocement concrete beam from the test results, as the concentration of molarity in the geopolymer also increases the load carrying capacity. And the load deflection graphs from Figure 24, 25 & Figure 26 were shown for the specimens.

![Graph showing ultimate load of different type beams]

**Figure 24. Ultimate load of different type beams.**
The load carrying capacity of the GPC beams is increasing as the concentration of sodium hydroxide increases in molarity terms. As the molarity increased the load carrying capacity of the concrete geopolymer beams also increased. The ultimate load increase for each geopolymer concrete is 10%.

8. Conclusion
Experimental studies are conducted to understand the effect of NaOH at different concentrations with GGBS and to compare those findings with cement concrete produced at M 40 grade. Geopolymer concrete’s strength characteristics and flexural behaviour made from 100% GGBS and M40 grade cement concrete.
The strength properties of GPC have been observed to be higher than that of standard concrete.
- The percentage increase difference between each geopolymer concrete mix with various sodium hydroxide solution concentrations was around 5 % to 6 % for 7days, 28 days and 56 days.
- When sodium hydroxide concentration increases, geopolymer concrete strength also increased by about 5% to 6%.
- And the flexural behaviour and strengths of Reinforced Geopolymer Concrete and RCC Beams are the ultimate load of geopolymer concrete was higher than the M 40 grade concrete. As the molarity increased the load carrying capacity of the concrete geopolymer beams also increased. The ultimate load increase for each geopolymer concrete was approximately 8% to 11%.

9. Reference
[1] Duxson P, Fernández-Jiménez A, Provis JL, Lukey GC, Palomo A and van Deventer JS 2007 Geopolymer technology: the current state of the art Journal of materials science 42 2917-33
[2] Nuruddin MF, Demie S and Shafiq N 2011 Effect of mix composition on workability and compressive strength of self-compacting geopolymer concrete Canadian Journal of Civil Engineering 38 1196-203
[3] Dattatreya JK, Rajamane NP, Sabitha D, Ambily PS and Nataraja MC 2011 Flexural behaviour of reinforced Geopolymer concrete beams International journal of civil & structural engineering 2 138-59
[4] Sanni SH and Khadiranaikar DR 2013 Performance of Geopolymer Concrete Under Various Curing Conditions International Journal of Science Research 2
[5] Ramanathan P, Baskar I, Muthupriya P and Venkatasubramani R 2013 Performance of self-compacting concrete containing different mineral admixtures KSCE journal of Civil Engineering 17 465-72
[6] Reddy MV 2013 Durability aspects of standard concrete
[7] Jaffery MI, Kumar YH and Kumar BS 2006 Study on strength and durability parameters of geo polymer concrete with ggbs for 12m and 14m alkali activators
[8] Gayathri G, Ramya VS, Yasotha T and Dheenedhayalan M 2016 Experimental investigation on geopolymer concrete with e-waste IJRRASE 8 280-91
[9] Jayaseela J and Vishnumur BG 2015 Study on workability and durability characteristics of self-compacting geopolymer concrete composites 1246-56
[10] Kumar SG, Aleem MA and Dinesh S 2015 Application of geopolymer concrete International Research Journal of Engineering and Technology 2 96-9
[11] Manoj Kumar N and Hanitha P 2016 Geopolymer concrete by using Fly ash and GGBS as a replacement of cement IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
[12] Sonebi M, Grünewald S and Walraven J 2007 Filling ability and passing ability of self-consolidating concrete ACI Materials Journal 104 162
[13] Reddy KM and Kumar GN 2017 Experimental study on Self Compacting Geopolymer Concrete International Research Journal of Engineering and Technology 4 953-7
[14] Mathew G and Joseph B 2018 Flexural behaviour of geopolymer concrete beams exposed to elevated temperatures Journal of Building Engineering 15 311-7
[15] Reddy CJ and Elavenil S 2017 Geopolymer Concrete with Self Compacting: A Review International Journal of Civil Engineering and Technology 8
[16] Kumar SG, Aleem MA and Dinesh S 2015 Application of geopolymer concrete International Research Journal of Engineering and Technology (IRJET) 2 96-9
[17] Iswarya G and Reddy VV 2018 Behaviour and Experimental Study on Concrete as Partial Replacement of Fine Aggregate with Copper Slag and Cement with GGBS International Journal of Applied Engineering Research 13 279-83
[18] Malepati Nagarjuna and Praveen Kumar M 2017 A Study on Workability and Split Tensile Strength of Multi Blend Concrete of M20 Grade International Research Journal of Engineering and Technology 4
[19] Nath P and Sarker PK 2012 Geopolymer concrete for ambient curing condition Proc. Australasian Structural Engineering Conference 2012: The past, present and future of structural engineering 225
[20] Amin M and Nasier S 2014 Geopolymer concrete-A solution for cementitious concrete pollution A Review Technology 3
[21] Verma M and Dev N 2018 Geopolymer concrete: A way of sustainable construction International Review of Recent Research 1 201-5
[22] Supriya Kulkarni 2018 Study on Geopolymer Concrete International Research Journal of Engineering and Technology 5
[23] Chandru P and Dhanalakshmi G. An Experimental Investigation on Utilization of Ground Granulated Blast Furnace Slag And Waste Foundry Sand As A Partial Replacement In Concrete. International Journal of Exploring Emerging Trends in Engineering 3
[24] Jayasree S and Ganesan N, Abraham R 2016 Effect of ferrocement jacketing on the flexural behaviour of beams with corroded reinforcements Construction and Building Materials 121 92-9
[25] Kumar PU and Kumar BS 2016 Flexural Behaviour of Reinforced Geopolymer Concrete Beams with GGBS and Metaakoline International Journal of Civil Engineering and Technology 7
[26] Kumar BS and Ramesh K Analytical Study on Flexural Behaviour of Reinforced Geopolymer Concrete Beams by ANSYS InIOP Conference Series: Materials Science and Engineering 455 01-09
[27] Srinivasa Rao G and Sarath Chandra Kumar. B 2019 Experimental Investigation of GGBS based Geopolymer Concrete with Steel Fibers IJITCE 7 49-55
[28] Kumar S, Gautam PD and Kumar BS 2019 Effect of Alkali Activator Ratio on Mechanical Properties of GGBS based Geopolymer Concrete IJITEE 8 947-952