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"EXPERIMENTAL STUDY ON COMPRESSIVE AND FLEXURAL STRENGTH OF STEEL FIBER REINFORCED GEOPOLYMER CONCRETE"

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ABSTRACT

The demand of concrete is increasing day by day and Cement is used for satisfying the need of development of infrastructure facilities, 1 tone cement production generates 1 tone CO_2, which adversely affect the environment. In order to reduce the use of OPC and CO_2 generation, the new generation concrete has been developed such as GEOPOLYMER CONCRETE. It uses GGBS and Alkaline Solution as their Binding Materials. Geopolymer concrete requires ambient curing.

The objective of the present work is to study the effect of GGBS in Geopolymer concret. By replacing OPC by 100% with GGBS and inspecting the Fresh Properties and Hardened properties at 7 days. The casted beams will be cured at normal room temperature and to ascertain the behavior of concrete mixed with GGBS, thereby examining the changes of properties like flexural Strength and workability.

The present paper deals with investigating characteristics of M20, M30 and M40 concrete with 100% replacement of cement with GGBS, steel fiber. The scope of present investigation deals with flexural strength property of concrete, on the effect of replacement of cement by GGBS with 100 percentage was used in concrete mix containing composite steel fibers are different percentage (i.e. 0%, 0.5%, 1.5%, 2.5%, 3.5% and 4.5%). In this project we are conducting Flexural strength test on beam (size: 100mm x 100mm x 500mm) and Compressive strength test on cube (size: 100mm x 100mm x 500mm). The relation between Flexural strength of beam and Compressive strength of cube is found out through result obtained.

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KEYWORDS: Geopolymer concrete, sodium silicate, sodium hydroxide, granulated blast furnace slag, Compressive strength, and flexural strength of concrete

INTRODUCTION

Concrete is one of the most widely used construction materials and the Portland cement is a main component for making concrete. Concrete usage around the world is second only to water. Ordinary Portland cement (OPC) is conventionally used as the primary binder to produce concrete. The production of cement generates large amount of carbon dioxide. Carbon dioxide could be reduced if the production of cement could be reduced. The production of one ton of cement emits approximately one ton carbon dioxide to the atmosphere, which leads to global warming conditions. So, one of the ways to produce environmentally friendly concrete is to reduce the use of Ordinary Portland Cement by replacing cement with by-product materials such as GGBS . One of the efforts to produce more environmentally friendly concrete is to replace the Portland cement in concrete with by-product materials such as GGBS. An effort to make environmentally friendly concrete is the development of inorganic alumina-silicate polymer, such as GGBS that are rich in silicon and aluminium called Geopolymer, synthesized from materials of geological origin or by-product materials such as GGBS that are rich in Silicon and Aluminium. GGBS (Ground Granulated Blast Slag) is a waste material Generated in iron or Slag Industries have significant impact on Strength and Durability of Geopolymer Concrete.The production of Portland cement consumes considerable energy and at the same time contributes a large volume of CO_2 to the atmosphere. The climate change due to global warming has become a major concern. The global warming is caused by the emission of greenhouse gases, such as carbon dioxide (CO_2), to the atmosphere by human activities. The cement industry is held responsible for some of the CO_2 emissions, because the production of one ton of Portland cement emits approximately one ton of CO_2 into the atmosphere [1]. However, Portland cement is still the main binder in concrete construction prompting a search for more environmentally friendly materials. Several efforts are in progress to supplement the use of Portland cement in concrete in order to address the global warming issues. These include the utilization of supplementary cementing materials such as silica fume, granulated blast furnace slag, rice-husk ash and metakaolin, and the development of alternative binders to Portland cement.

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Fly Ash is a main solid waste generated from the coal combustion in the power stations. Waste created by a typical 500-megawatt coal plant includes more than 125,000 tons of ash and 193,000 tons of sludge from the smokestack scrubber each year. Presently, as per the Indian Ministry of Environment and Forest figures, only 20% to 30% of fly ash is used in manufacturing cements, construction, concrete, block and tiles and some disposed off in landfills and embankments. More than 75% of this waste is unutilized leading to several environmental problems of the air, soils and surface and ground-water pollution. Therefore proper disposal and utilization 4 of these ashes are required to preserve the ecosystem from severely or permanently damaged by the uncontrolled coal plant waste disposal. Fly ash, which is rich in silica and alumina, has full potential to use as one of the source material for geopolymer binder. The utilization of fly ash in the development of geopolymeric materials for construction purposes has been and continues to be subject of many research studies. Recent works on the geopolymerisation of fly ash, reported production of geopolymeric materials with high mechanical strength, low density, less water absorption, negligible shrinkage and significant fire and chemical resistance.

Significant research works on fly ash based geopolymer concrete manufactured from fly ash in combination with sodium silicate and sodium hydroxide solution has been carried out by several researchers and they have reported higher strength and better durability of geopolymer concrete than Portland cement concrete. Current applications of geopolymer concrete are affected by its curing method. The requirement of elevated temperature in its maturing period is supplied with electric equipment that could generate hot steam or heat. This method would prevent the geopolymer concrete to be applied in a cast in situ concrete work. Therefore this research is focused on the utilization of ambient temperature to cure the geopolymer concrete. .

Applications:

The uniform dispersion of fibers throughout the concrete mix provides isotropic properties not common to conventionally reinforced concrete. The applications of fibers in concrete industries depend on the designer and builder in taking advantage of the static and dynamic characteristics of this new material. The main area of FRC applications are

1. Runway, Aircraft Parking, and Pavements: For the same wheel load FRC slabs could be about one half the thickness of plain concrete slab. Compared to a 375mm thickness' of conventionally reinforced concrete slab, a 150mm thick crimped-end FRC slab was

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used to overlay an existing as Properties and Applications of Fiber Reinforced Concrete 53 phaltic-paved aircraft parking area. FRC pavements are now in service in severe and mild environments.

2. Tunnel Lining and Slope Stabilization: Steel fiber reinforced shortcrete (SFRS) are being used to line underground openings and rock slope stabilization. It eliminates the need for mesh reinforcement and scaffolding.
3. Blast Resistant Structures: When plain concrete slabs are reinforced conventionally, tests showed (llj that there is no reduction of fragment velocities or number of fragments under blast and shock waves. Similarly, reinforced slabs of fibrous concrete, however, showed 20 percent reduction in velocities, and over 80 percent in fragmentations.
4. Thin Shell, Walls, Pipes, and Manholes: Fibrous concrete permits the use of thinner flat and curved structural elements. Steel fibrous shortcrete is used in the construction of hemispherical domes using the inflated membrane process. Glass fiber reinforced cement or concrete (GFRC), made by the spray-up process, have been used to construct wall panels. Steel and glass fibers addition in concrete pipes and manholes improves strength, reduces thickness, and diminishes handling damages.
5. Dams and Hydraulic Structure: FRC is being used for the construction and repair of dams and other hydraulic structures to provide resistance to capitation and severe erosion caused by the impact of large water debris.
6. Other Applications: These include machine tool frames, lighting poles, water and oil tanks and concrete repairs.

MATERIALS

Ground Granulated Blast Furnace Slag (GGBS)

Ground granulated blast furnace slag comprises mainly of calcium oxide, silicon di-oxide, aluminium oxide, magnesium oxide. It has the same main chemical constituents as ordinary Portland cement but in different proportions. And the addition of G.G.B.S in Geo-Polymer Concrete increases the strength of the concrete and also curing of Geo-Polymer concrete at room temperature is possible. Ground granulated blast furnace slag (GGBS) is a by-product from the blast-furnaces used to make iron. These operate at a temperature of about

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1,500 degrees centigrade and are fed with a carefully controlled mixture of iron-ore, coke and limestone. The iron ore is reduced to iron and the remaining materials form a slag that floats on top of the iron. This slag is periodically tapped off as a molten liquid and if it is to be used for the manufacture of GGBS it has to be rapidly quenched in large volumes of water. The quenching optimizes the cementitious properties and produces granules similar to coarse sand. This "granulated slag‟ is then dried and ground to a fine powder. GGBS is one of the „greenest‟ of construction materials as well as the environmental benefit of utilizing a by-product, GGBS replaces something that is produced by a highly energy-intensive process. By comparison with Portland cement, manufacture of GGBS requires less than a fifth the energy and produces less than a fifteenth of the carbon dioxide emissions. GGBS has been brought from CONMIX RMC PLANT located near dumping yard Karawar road Hubballi.

Chemicals

In this experimental work, chemicals are the very important constituents. Sodium Silicate and Sodium Hydroxide liquid are obtained commercially from local suppliers in Salem.

1. Sodium Hydroxide

The sodium hydroxide solids were of a laboratory grade in pellets form with 99% purity, obtained from local suppliers. The sodium hydroxide (NaOH) solution was prepared by dissolving the pellets (a small, rounded, compressed mass of a substance of sodium hydroxide) in water. The mass of sodium hydroxide solids in a solution varied depending on the concentration of the solution expressed in terms of molar, M. For instance, sodium hydroxide solution with a concentration of 10M consisted of 10x40 = 400 grams of sodium hydroxide solids (in pellet form) per liter of the solution, where 40 is the molecular weight of sodium hydroxide. It has been brought from VENKATESHWAR ENTERPRICES near Gandhi chowk Dharwad

2. Sodium Silicate

Sodium silicate solution obtained from local suppliers was used. The chemical composition of the sodium silicate solution was Na_2O=14.7%, SiO_2=29.4%, and water 55.9% by mass. The mixture of sodium silicate solution and sodium hydroxide solution forms the alkaline liquid. It is purchased from SHANTI CHEMICALS near GIT collage Belgaum.

Water

Distilled water was used for the preparation of sodium hydroxide solution and sodium silicate for extra water added to achieve workability.

Fine Aggregate

The fine aggregate used in the project was locally supplied and conformed to grading zone I as per IS: 383:1970. It was first sieved through 4.75mm sieve to remove any particles greater than 4.75mm. M-sand was used as fine aggregate. The gradation of the sand was determined by sieve analysis as per IS 383 (1970) and presented in the testing of aggregate. The grading curve of the fine aggregate as per IS 383 (1970) M-sand has been purchased from RR LAND MARKS near PRESIDENT Hotel Hubballi.

Coarse Aggregate

Locally available coarse aggregate having the maximum size of (10 - 20mm) were used in this project, Crushed granite stones of size 20 mm and 10 mm were used as coarse aggregate. The gradation of the coarse aggregate of size 20mm and 10mm was determined by sieve analysis as per IS 383 (1970). The grading curves of the coarse aggregates as per IS 383 (1970) are shown in testing of aggregate. It has been purchased from RR LAND MARKS near PRESIDENT Hotel Hubballi.

Steel Fibre

Hooked-end steel fibres made with low carbon steel having a length of 35 mm and a diameter of 0.7 mm thus giving an aspect ratio of 50 were used and they are shown in below Figure. Steel fibers are purchased from TOOLING SOLUTION near Neharu nagar bhosari MIDC Pune.

METHOLDOLOGY

In this experimental work, Steel Fiber Reinforced GGBS based geopolymer Concrete specimens for M20, M30 and M40 Grades mix were prepared without cement to study the strength characteristics such as compressive strength and flexural strength. Steel fibers as reinforcement materials were added at0%, 0.5%, 1.50%, 2.5%, 3.5% and 4.5% by the weight of binding agent. And hence a comparison is made between Compressive strength of different grades with different % of steel fibers and also Comparison between flexural strength of different grades with different % of steel fibers.

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RESULTS AND DISCUSSION

Compressive Strength Results of Cubes

Table 1: Compressive strength of SFRGPCC specimens for M20 mix

Steel fiber content (%)	Ultimate load in kN	Compressive strength in N/mm²	Average Compressive strength in N/mm²	Compressive strength for standard cube (150x150x150)
0%	255.2	25.52	33.78	30.42
0%	373.1	37.31		
0%	285.3	38.53		
0.5%	512.1	51.21	50.62	45.558
0.5%	521.6	52.16		
0.5%	485.2	48.52		
1.5%	546.5	54.65	54.83	49.347
1.5%	548.4	54.84		
1.5%	550.1	55.01		
2.5%	641.7	64.17	64.85	58.365
2.5%	655.6	65.56		
2.5%	648.2	64.82		
3.5%	670.3	67.03	66.74	60.066
3.5%	656.8	65.68		
3.5%	675.2	67.52		

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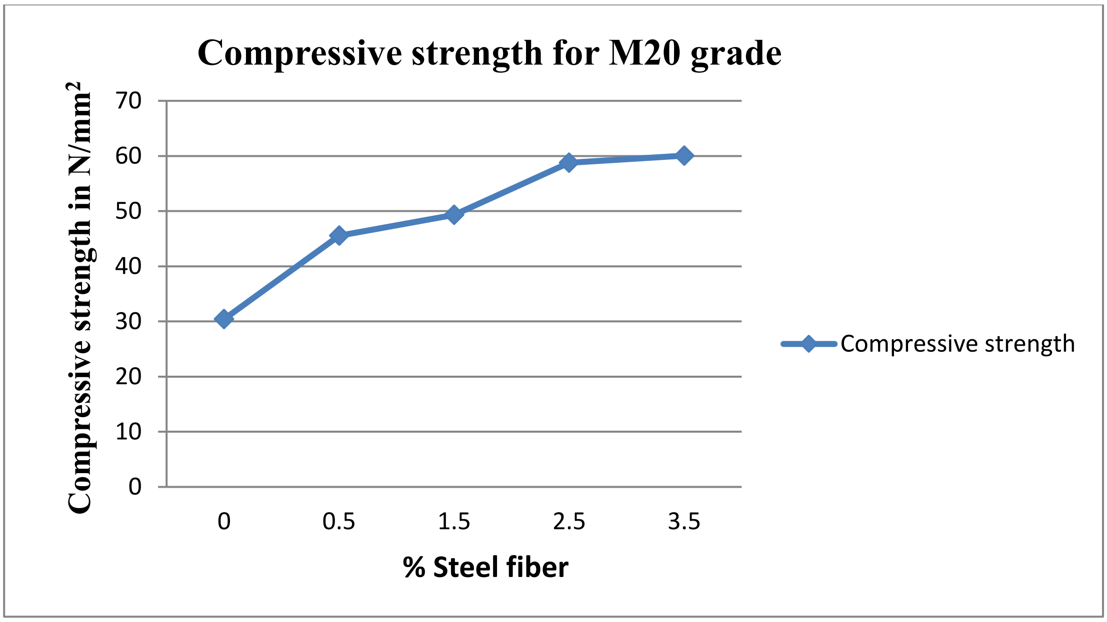

Graph.1: Compressive strength of M20 grade

From the table 1 and Graph No.1 the maximum compressive strength of cube obtained is 60.066 MPa at 3.5% of steel fiber and compressive strength got increased by 49%, 62%, 91%, 97% for 0.5%, 1.5%, 2.5%, 3.5% respectively when compared to 0% of steel fiber.

Table 2: Compressive strength of SFRGPCC specimens for M30 mix

Steel fiber content (%)	Ultimate load in kN	Compressive strength in N/mm^2	Average Compressive strength in N/mm^2	Compressive strength for standard cube (150x150x150)
0%	374.7	37.47	40.27	36.243
0%	422.6	42.26		
0%	410.8	41.08		
0.5%	538.6	53.86	54.44	48.996
0.5%	542.4	54.24		
0.5%	552.3	55.23		
1.5%	555.1	55.51	56.91	51.219
1.5%	588.7	58.87		
1.5%	563.5	56.35		

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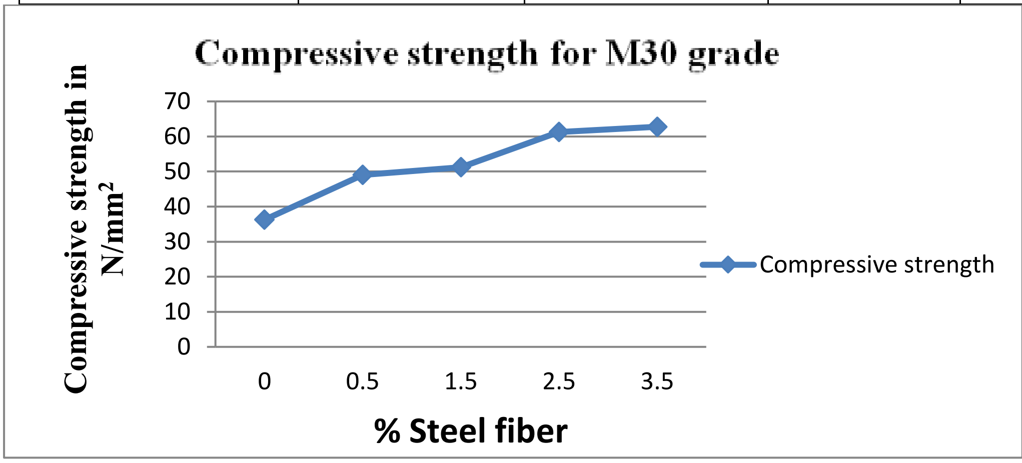
2.5%	679.3	67.93	68.05	61.245
2.5%	681.5	68.15		
2.5%	680.7	68.07		
3.5%	698.2	69.82	69.72	62.766
3.5%	688.7	68.87		
3.5%	705.3	70.53		



Graph.2: Compressive strength of M30 grade

From the table 2 and Graph No.2 the maximum compressive strength of cube obtained is 62.766MPa at 3.5% of steel fiber and compressive strength got increased by 34%, 35%,69%, 73% for 0.5%, 1.5%, 2.5%, 3.5% respectively when compared to 0% of steel fiber.

Table No.3 : Compressive strength of SFRGPCC specimens for M40 mix

Steel fiber content (%)	Ultimate load in kN	Compressive strength in N/mm^2	Average Compressive strength in N/mm^2	Compressive strength for standard cube (150x150x150)
0%	424.9	42.49	45.66	40.194
0%	467.2	46.72		
0%	477.7	47.77		
0.5%	543.0	54.30		

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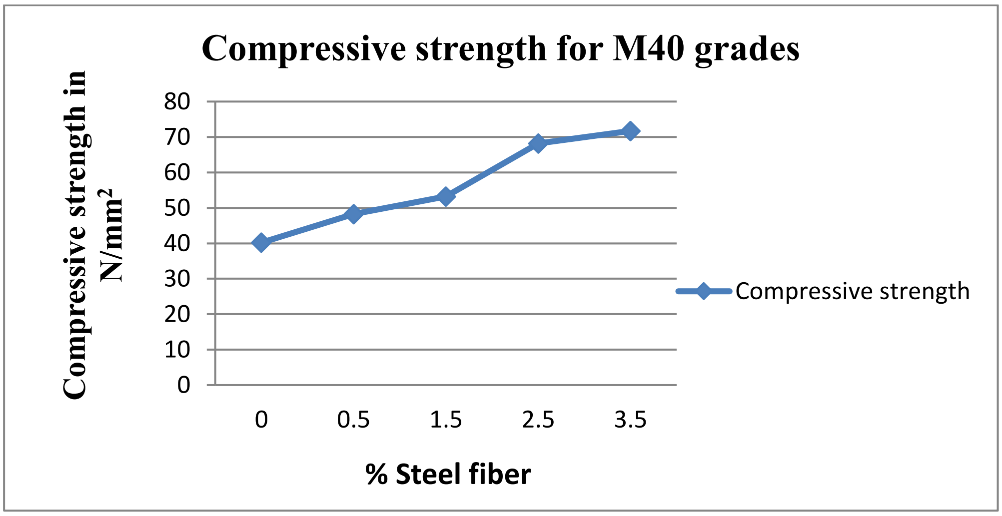
0.5%	546.1	54.61	53.64	48.276
0.5%	520.3	52.03		
1.5%	591.8	59.18	59.14	53.226
1.5%	592.1	59.21		
1.5%	590.5	59.05		
2.5%	747.4	74.74	75.81	68.228
2.5%	768.3	76.83		
2.5%	758.6	75.86		
3.5%	790.3	79.03	79.68	71.712
3.5%	801.5	80.15		
3.5%	798.7	79.87		



Graph No..3: Compressive strength of M40 grade

From the table 3 and Graph No.3 the maximum compressive strength of cube obtained is 62.766MPa at 3.5% of steel fiber and compressive strength got increased by 20%, 32%,70%, 78% for 0.5%, 1.5%, 2.5%, 3.5% respectively when compared to 0% of steel fiber.

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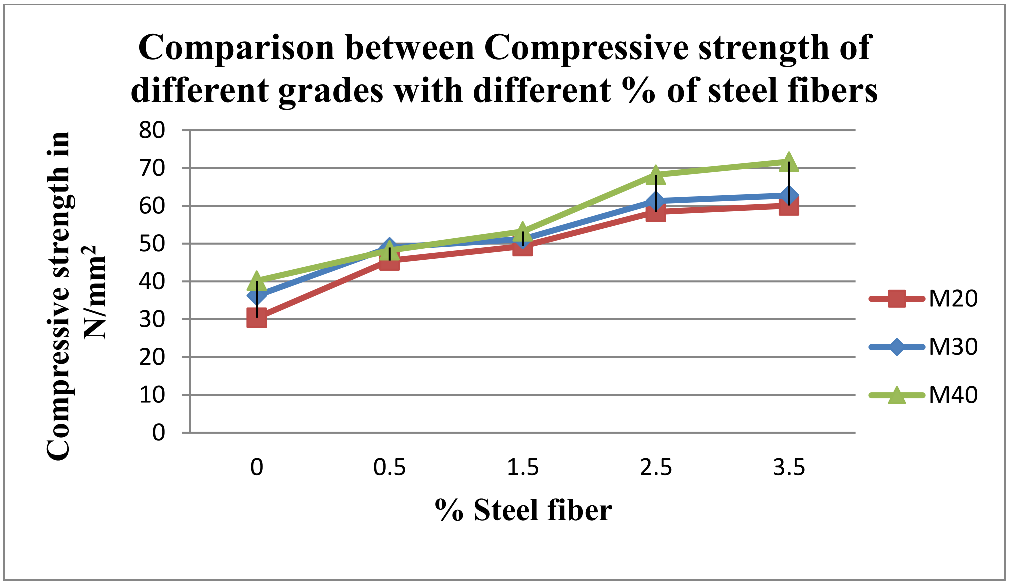

Graph No.4: Comparison between Compressive strength of different grades with different % of steel fibers

From the fig 28 the graph of % of steel fibers Vs compressive strength is plotted for different grades and the strength of concrete kept increasing with the increase in percentage of steel fiber for different grades and maximum value of compressive strength obtained is 71.712Mpa at 3.5% steel fiber for M40 grade.

Flexural Strength of Beam

Equation used for finding Flexural strength of concrete for 3-Point loading is as follow

$f_{cr}= p \times l/(bd^2)$

Where: p= load in N

l= length of beam in mm.

b= breadth of beam in mm.

d= depth of beam in mm.

Table 4: Flexural strength of SFRGPCC specimens for M20 mix

Steel fiber content (%)	Ultimate load in kN	Flexural strength in N/mm^2	Average Flexural strength N/mm^2
0%	7.87	3.935	3.985
0%	8.07	4.035	
0%	7.97	3.985	

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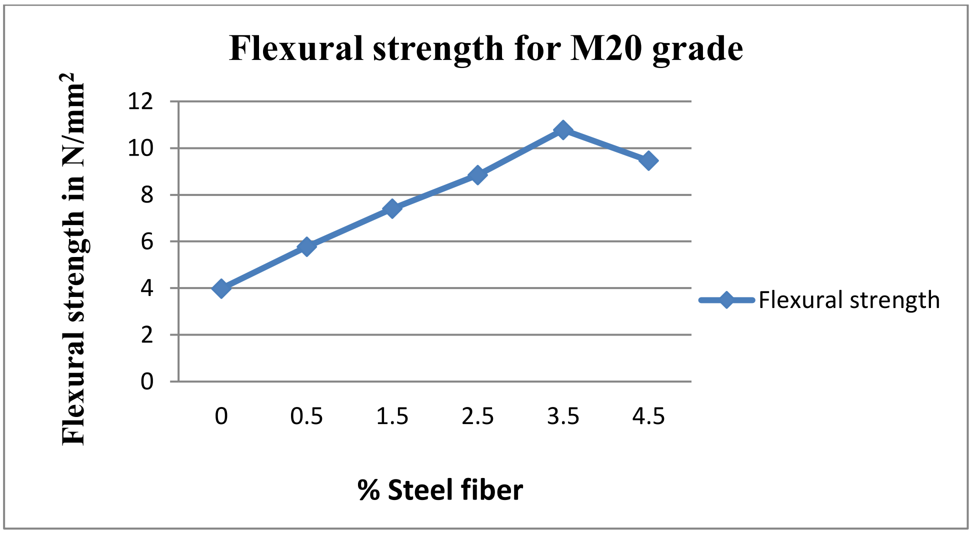
0.5%	11.67	5.835	5.775
0.5%	11.43	5.715	
0.5%	11.55	5.775	
1.5%	14.59	7.295	7.410
1.5%	15.05	7.525	
1.5%	14.82	7.410	
2.5%	17.43	8.715	8.845
2.5%	17.94	8.970	
2.5%	17.70	8.850	
3.5%	21.75	10.875	10.78
3.5%	20.38	10.190	
3.5%	22.55	11.275	
4.5%	19.89	9.945	9.46
4.5%	18.56	9.280	
4.5%	18.36	9.180	



Graph No.5: Flexural strength of M20 grade Beam

From the table 4 and Graph No.5 the maximum flexural strength of beam obtained is 10.78Mpa at 3.5% of steel fiber and got reduced to 9.46Mpa for 4.5% of steel fiber.

Table 5: Flexural strength of SFRGPCC specimens for M30 mix

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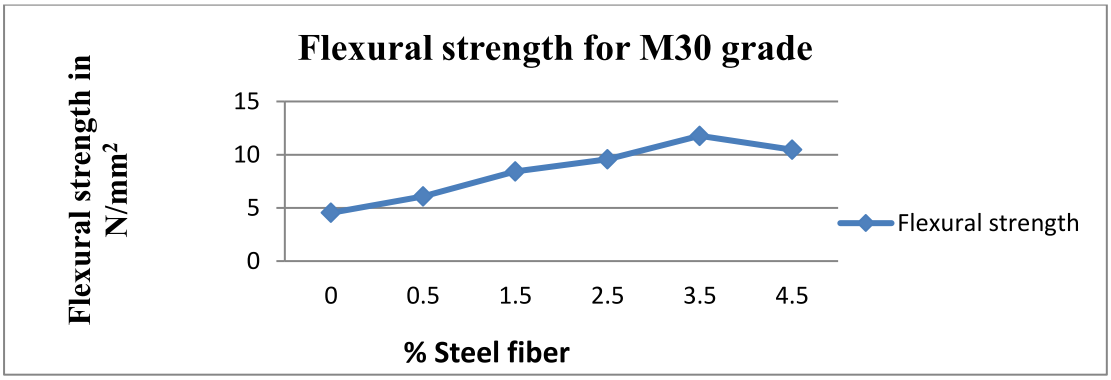
Steel fiber content (%)	Ultimate load in kN	Flexural strength in N/mm^2	Average Flexural strength in N/mm^2
0%	8.96	4.480	4.532
0%	9.05	4.525	
0%	9.18	4.590	
0.5%	12.31	6.155	6.085
0.5%	11.99	5.995	
0.5%	12.21	6.105	
1.5%	16.67	8.335	8.432
1.5%	17.02	8.510	
1.5%	16.90	8.450	
2.5%	18.93	9.465	9.553
2.5%	19.07	9.535	
2.5%	19.32	9.660	
3.5%	24.15	12.075	11.775
3.5%	23.47	11.375	
3.5%	23.75	11.875	
4.5%	21.22	10.610	10.460
4.5%	20.19	10.090	
4.5%	21.36	10.680	



Graph No.6: Flexural strength of M30 grade Beam

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From the table 5 and Graph No.6 the maximum flexural strength of beam obtained is 11.775Mpa at 3.5% of steel fiber and got reduced to 10.460Mpa for 4.5% of steel fiber.

Table 6: Flexural strength of SFRGPCC specimens for M40 mix

Steel fiber content (%)	Ultimate load in kN	Flexural strength in N/mm²	Average Flexural strength in N/mm²
0%	9.96	4.980	4.918
0%	9.72	4.860	
0%	9.83	4.915	
0.5%	15.2	7.600	7.473
0.5%	14.89	7.445	
0.5%	14.75	7.375	
1.5%	18.45	9.225	9.217
1.5%	18.25	9.125	
1.5%	18.6	9.300	
2.5%	20.49	10.245	10.440
2.5%	20.55	10.275	
2.5%	21.6	10.800	
3.5%	21.58	10.790	10.798
3.5%	22.09	11.045	
3.5%	21.12	10.560	
4.5%	19.85	9.925	9.870
4.5%	20.01	10.005	
4.5%	19.36	9.680	

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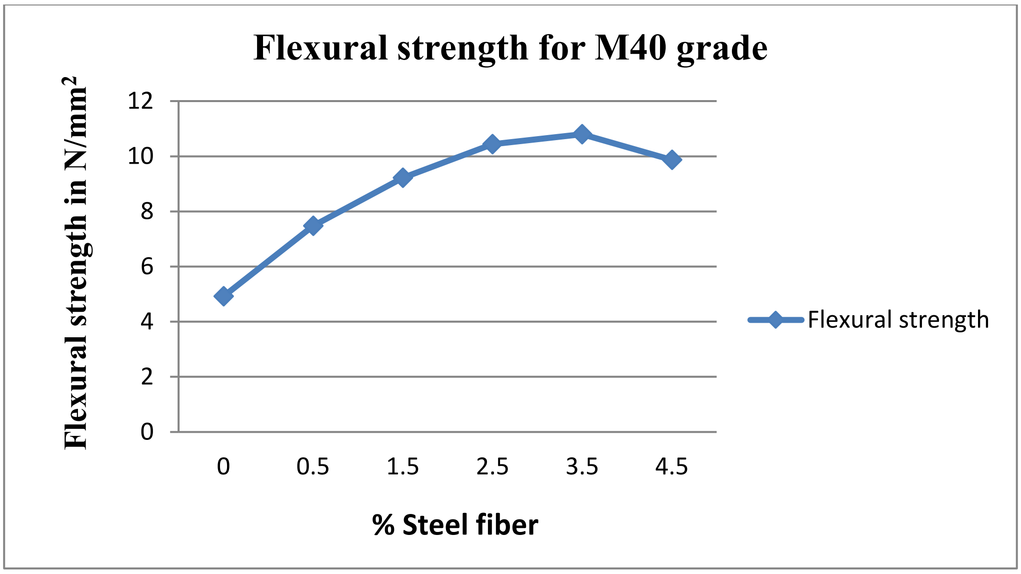
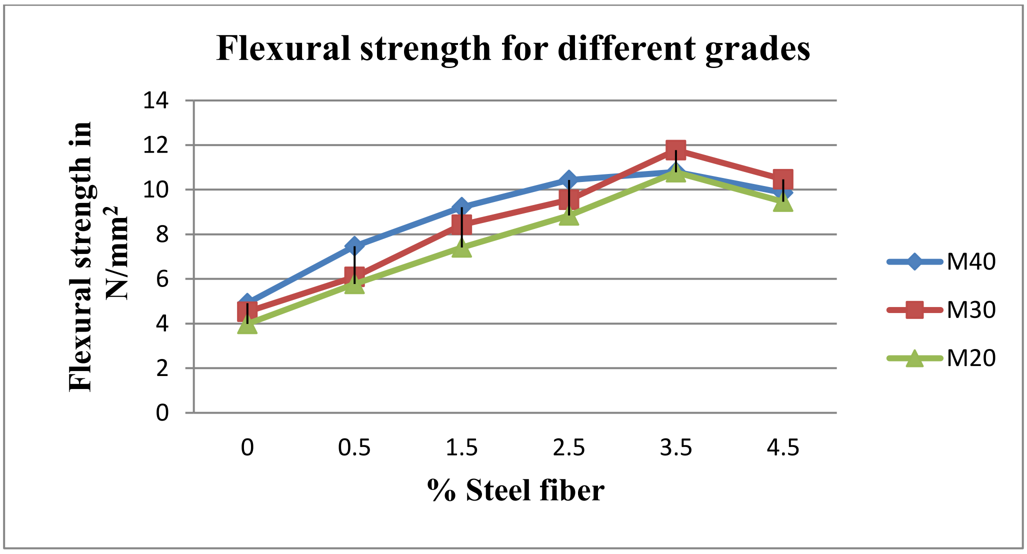


: Graph No.7 Flexural strength of M40 grade Beam

From the table 6 and Graph No.7 the maximum flexural strength of beam obtained is 10.789Mpa at 3.5% of steel fiber and got reduced to 9.870Mpa for 4.5% of steel fiber.



Graph No.8: Comparison between Flexural strength of different grades with different % of steel fibers

CONCLUSION

Based on the experimental study the following conclusions are made on GGBS based geopolymer concrete.

1. The addition of steel fibers to concrete will enhance its compressive strength and Flexural strength.
2. The Compressive strength of concrete increases with increase in different percentage of steel fibers with different grades of concrete.
3. The flexural strength of SFRGPC was found to increase with increase in percentage of steel fiber up to 3.5% beyond this 3.5% content of steel fiber in the concrete reduced the flexural strength.
4. The maximum average flexural strength obtained is 11.775N/mm^2 at 3.5% of steel fiber for 7 days at ambient curing.
5. The maximum average compressive strength obtained is 71.712N/mm^2 at 3.5% of steel fiber for 7 days at ambient curing.

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REFERENCES

1. Ajay Kumar Singh. *"Strength and Durability Test of Fly Ash and GGBS Based Geopolymer Concrete",* Int. Journal of Engineering Research and Application ISSN : 2248-9622, Vol. 6, Issue 8, (Part -1) August 2016, pp.139-142.
2. A.M. Shende, A.M. Pande, M. Gulfam Pathan, *"Experimental Study on Steel Fiber Reinforced Concrete for M-40 Grade",* International Refereed Journal of Engineering and Science (IRJES) ISSN (Online) 2319-183X, (Print) 2319-1821 Volume 1, Issue 1 (September *2012*).
3. Anusha, Dheekshith K, *"Study on Geopolymer Concrete using GGBS",* International Research Journal of Engineering and Technology (IRJET) ISSN: 2395 -0056 Volume: 04 Issue: 02 | Feb -2017.

International Research Journal in Global Engineering and Sciences. (IRJGES)
ISSN : 2456-172X | Vol. 4, No. 2, June-Aug 2019 Pages 120-136 | Cosmos Impact Factor (Germany): 5.195
Received: 02.08.2019 Published:28.08.2019

4. Aswani Sabu, Thomas Paul), *"Experimental Study on Comparison of Hooked- End and Crimped Steel Fibres",* International Journal for Research in Applied Science & Engineering Technology (IJRASET) Volume *4*, Issue IX, September *2016*.
5. Ganapati Naidu P, A.S.S.N.Prasad, S.Adiseshu, P.V.V.Satayanarayana *"A Study on Strength Properties of Geopolymer Concrete with Addition of G.G.B.S"* Volume 2, Issue 4 (July *2012*).
6. K. M. Chetan, K. C. Sachin, B. B. Gopal *"Experimental Studies on Strength Characteristics of GGBS based Geopolymer Concrete",* International Journal for Scientific Research and Development Volume 5, Issue 2 (2017).
7. M. Poojidha, K. Nirmalkumar (2016) *"Review Paper on Geopolymer Concrete by using GGBS",* International Research Journal of Engineering and Technology (IRJET) Volume 3- Issue 12 (2016).
8. Nikhil A. Gadge, Prof. S. S. Vidhale , *"Mix Design of Fiber Reinforced Concrete (FRC) Using Slag & Steel Fiber",* International Journal of Modern Engineering Research (IJMER) Volume 3, Issue 6 (2013)
9. M.S. SHETTY *" concrete technology seventh edition"* by S. CHAND PUBLICATION (ISO 9001: 2007)
10. V. Supraja, M. Kanta Rao *"Experimental study on Geo-Polymer concrete incorporating GGBS"*,International Journal of Electronics, Communication and Soft Computing Science and Engineering (IJECSCSE) Volume 2, Issue 2 August (2012).
11. International journal of pure and applied science and technology (IJPAST), ISSN 2229-6107 Volume 6, Issue 12 (2016).