JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

"ENHANCING CONCRETE PERFORMANCE INCORPORATING STEEL AND GLASS FIBERS WITH FLYASH REPLACEMENT AND ASSESSING ECONOMIC VIABILITY"

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Abstract : This project aimed to investigate the performance of steel and glass fibers in structural applications of fiber-reinforced concrete (FRC). The focus was on evaluating the effect of fiber type and content on the compressive strength and economic aspects of the FRC mix. FRC specimens were prepared with steel and glass fibers at specific dosages and aspect ratios. Compressive tests were conducted to assess the strength properties of the FRC, and the results were compared to those of plain M30 concrete and steel/glass fiber reinforced concrete.
A total of 36 cubes were cast, with 12 cubes for each type of concrete. The cubes underwent 7-day,14-Day, and 28-day curing, and the test results were analyzed. The findings revealed that the addition of fibers significantly enhanced the mechanical properties of the concrete. Steel fibers had the most significant impact on compressive strength, while glass fibers positively influenced both compressive strength and crack resistance. Additionally, the use of FRC resulted in reduced crack width and increased energy absorption capacity.
Overall, this project demonstrates the potential of FRC as a viable material for structural applications, especially in areas subjected to high loads and dynamic stresses. The findings contribute valuable insights for optimizing the design and utilization ofFRC in various engineering applications.

Keywords - Fiber reinforced concrete (FRC), steel fibers, glass fibers, compressive strength test.

1) INTRODUCTION

Concrete is known to exhibit weakness in tension, leading to the development of cracks during the hardening and drying stages.The presence of these cracks on the concrete surface not only detracts from its appearance but also serves as a pathway for waterand salt infiltration, increasing the risk of corrosion for reinforcing bars. Addressing this weakness would not only reduce maintenance costs for concrete structures but also extend their useful lifespan.
In recent times, fibers have emerged as competitive options for enhancing the mechanical properties of concrete. The inclusion of fibers uniformly distributed in all directions within the concrete matrix increases its resistance to plastic shrinkage. Importantly, this uniform dispersion of fibers helps prevent the initiation of small cracks and inhibits the formation of larger cracks.
Steel fibers reinforced concrete (SFRC) is an advanced composite material that combines plain concrete with steel fibers of varying lengths and diameters. SFRC significantly enhances the performance of concrete, particularly after cracking occurs under stress.

GFRC is highly moldable, allowing for intricate and complex shapes to be easily created. This makes it a popular choice for architectural applications where design flexibility is desired. FRC has excellent impact resistance and energy absorption properties. The incorporation of glass fibers helps to distribute and dissipate energy upon impact, reducing the risk of fracture or spalling.

2) OBJECTIVE

The aim of the work is to
1. To study the performance of concrete with the use of Steel & Glass Fiber.
2. To study the economic aspects after the addition of GFRC & SFRC.
3. To compare the compressive strength between GFRC, SFRC, and M30 Concrete.

4. To study the effect of GFRC & SFRC in correlation with crack resistance

3) MATERIALS AND EQUIPMENTS:

Materials:

Sr. No.	Materials	Source	Specifications	Properties			
				SpecificGravity	**Water Absorption**	**Size**	**Shape**
1	**Cement (OPC Ultratech)**	-	53 grade	3.15	-	-	-
2	**Fly Ash**	-	Pulverised Fly ash	2.25	-	-	-
3	**Crushed Sand**	Talegaon	-	2.72	3.23	-	-
4	**Coarse Aggregate 10mm**	Talegaon	-	2.92	1.08	10mm	Angular
5	**Coarse Aggregate 20mm**	Talegaon	-	2.92	0.84	20mm	Angular
6	**Naphtha Admixture**	-	BASF	1.2	-	-	-
7	**Steel Fiber**	-	Hooked End,Crimped	-	-	Length = 50 mm, Dia= 1mm	
8	**Glass fiber**	-	-	-	-	Length = 50 mm, Dia= 1mm	

9. Water:
Water should be free from acids, oils, alkalies, vegetable matter, or other organic impurities. Water used in the project was borewell water which was purified by the purifier present in the plant to reduce the hardness of water and then used for production

fig no.1
opc ultratech (53 grade)

fig no. 2
fly ash

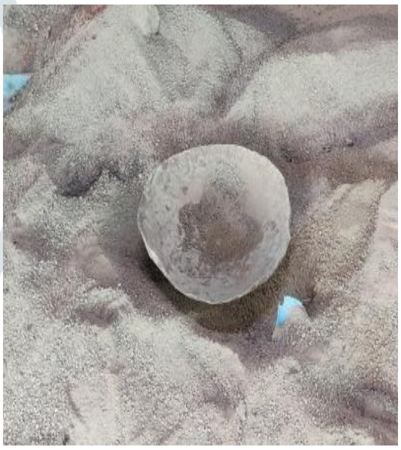


fig no. 3
crushed sand

fig no.3
Coarse Aggregate 10mm

fig no.4
Coarse Aggregate 20mm

fig no.5
Naphtha Admixture

fig no.6
steel fiber

fig no.7
glass fibers

EQUIPMENTS:

For testing of materials and cubes, different types of equipment used are as follows:
Sieves: standard IS sieves are used of different sizes as follows:
For coarse aggregate: 25 mm, 20mm,16mm,12.5 mm, 10 mm 4.75 mm, pan.
For fine aggregate: 4.75mm, 2.36mm, 1.18mm, 0.600mm, 0.300mm, 0.150mm, pan, etcFor cement: 90 microns
For fly ash: 45 microns
Pycnometer: To find the specific gravity of aggregates
Impact testing Machine: Manually operated machine with a hammer weighing 14kgs to find the impact value of aggregateFlakiness gauge: Metal Gauge as per mentioned in IS:2386(Part 1)-1963 Clause 4.2.b.
Elongation gauge: Metal Gauge as per mentioned in IS:2386(Part 1)-1963 clause 5.2.b.Hydrometer: To find the specific density of the liquid(admixture).
Mixer: Pan mixer with a capacity of 150kgs which is electrically operated.

Moulds: Standard metal moulds of 150mm x 150mm x 150mm.
CTM: Compression Testing Machine of capacity tons with servo motor controlled and automatic graph generation system. Oven: Hot air oven manufactured by EIE Instruments Pvt. ltd.
Balance:

1) Digital weighing machine by PESCO Max weight 10kgs, minimum 10gms accuracy up to 0.1.
2) Weigh balance by PESCO Max weight 100kgs, accuracy up to 0.001.

fig no. 8 sieve apparatus

fig no. 9 pycnometer

fig no. 10 thickness guage & elongation guage

fig no.11 hydrometer

fig no. 12 pan mixer

fig no. 13 moulds

fig no. 14 compression testing machine

fig no. 15 oven

fig no. 16 weigh balance

4) METHODOLOGY:

The methodology for fiber-reinforced concrete (FRC) typically involves the following steps:

1. Material selection: The first step in the process is to select the appropriate materials for the mix. This includes cement (OPC 53), coarse aggregates (10mm & 20mm), fine aggregate, fibers (steel & glass), and chemical admixture (naphtha).

2. Testing of material: All the materials required are tested according to IS code recommendations for the proper mixdesign.

3. Mix design: After selecting materials, the mix design is established. Based on the testings of raw material & determiningthe correct proportions of each material to achieve the mean target strength, workability, and other properties of the concrete. We adopted the M30 mix design.

4. Mixing: The materials were then mixed together using a concrete mixer, ensuring that the fibers are evenly distributed throughout the mix.

5. Placing and finishing: The cubes were cast manually by each individual & Care was taken to ensure that the fibers wereevenly distributed throughout the concrete during the casting process.

6. Curing: After 24 hours of the casting process, the FRC was allowed to cure properly in the curing tank. This involveskeeping the concrete moist and at the appropriate temperature to allow it to harden and develop its full strength.

7. Testing: Finally, the cubes were tested under CTM and the results were analyzed. It includes testing for compressivestrength. Throughout the process, we have followed IS code standards and best practices to ensure that the FRC is of high quality andperforms as intended.

5) EXPERIMENTAL WORK:Compressive strength test

The quantities of materials for the mix were determined through careful calculations. Initially, standard M30 concrete cubes were cast, followed by the gradual addition of steel and glass fibers. The mix was prepared using a pan mixer and poured into cubic molds, ensuring adherence to the procedures outlined in the relevant IS codes. In total, 36 cubes were cast manually according to the established protocol. All cubes were left undisturbed for 24 hours for proper finishing and underwent appropriate curing for a duration of 28 days to ensure proper development of their strength. In the testing phase, the cubes were individually tested at different curing periods: 7, 14, and 28 days. The testing involved subjecting each cube from the normal M30 mix, as well as the steel and glass fiber- reinforced categories, to compressive testing using a compression testing machine. The following are the observations obtained from the tests.

Target mean strength	**Compressive strength (in N/mm2)**		
38.25 N/mm2	**7 days**	**14 days**	**28 days**
Normal M30 grade	25.22	32.44	41.28
M30 Steel Fiber grade	28.25	38.33	49.27
M30 glass Fiber grade	41	48.51	54.36

fig no. 17 process of testing under CTM

Economic viability

Concrete is a widely utilized material in the construction industry due to its crucial role in providing strength to structures. Its impact on the economy of any construction project is significant. In this study, we compared the economic aspects of M30 concrete with the addition of glass and steel fiber.

Based on our observations, the cost of producing one kilogram of normal M30 grade concrete amounted to 8.6 Rs. This concrete mixture resulted in a strength that exceeded the target mean strength by 7.92%.
Alternatively, the cost of producing one kilogram of SFRC (Steel Fiber Reinforced Concrete) was 9.35 Rs, providing a strength that exceeded the target mean strength by 23.28%.
Similarly, the cost of producing one kilogram of GFRC (Glass Fiber Reinforced Concrete) was 8.86 Rs, resulting in a strengththat surpassed the target mean strength by 42.11%.
This study indicates that by reducing the cement content in the concrete mix, we can enhance its economic viability. The achievedstrengths were higher than the target mean strength, which not only contributes to cost savings but also helps conserve raw materials.

Crack resistance

Glass fibers: The inclusion of glass fibers in FRC enhances its crack resistance. Glass fibers act as a reinforcement component in the concrete matrix. They distribute tensile stresses and help to control crack propagation. When cracks start to develop in the concrete, the glass fibers provide additional strength and prevent the cracks from growing or spreading further. This results in improved crack resistance and durability of the FRC. Glass fibers also contribute to reducing crack widths and increasing the energy absorption capacity of the concrete.

Steel fibers: Steel fibers are known for their excellent tensile strength and ductility. In FRC, steel fibers provide reinforcement within the concrete matrix. When cracks form, the steel fibers bridge the cracks and transfer the stresses across the cracked sections. This bridging effect helps to distribute the applied loads and prevent crack propagation. Steel fibers effectively enhance the post-cracking behavior of the concrete, increasing its toughness and ductility

6) RESULT: Compressive strength:

In the comparison for compressive strength of our three mixes i.e. M30 concrete, SFRC & GFRC after the observation, we founda noticeable increase in the strength of the concrete mix.
Which is as follows:

Target mean strength	**Compressive strength (in N/mm²)**		
38.25 N/mm²	**7 days**	**14 days**	**28 days**
Normal M30 grade	25.22	32.44	41.28
M30 Steel Fiber grade	28.25	38.33	49.27
M30 glass Fiber grade	41	48.51	54.36

From the above table, we can notice the difference between the strength of all three concrete types for 7 days, 14 days, & 28 days.The mix was designed for a target mean strength of 38.25 N/mm² Where for 28 days the casted concrete of Normal M30 mix had 7.92% more gain than the target mean strength. And SFRC for 28 days strength showed 23.28%more strength than the target mean strength.
The GFRC showed a maximum gain in the strength of concrete i.e. 42.11% than the target mean strength.

Economic viability:

For any project, it is important to make it as economical as the main reduction that can be made in reducing cement content in concrete, but the strength of concrete should not be affected in a manner that is quite difficult to attain. To check the effect of steeland glass fiber on the economy of the mix we made an approx estimate of raw materials required for making the mix, the amount calculated is displayed in the table below:

Grade	**Rs per kg**
Normal M30	8.6
M30 with Steel fibers	9.35
M30 with Glass fibers	8.86

The amount displayed in the above table is for producing 1 kg of concrete of each type, for Normal M30 concrete we found out 8.6Rs is required for 1 kg. For SFRC 9.35Rs is required for 1 kg of production. And for GFRC it takes 8.86Rs for producing 1 kg of concrete mix

Crack resistance:

One of the major problems that arise in concrete is cracking but in our experiment, we studied that the addition of steel fibers held the cracks in the concrete and did not let it spread any further, whereas in the case of Glass fiber, the cracks did not occur easily and after the development of cracks the fibers held them in such manner that it increased the compression capacity of the concrete.In summary, both glass fibers and steel fibers contribute significantly to the crack resistance of fiber-reinforced concrete. Glass fibers help control crack propagation and reduce crack widths, while steel fibers provide bridging effects and enhance the post- cracking behavior of the concrete, improving its toughness and durability.

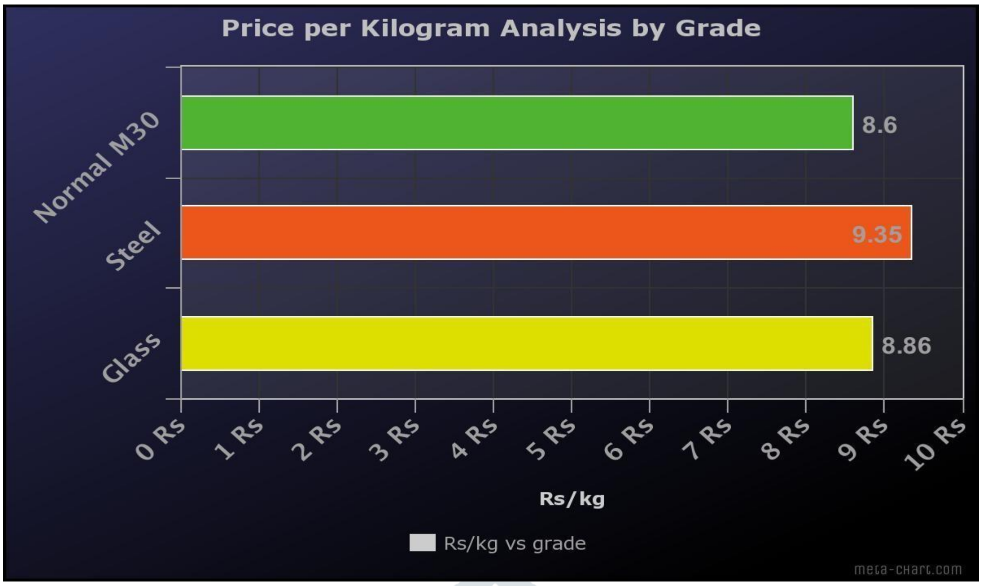
7) CONCLUSION:

The following table represents the % gain in compressive strength of concrete after 7 DAYS, 14 DAYS, & 28 DAYS

	Target mean strength (38.25 (N/mm²)	**7 days (%)**	**14 days (%)**	**28 days (%)**	**Conclusion (after 28 days)**	**Remark**
Normal M30 grade	100%	65.935	84.810	107.922	7.92% gain than target mean strength	Thus we can reduce cement content
Incorporation of steelfibers (% increase in strength)	100%	73.856	100.209	123.582	23.28% gain than targetmean strength	
Incorporation of glass fibers (% increase in strength)	100%	107.190	126.824	142.118	42.11% gain than targetmean strength	

The above table is represented in graphical manner representing DAYS VS % GAIN:

Based on the calculations and graph obtained from the experiment, it can be concluded that the addition of glass fibers to the normal M30 concrete mix resulted in the highest compressive strength. The compressive strength of glass fiber reinforced concrete was found to be 42.11% higher than the target mean strength. This indicates that glass fibers significantly enhance the strength of the concrete.



Furthermore, the use of glass fibers in reinforced concrete proves to be more economical compared to steel fiber reinforced concrete and normal M30 grade concrete. The exceptional increase in strength provided by glass fibers allows for a reduction in the cement content of the mix, leading to cost savings in production.

In terms of crack resistance, glass fibers outperformed steel fibers. Glass fiber reinforced concrete exhibited cracking at a higher stress level of 50.29N/mm2, whereas steel fiber reinforced concrete showed cracks at 42.27 N/mm2. This demonstrates the superior crack resistance properties of glass fibers.

In summary, the addition of glass fibers to the concrete mix not only significantly increases the compressive strength but also offers economic advantages by reducing production costs through cement content optimization. Moreover, glass fibers provide enhanced crack resistance compared to steel fibers.

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