Experimental Investigation of Mechanical Properties of Geopolymer Concrete Using Combination of Steel and Glass Fiber

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March 28, 2022

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ABSTRACT

Concrete is one of the most generally utilized development materials, it is typically connected with Portland concrete as the fundamental part of making concrete. The interest for concrete as a development material is on the increment. It was estimated that the production of cement will increase about from 1.5 billion tons in 1995 to 2.2 billion tons in 2015.

Then again, environmental change because of an Earth-wide temperature boost, one of the best ecological issues has turned into a main pressing issue during the last ten years. Human activities enhance the release of greenhouse gases into the atmosphere, such as CO2, causing global warming. CO2 accounts for around 65 percent of global warming among greenhouse gases. The concrete business is liable for around 6% of all CO2 discharges because the production of one ton of Portland cement emits approximately one ton of CO2 into the atmosphere.

As far as diminishing an Earth-wide temperature boost, the geopolymer innovation could lessen the CO2 outflow to the climate brought about by concrete and totals enterprises by around 80%.

The research utilized low-calcium (ASTM Class F) fly ash as the base material, GGBS, alkaline solution for making geopolymer concrete. The concrete properties studied included the compressive strength, flexural strength and split tensile strength behaviour of the concrete upon using fibres (glass and crimped steel).

Keywords: Ground granulated blast furnace slag, crimped steel fibre, glass fibre.

1. INTRODUCTION

1.1 General

There are two primary constituents of Geopolymers, to be specific the source materials and the basic fluids. The source materials for Geopolymers in light of alumina-silicate should be wealthy in silicon (Si) and aluminum (Al). These could be the most widely available natural minerals like kaolinite, clays, and so on. By-product materials such as fly ash, silica fume, slag, rice-husk ash, red mud, and others can also be used. The decision of the source materials for making Geopolymers relies upon variables like accessibility, cost, sort of utilization, and explicit interest of the end clients.

1.2 Background

The first geopolymer concrete created during the 1980s was of the sort (K, Na, Ca)- poly(silicate) (or slag-based geopolymer concrete) and came about because of the exploration advancements completed by Joseph Davidovits and J.L. Sawyer at Lone Star Industries, USA and yielded the invention of Payment cement. Geopolymers have been known to be useful binders in concrete for over 60 years, however, recently developed quickly in Australia because of the reality they have a CO2 impression which is around 80% lower than OPC concrete.

1.3 working of geopolymer concrete

Water, expelled from the geopolymer matrix during the curing and further drying periods leaves behind nano-pores in the framework, which give advantages to the exhibition of geopolymer. The water in a low-calcium fly ash-based geopolymer combination, consequently, assumes no immediate part in the substance response that happens; it merely provides the workability to the mixture during handling. During the hydration process, water in a Portland cement concrete mixture undergoes a chemical reaction.

1.4 Types of Geopolymer Concrete

There are four varieties of geopolymer concrete now in use in construction industry.

1. Geopolymer based on slag
2. Geopolymer based on rocks
3. Geopolymer based on fly ash
4. Geopolymer based on ferro-sialate

2. LITERATURE REVIEW

This chapter gives a quick rundown of geopolymer terminology and chemistry, as well as prior geopolymer research.

A lot of examinations have been accounted for on geopolymer concrete regarding the mechanical properties like compressive, split tensile and flexural strength behavior by addition of certain replacement material and by adding different fibres. My study is based on the findings of a multi-field literature review.

B.V.Rangan studied the efficient advantages of low calcium fly ash based geopolymer concrete with respect to the environmental friendly concept. He undergone with the constituents to be used in the preparation of Geo polymer concrete. After the review and result conclusions, they presumed that geopolymer concrete requires a basic method of mix design for its preparation. They also mentioned about the mix design required for the specific grade. However we have a separate code of practice for mix design of traditional concrete, it can't be utilized directly for the geopolymer concrete. Apart from the water to geo polymer solids ratio, the essential concept of mix design stays the same; In the strength-increasing factor, molarity concentration is critical. The strength has increased around 10-20% compared to the 7 days testing.

P. Sangeetha et al (2011) reported that increase in the percentage of glass fiber by weight of concrete (0.1%, 0.2%& 0.3%) increases the compressive and impact strength. Compressive strength was found to improve by as much as 23%.

Eswari, et al. (2008) did an experimental investigation on the ductility performance of hybrid fibre reinforce concrete. The effect of fibre content on the ductility of hybrid fibre reinforced concrete specimens with various fibre volume fractions was studied. The hybrid fibre reinforced concrete examples show upgraded strength in flexure. The hybrid fibre reinforced concrete examples show an increase in comparison with plain concrete. At all load levels, the hybrid fibre reinforced concrete specimens show reduced crack width.

3. METHODOLOGY

3.1 Experimental Investigation

To foster the fibre-based geopolymer concrete, hence, a thorough experimentation process was utilized. The point of the review was to recognize the striking boundaries that upgrade the combination extents and the properties of low calcium fly ash-based geopolymer concrete.

Beyond what many would consider possible, the current practice utilized in the assembling and testing of Ordinary Portland Cement (OPC) concrete was followed. The aim of this action west ease the promotion of this 'new' material to the concrete construction industry.

To improve on the advancement cycle, the compressive strength was chosen as the benchmark boundary. This is normal on the grounds that compressive strength has inherent significance in the underlying model of substantial constructions (Neville 2000).

Generally, geopolymer composites can be made utilizing different source materials, the current review utilized just low-calcium (ASTM Class F) dry fly ash.

In addition, as with OPC, the aggregates accounted for 75-80% of the overall mass of the concrete.

3.2 Materials

3.2.1 Fly Ash

The finely split waste that arises from the combustion of ground or powdered coal and is conveyed by flue gases from the combustion zone to the particle treatment system is referred to as fly ash (ACI Committee 232 2004).

Fly Ash

3.2.2 GGBS (Ground Granulated Blast Furnace Slag)

The abbreviation GGBS stands for ground granulated blast furnace slag. It is acquired by extinguishing liquid iron slag from blast furnace slag in water or steam, dried and ground into a fine powder. Its utilization brings about a lower heat of hydration and lower temperature increases, further it decreases the gamble of harms brought about by alkali-silica reaction. Gives higher protection from chloride entrance lessening the gamble of reinforcement erosion and gives higher protection from attacks by Portland cement sulphate and different chemicals. The utilization of GGBS expands the existence of the structure by up to 50% had just been utilized and blocks the need for stainless reinforcement. It is additionally regularly used to restrict the temperature increase in enormous concrete pours, which forestalls the event of micro breaking.

USES OF GGBS

All of the technical advantages that GGBS provides to concrete are well known to specifiers, including:

1. Lower early age temperature rise, reducing the thermal cracking in large pours.
2. Better workability, allowing for easier placement and compaction.
3. Elimination of the risk of damaging internal reaction such as ASR.
4. Chloride ingress resistance is high, lowering the possibility of reinforcement corrosion.
5. Considerable sustainability benefits.

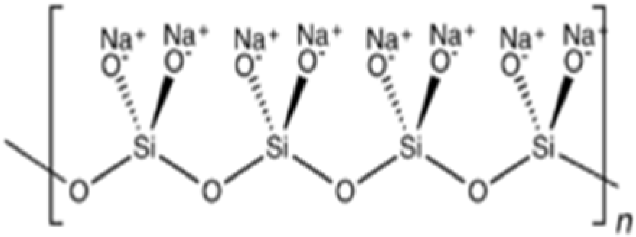
GGBS

3.2.3 Alkaline Liquid

A combination of sodium silicate solution and sodium hydroxide solution was chosen as the alkaline liquid. Potassium-based solutions were more likely to be utilised than sodium-based solutions since they were less expensive. The sodium hydroxide solids were pellets form (3 mm), with a specific gravity of 1.51, 98% purity.

3.2.4 Sodium silicate

Sodium silicates and sodium hydroxide are utilised in alkaline solutions. The pure type of sodium silicate solution is boring or white in shading. Sodium silicate responds with lime that is available in our concrete.



Sodium Silicate

3.2.5 Super Plasticizer

Super plasticizer that we use is water reducer it decrease the water cement ratio without effecting the workability of our fibre based Geo-polymer concrete. The super plasticizer we are using is SP-430.

High Range Water Reducer (HRWR) and retarding admixtures, Type F and Type G, are used to reduce the amount of water by 12 to 30% while maintaining a specific level of consistency and workability (typically from 75 mm to 200 mm) and to increase workability for reduction in w/c ratio. The utilization of super plasticizers might deliver high-strength concrete (compressive strength up to 22,000 psi). Super plasticizers can likewise be used in delivering flowing concrete utilized in a heavily reinforced structure with difficult to reach regions.

Super plasticizers are divided into four categories:

1. Suffocated naphthalene
2. Suffocated melamine
3. Modified Lignosulphonate
4. High doses of water reducing and accelerating admixtures are combined.

Super Plasticizer

3.2.6 Aggregates

1. Coarse Aggregate

Most coarse aggregate particles were of granite form. Coarse Aggregate is made up of machine crushed 12.5 mm angular granite metal from a local source. Overall, It should be free of impurities like dust , dirt, and organic matter, etc.

Coarse Aggregate

2. FINE AGGREGATE

The fine material utilised for preparation was river sand acquired from a local source. It should be free of silt, clay, organic pollutants, and other contaminants. In line with IS: 2386-1963, the sand is examined for various parameters such as specific gravity, bulk density, and so on. The particle size distribution or grading is similar to zone – II or IS: 383 – 1970. The fineness modulus of sand aggregate is 3.42. To avoid water absorption, surface dry sand was utilised in the geopolymer mix.

Fine Aggregate

3.2.7 GLASS FIBRE

Glass fibre is a material made up of several extremely tiny glass fibres. Russell Games Slater of Owens-Corning invented glass wool, which is now known as "fibreglass," as a material to be utilised as thermal building insulation in 1932–1933.

Glass Fiber

3.3 Mix Design Requirement

1. The following are the requirements that determine the selection and proportioning of mix ingredients:
2. The structural consideration's minimum compressive strength requirement.
3. With compacting machinery available, appropriate workability is required for thorough compaction.

4. GEOPOLYMER MORTAR

4.1 Material Preparation

To begin, gather the materials and weigh them to the required proportions, i.e. fly ash, sand, coarse aggregates, GGBS, NaOH and Na_2SiO_3 (sodium silicate) solution. As an alkaline activator, a mixture of sodium hydroxide and sodium silicate solution was used. Sodium hydroxide solution is ready by taking the predefined weight of sodium hydroxide pellets into a container and adding the necessary measure of water as indicated by its molarity. It is broadly accessible and is more affordable than potassium hydroxide solution. The alkaline activator was created in a lab environment. To avoid the presence of unknown impurities, the sodium hydroxide pellets were dissolved in distilled water.

4.2 Mixing

a. Hand mixing

1. Concrete is mixed in one of two ways, depending on the quality and quantity of concrete required. Mechanical mixers are typically utilised for mass concrete where high quality is required.
2. Mixing by hand is utilized uniquely to explicit situations where quality control isn't of much significance and the amount of cement required is less. The stone aggregate is cleaned to remove any dirt, dust, or other foreign material before being mixed.
3. The basic goal of mixing concrete is to achieve a homogenous mixture with consistent properties like colour and consistency.

Hand Mixing

4.3 Size of Test Specimen

Test specimens cubical size shall be 15x15x15cm. Cylindrical test specimens will have a length equivalent to two times the diameter. They will have a diameter of 15 cm and a height of 30 cm. Beam moulds will have the aspects 15x15x70 cm.

Cylinder Cube Beam

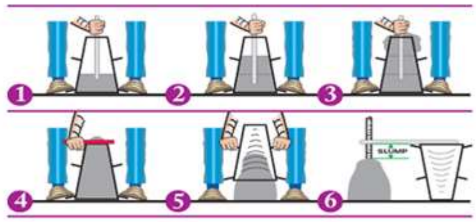
4.4 Testing

All of the specimens were removed after ambient curing and left to cure at room temperature. They were kept at room temperature until they were put to the test. The Compression Testing Machine was used to test the compressive strength of the Geopolymer mortar specimens for 3 and 7 days, and the Tensile Strength Machine was used to test the tensile strength. The specimens were subjected to a 1700 N/sec compressive force and tensile strength test until they failed. The three tests' average results were used to calculate the reported strengths.

4.4.1 Slump Cone Test

Slump Cone

The following is the shape of the concrete slump that can be identified during the slump test:



Workability of concrete

Degree of Workability	Slump (mm)
Low	25-75
Medium	50-100 75-100
High	100-150
Very high	150-200

4.4.2 Compression Strength Test

This single test can be used to determine whether or not concrete has been correctly prepared. Many factors influence the compressive strength of concrete, including the water-cement ratio, fly ash strength, concrete material quality, and quality control during the manufacturing process. For a large portion of the works cubical molds of size, 15 cm x 15cm x 15 cm are regularly used. This concrete has filled in the mould and been properly tempered to avoid voids. These moulds are removed after 24 hours, and test specimens are placed for ambient curing. These specimens' top surfaces should be level and smooth. This is finished by putting paste and spreading flawlessly the overall region of the specimen. After 3, 7, and 28 days of curing, these specimens are evaluated using a compression testing equipment. Specimens should be loaded gradually at a rate of 140 kg/cm^2 per minute until they fail. Concrete's compressive strength is calculated by dividing the load at failure by the specimen's area.

Compression strength test

4.4.3 Split Tensile Strength Test

Of these is tensile strength. It is impossible to apply correct axial load in a direct tensile strength test. The mould and base plate will be covered with a meager film of mould oil before use, to forestall the bond of the concrete, get ready three cylindrical concrete cylinders. the specimens can be tasted after following the procedure of moulding and ambient curing for the specified number of days, The cylindrical specimen is placed in the manner that the load applied on the specimen should be perpendicular to the longitudinal axis of the specimen. Within the range, the load should be applied gradually at a nominal rate of 1.2 N/mm^2 to 2.4 N/mm^2. Record the maximum applied load provided by the testing equipment at the time of failure.

Split tensile strength test

4.4.4 Flexural Strength Test

The test specimens were prepared after curing for the prescribed number of days in ambient conditions, i.e. (7 days, 14 days, and 28 days). The specimen will be positioned in the machine so that the load is applied to the uppermost surface as it was cast in the mould. The specimen's axis must be precisely aligned with the loading device's axis. The load was increased until the specimen failed, and the maximum applied load on the specimen was recorded during the test.

Flexural strength test

5. RESULTS AND DISCUSSION

5.1 General

The strength parameters of fiber-based geopolymer concrete are reviewed in this chapter. The compressive strength, flexural strength, and tensile strength of geopolymer concrete reinforced with fibres (crimped steel fibre and glass fibre) are studied.

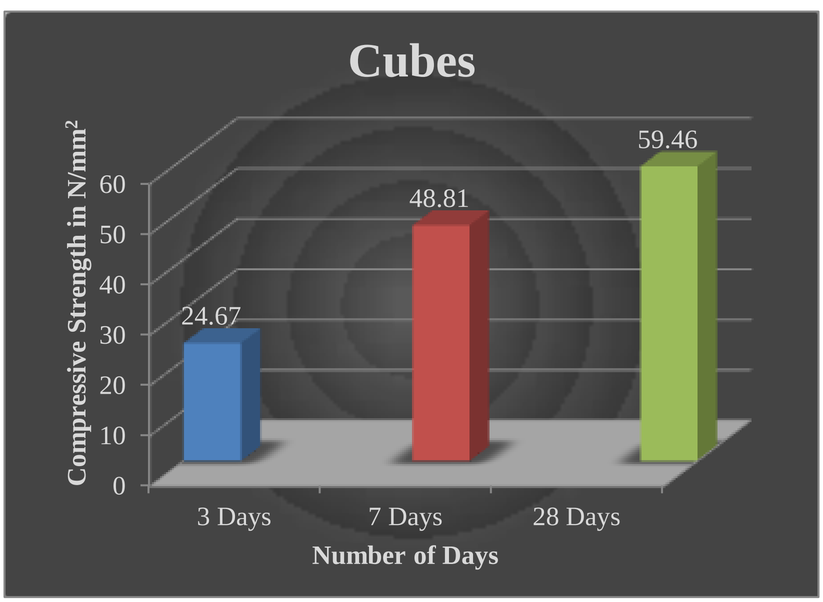
5.2 Concentration of alkaline solution, fly ash, GGBS, and fibers

Mix was prepared for M50 to study the impact of Molarity (or) concentration of Sodium Hydroxide solution, fly ash, GGBS, and fibres (for example crushed steel and glass fibres) on the compressive strength of geopolymer concrete. The concentration of NaOH of 8M was utilized. For M50 mix for the beams, the fly ash content was kept zero and GGBS was kept 100% further sand and Na2SiO3 proportions were kept steady.

5.3 Tests on M50 cubes, cylinders and prisms using steel fibers

Mix	3 days		7 days		28 days	
	Compressive strength (N/mm^2)	Average strength (N/mm^2)	Compressive strength (N/mm^2)	Average strength (N/mm^2)	Compressive strength (N/mm^2)	Average strength (N/mm^2)
Standard Mix	24.5 24.4 24.8	24.67	48.7 48.72 49.02	48.81	59.3 59.42 59.67	59.46

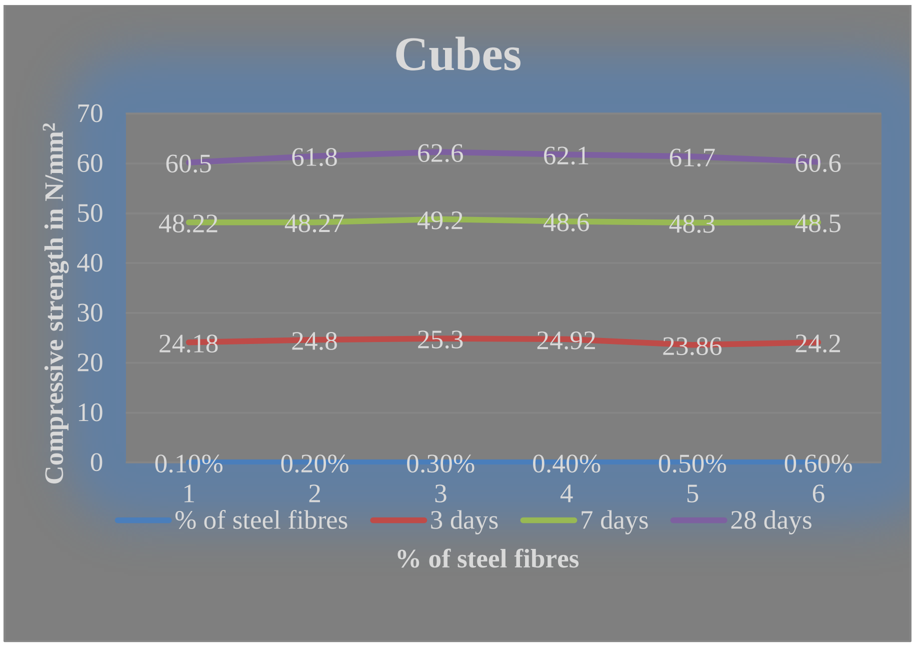
A. Compressive strength for standard mix (Cubes)



A. Compressive strength for standard mix (Cubes)

% of steel fibres	3 days	7 days	28 days
0.1%	24.18	48.22	60.5
0.2%	24.8	48.27	61.8
0.3%	25.3	49.2	62.6
0.4%	24.92	48.6	62.1
0.5%	23.86	48.3	61.7
0.6%	24.2	48.5	60.6

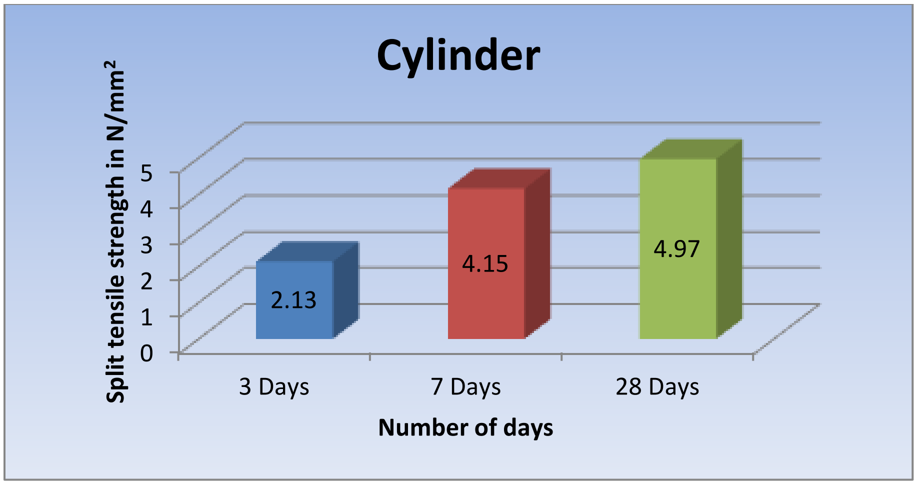
A1. Steel fibre compression strength of M50 cubes



A1. Steel fibre compression strength of M50 cubes

Mix	3 days		7 days		28 days	
	Tensile strength (N/mm^2)	Average strength (N/mm^2)	Tensile strength (N/mm^2)	Average strength (N/mm^2)	Tensile strength (N/mm^2)	Average strength (N/mm^2)
Standard Mix	2.02 2.04 2.32	2.13	4.15 4.12 4.17	4.15	4.96 4.98 4.97	4.97

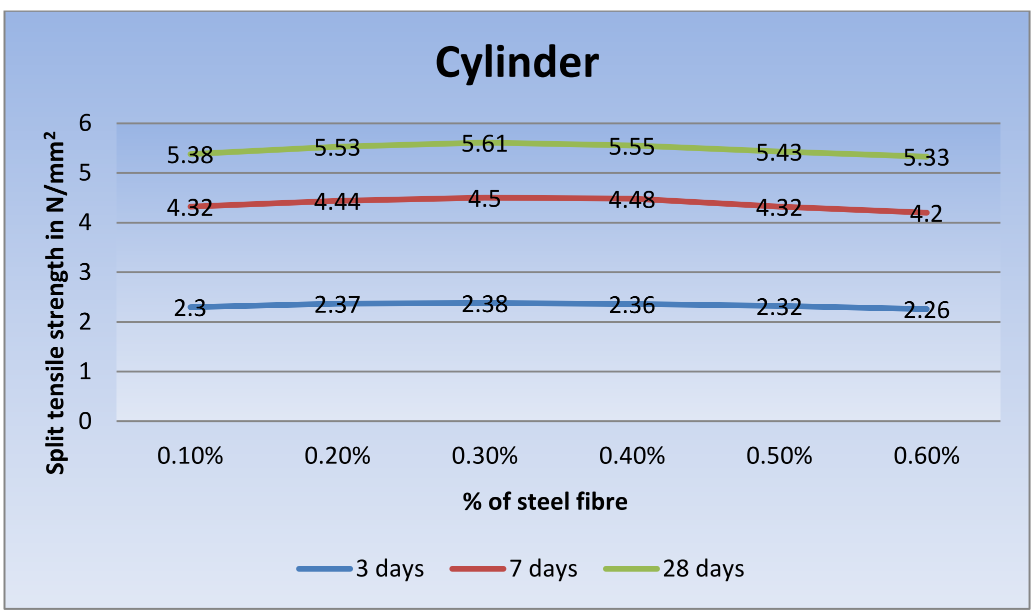
B. Split tensile strength of Standard Mix (Cylinder)



B. Split tensile strength of standard mix (Cylinders)

% of steel fibres	3 days	7 days	28 days
0.1%	2.3	4.32	5.38
0.2%	2.37	4.44	5.53
0.3%	2.38	4.5	5.61
0.4%	2.36	4.48	5.55
0.5%	2.32	4.32	5.43
0.6%	2.26	4.2	5.33

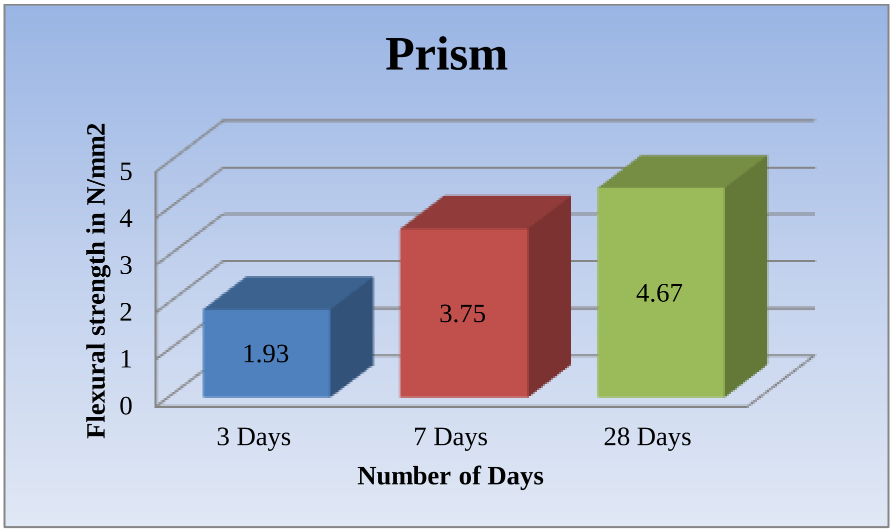
B1. Steel fibre split tensile strength of M50 cylinders



B1. Steel fibre split tensile strength of M50 cylinders

Mix	3 days		7 days		28 days	
	Flexural strength (N/mm^2)	Average strength (N/mm^2)	Flexural strength (N/mm^2)	Average strength (N/mm^2)	Flexural strength (N/mm^2)	Average strength (N/mm^2)
Standard Mix	1.92 1.93 1.93	1.93	3.77 3.80 3.78	3.75	4.64 4.68 4.70	4.67

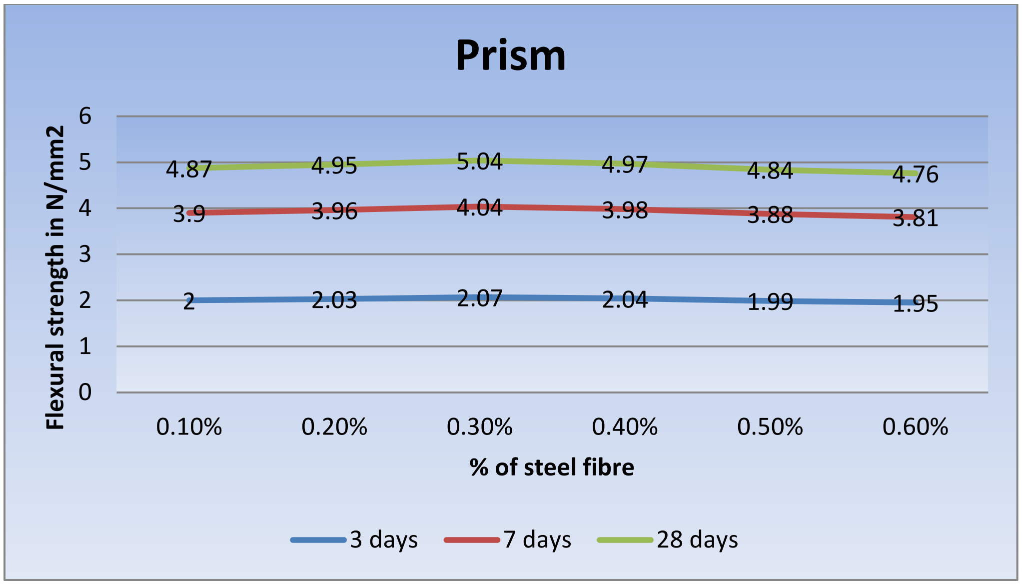
C. Flexural strength of Standard Mix (Prism)



C. Flexural strength of Standard Mix (Prism)

% of steel fibres	3 days	7 days	28 days
0.1%	2.0	3.9	4.87
0.2%	2.03	3.96	4.95
0.3%	2.07	4.04	5.04
0.4%	2.04	3.98	4.97
0.5%	1.99	3.88	4.84
0.6%	1.95	3.81	4.76

C1. Steel fibre Flexural strength of M50 Prism

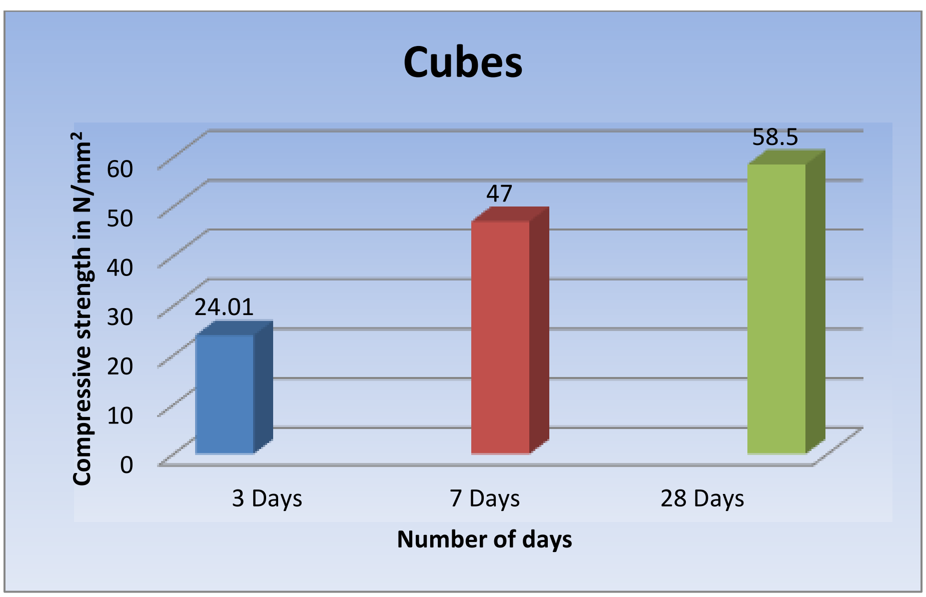


C1. Steel fibre Flexural strength of M50 Prism

5.4 Test on M50 cubes, cylinders, prisms using glass fiber

Mix	3 days		7 days		28 days	
	Compressive strength (N/mm^2)	Average strength (N/mm^2)	Compressive strength (N/mm^2)	Average strength (N/mm^2)	Compressive strength (N/mm^2)	Average strength (N/mm^2)
Standard Mix	24.32 24 23.7	24.01	47.7 46.9 46.4	47	59 58.1 58.4	58.5

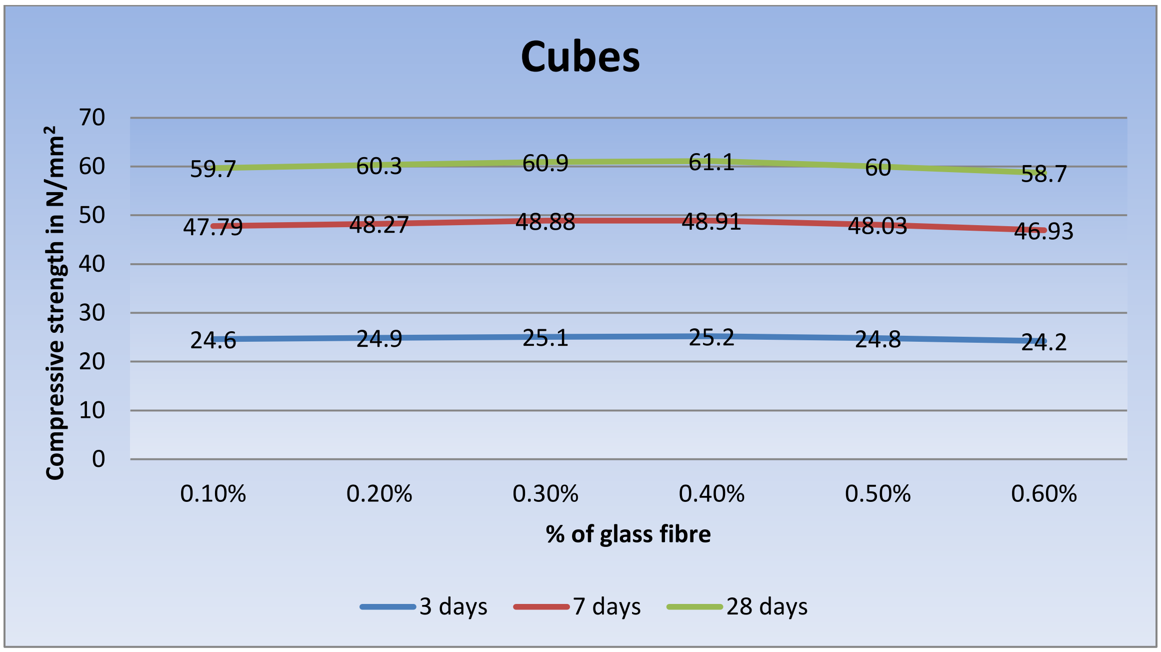
A. Compressive strength of standard mix (Cubes)



A. Compressive strength of standard mix (Cubes)

% of glass fibres	3 days	7 days	28 days
0.1%	24.6	47.79	59.7
0.2%	24.9	48.27	60.3
0.3%	25.1	48.88	60.9
0.4%	25.2	48.91	61.1
0.5%	24.8	48.03	60
0.6%	24.2	46.93	58.7

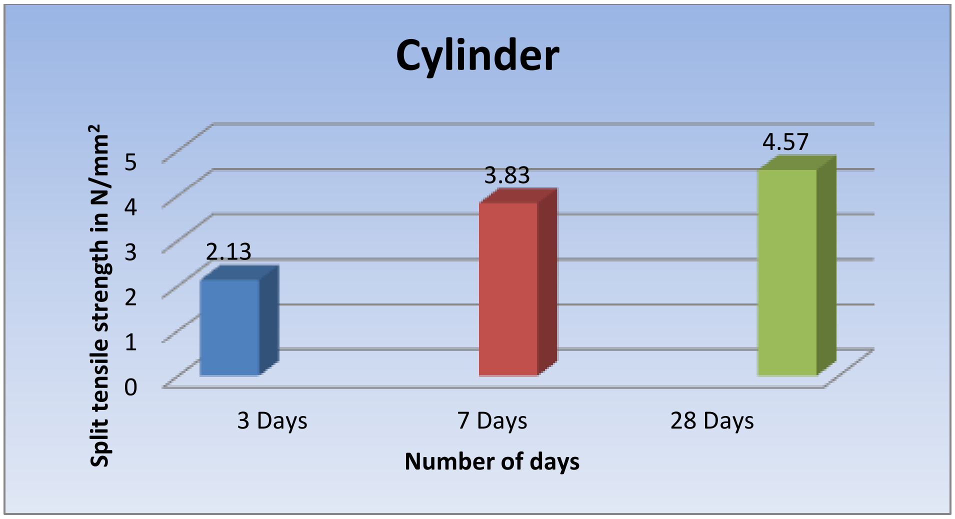
A1. Glass fibre Compressive strength of M50 cubes



A1. Glass fibre Compressive strength of M50 cubes

Mix	**3 days**		**7 days**		**28 days**	
	Tensile strength (N/mm^2)	Average strength (N/mm^2)	Tensile strength (N/mm^2)	Average strength (N/mm^2)	Tensile strength (N/mm^2)	Average strength (N/mm^2)
Standard Mix	2.16 2.12 2.1	2.13	3.94 3.91 3.65	3.83	4.78 4.58 4.36	4.57

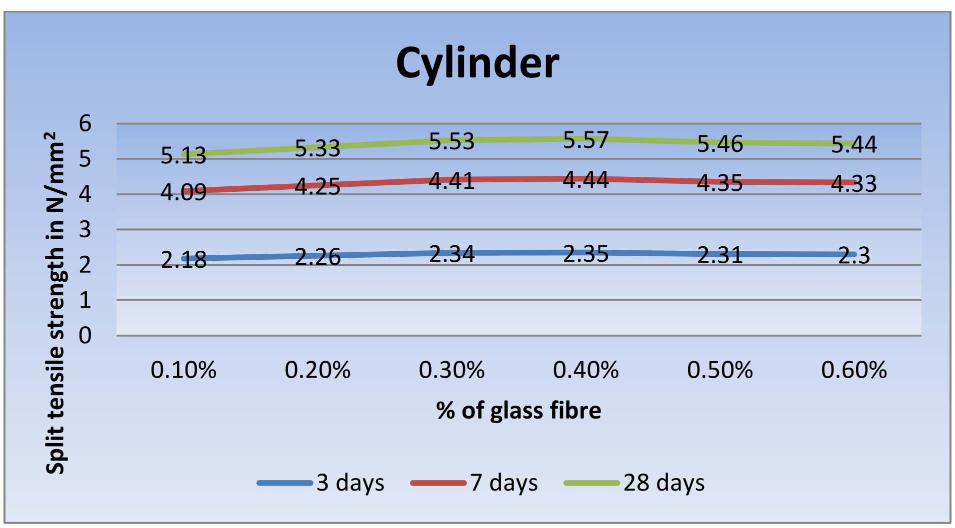
B. Split tensile strength of standard mix (Cylinder)



B. Split tensile strength of standard mix (Cylinder)

% of glass fibres	3 days	7 days	28 days
0.1%	2.18	4.09	5.13
0.2%	2.26	4.25	5.33
0.3%	2.34	4.41	5.53
0.4%	2.35	4.44	5.57
0.5%	2.31	4.35	5.46
0.6%	2.3	4.33	5.44

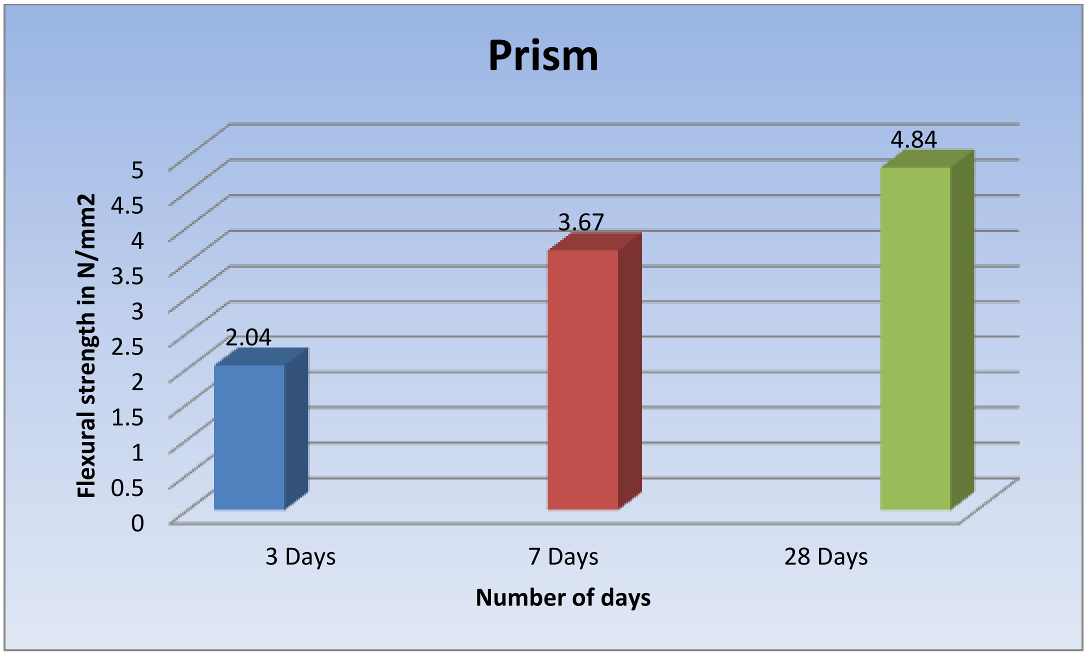
B1. Glass Fibre Split tensile strength of M50 cylinders



B1. Glass Fibre Split tensile strength of M50 cylinders

Mix	3 days		7 days		28 days	
	Flexural strength (N/mm^2)	Average strength (N/mm^2)	Flexural strength (N/mm^2)	Average strength (N/mm^2)	Flexural strength (N/mm^2)	Average strength (N/mm^2)
Standard Mix	2.13 2.05 1.93	2.04	3.86 3.7 3.46	3.67	4.74 4.54 4.24	4.84

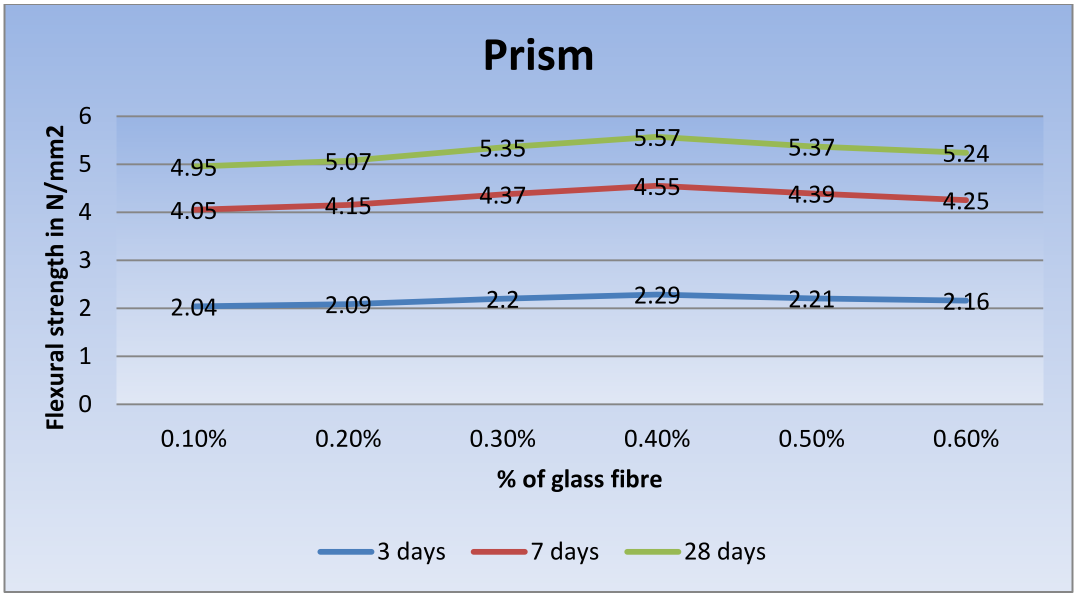
C. Flexural strength of standard mix (Prism)



C. Flexural strength of standard mix (Prism)

% of glass fibres	3 days	7 days	28 days
0.1%	2.04	4.05	4.95
0.2%	2.09	4.15	5.07
0.3%	2.2	4.37	5.35
0.4%	2.29	4.55	5.57
0.5%	2.21	4.39	5.37
0.6%	2.16	4.25	5.24

C1. Glass fibre Flexural strength of M50 prism

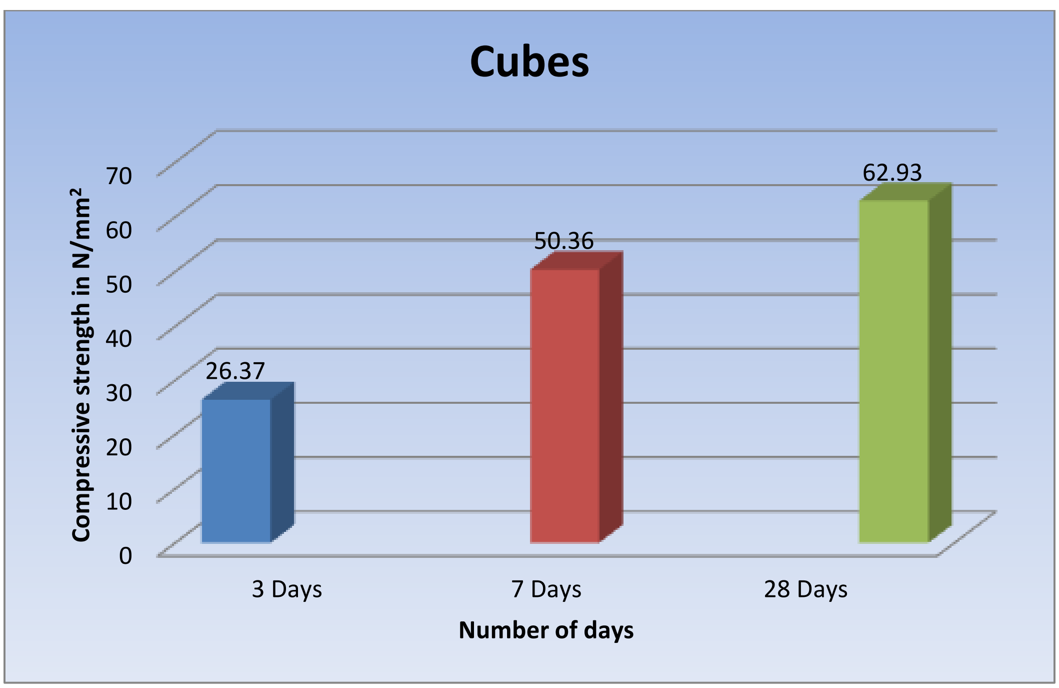


C1. Glass fibre Flexural strength of M50 prism

5.5 Test on M50 cubes, cylinders, prisms using combined steel & glass fiber

Combination of steel and glass fibres	3 days	7 days	28 days
Steel + glass fibres	26.37	50.36	62.93

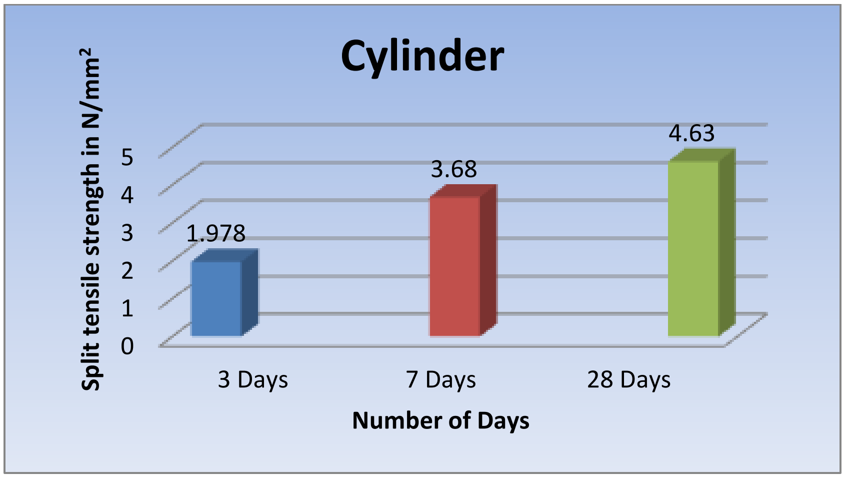
A. Maximum compressive strength obtained for cubes by combined use of fibre



A. Maximum compressive strength obtained for cubes by combined use of fibre

Combination of steel and glass fibres	3 days	7 days	28 days
Steel + glass fibres	1.978	3.68	4.63

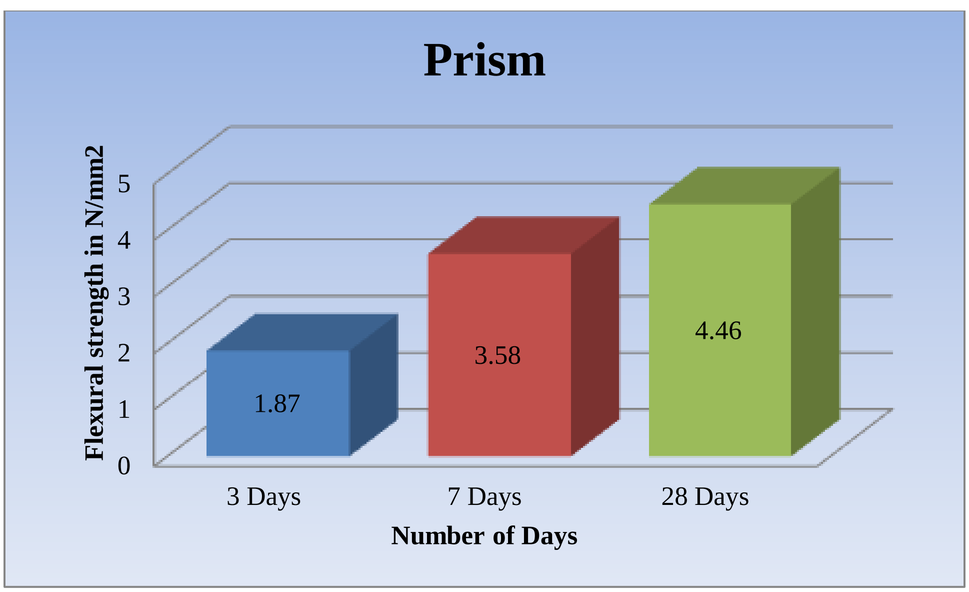
B. Maximum split tensile strength obtained for cylinders by combined use of fibre



B. Maximum split tensile strength obtained for cylinders by combined use of fibre

Combination of steel and glass fibres	3 days	7 days	28 days
Steel + glass fibres	1.87	3.58	4.46

C. Maximum flexural strength for prisms by combined use of fibre



C. Maximum flexural strength for prisms by combined use of fibre

6. CONCLUSIONS

In this project the discussed analysis and test results of geopolymer concrete with added ASTM fly ash, GGBS, SPF 430 plasticizers, alkaline solution and crimped steel and glass fibre were used to investigate the concrete's mechanical qualities. The fibre utilized in different proportions facilitates to identify the maximum strength achieved at different proportions.

Based on the experimental work for M50 grade geopolymer concrete using hybrid fibres reported in the study, the following conclusions are drawn:

1. Geopolymer concrete can be widely used in the manufacture of precast structures. It very well may be utilized in regions where quicker strength accomplishment is required. Fibre reinforced geopolymer concrete avoids the use of cement in concrete, hence reducing global warming and maximising the usage of fly ash.
2. In geopolymer concrete based on glass fibre, steel fibre, or a mix of fibres, a higher sodium hydroxide solution concentration leads in higher compressive strength.
3. The compressive strength due to ambient curing for combination of fibres based geopolymer concrete does not depend on time period.
4. The additions of super plasticizers are taken in different ratios, 2% of super plasticizers get the best results for compressive strength.
5. Super plasticizer % is taken in a limit if it exceeds the limit, then automatically the compressive strength decreases.
6. Compressive strength and setting time are both improved by increasing the GGBS component in the mix. (i.e., by adding GGBS in more quantity sets fast than normal geopolymer concrete without GGBS).

7. FUTURE SCOPE OF THE STUDY

The scope of this study is focused on the properties of geopolymer concrete with crimped steel and glass fibre as hybrid fibres. Six volume percentages of crimped steel and glass fibre are utilized to investigate the influence properties of concrete. The study's scope and limitations are as follows:

1. The cement for the M50 grade concrete mix can be supplemented by fly ash and GGBS in various proportions for higher strength achievement.
2. Various types of fibres may be used to evaluate parameters of strength in various proportions.
3. The measurements of the crushed aggregate used are 10 mm or 12 mm.
4. Testing and analyzing concrete predominantly on compressive strength, tensile strength fracturing and concrete specimen flexural strength.

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