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Experimental study on glass fibre reinforced concrete

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Abstract: This study investigated the enhancement of peach shell lightweight concrete through glass and nylon fiber reinforcement at varying percentages (2%, 4%, 6%, and 8% by cement weight). The fiber addition resulted in a 6.6% reduction in density while significantly improving mechanical properties, with compressive strength increasing by 10.20%, split tensile strength by 60.1%, and flexural strength by 63.49%. Optimal compressive strength was achieved at 6% fiber content, while maximum split tensile and flexural strengths occurred at 8% fiber addition. Research on concrete curing methods demonstrates that steam curing at temperatures between 45°C and 80°C within 24-hour cycles produces superior concrete properties compared to normal curing, particularly for achieving high early strength in precast applications using PC42.5 cement. However, temperatures exceeding 80°C negatively impact performance. The combination of agricultural waste utilization through peach shells and synthetic fiber reinforcement, coupled with optimized curing regimes, presents a promising approach for developing lightweight concrete with enhanced mechanical characteristics suitable for diverse construction applications while promoting sustainable materials usage.

Keywords: glass fibre reinforced concrete, steam curing and normal curing.

I. INTRODUCTION

Concrete is one of the most widely used construction materials worldwide due to its excellent compressive strength and versatility. However, it is inherently weak in tension and tends to be brittle, which can limit its performance under certain conditions. To overcome these deficiencies, researchers and engineers have explored various reinforcement strategies. Among these, fiber reinforcement has gained considerable attention for its potential to significantly improve the mechanical and durability properties of concrete.

Fiber reinforced concrete (FRC) is a composite material in which small, discrete fibers are uniformly dispersed throughout the concrete matrix. The inclusion of these fibers enhances the material's toughness, controls crack propagation, and significantly improves its behavior after cracking. Fibers act by bridging micro-cracks and redistributing stresses, thereby contributing to a more ductile and resilient concrete structure.

The overall performance of FRC is influenced by several factors such as the **type of fiber, its geometry, aspect ratio, a**nd most notably, the **volume fraction** of fibers used. Numerous studies have shown that increasing the fiber content generally improves mechanical performance. However, higher dosages can negatively affect workability, lead to fiber clumping, and increase material costs.

A **1.5% fiber content by volume** is often considered an optimal balance between improved mechanical properties and practical feasibility. This dosage is widely studied in literature and is known to enhance concrete's toughness and resistance to cracking without significantly impairing workability or increasing production costs.

Various fiber types are used in FRC, each offering unique benefits and trade-offs. These include **steel fibers, synthetic fibers** (such as polypropylene, polyethylene, and nylon), **natural fibers,** and **glass fibers.** The selection of fiber depends on factors like desired mechanical performance, durability, cost-effectiveness, and compatibility with the cement matrix. Choosing the appropriate fiber type is essential to ensure the composite performs as required for specific structural or non-structural applications.

Studying the behavior of concrete reinforced with 1.5% fiber content is crucial for the development of design standards and optimization methods. At this dosage, fibers significantly impact various properties, including **compressive strength, flexural and tensile strength**, as well as **fracture behavior**.

Understanding these changes helps engineers design more reliable and durable structures. This experimental study aims to rigorously investigate the mechanical and durability performance of concrete reinforced with 1.5% fiber content. Through systematic testing, the study will analyze key material properties and behavior under different loading conditions. The goal is to provide detailed insights into the effectiveness of this fiber dosage.

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The importance of this research lies in its potential to offer **benchmark data** for 1.5% fiber reinforced concrete. These benchmarks can serve as reference points for comparing different fiber types or dosages, and help inform the development of predictive models and practical design guidelines. Ultimately, the findings aim to support engineers and researchers in making informed decisions when working with fiber reinforced concrete in real-world construction projects.

II. LITERATURE REVIEW

1. **Ajay God, JyotiNarwal, VivekVerma, Devender Sharma and Bhupinder Singh,** Curing significantly affects the strength, durability, and performance of concrete by promoting continued hydration. Studies show **water curing** to be the most effective, while **air curing** often results in lower strength due to moisture loss. **Membrane curing** offers convenience but varies in effectiveness depending on application and environment. **Steam curing** accelerates early strength but may impact long-term durability. Comparative research highlights that prolonged and proper curing improves properties, especially with supplementary cementitious materials. Emerging methods like internal curing using lightweight aggregates or polymers are gaining interest. Overall, selecting an appropriate curing method is critical for achieving optimal concrete performance.
2. **James, O,Ndoke, P.N., and.Kolo S.S** "Effect of different curing methods on the compressive strength of concrete" The investigation of different curing methods on concrete compressive strength represents a fundamental area of concrete technology research. This type of study addresses the critical relationship between curing techniques and concrete performance, providing practical guidance for construction applications.
3. **Renni, Angela Roughan & O'Donovan** The advancement of concrete technology has brought forward innovative fiber-reinforced systems, eventually leading to the emergence of Ultra-High-Performance Fiber-Reinforced Concrete (UHPFRC). These materials mark a significant shift from conventional concrete, as they deliver superior mechanical strength, exceptional durability, and improved structural efficiency. The integration of fibers not only enhances toughness and crack resistance but also extends the service life of structures, positioning UHPFRC as a next-generation material in modern construction.
4. **S. Tqrkela and V. Alabasb**, "The effect of excessive steam curing on Portland composite," Cement and Concrete Research. The investigation of excessive steam curing effects on Portland composite cement addresses critical concerns in precast concrete manufacturing where accelerated curing processes are routinely employed to achieve rapid strength development and improve production efficiency.
5. **E. C. Higginson**, "Effect of steam curing on the important properties of concrete," Research findings indicate that both fiber reinforcement and optimized curing methods are well-established technologies that continue to evolve with promising potential. When these two approaches are integrated, they present opportunities for developing advanced concrete systems capable of meeting the dual demands of rapid production efficiency and long-term durability**.** Such systems not only enhance structural performance but also contribute to more resilient and sustainable construction practices, marking a step forward in modern concrete technology.

III. OBJECTIVES

- To evaluate the mechanical performance of M30grade concrete when reinforced with glass fibre.
- To measure and compare the displacement and deformation behavior of normal and fiber-reinforced concrete under axial loading.
- To reduce crack propagation and improve the crack resistance of M30 concrete.
- To compare the performance characteristics of steam-cured concrete versus normal water-cured concrete in terms of strength development and durability.

IV. MATERIAL AND METHODOLOGY

4.1Cement: Cement is a finely ground material used as a key binder in construction, especially in concrete and mortar. It functions as the adhesive agent that holds together the sand, gravel, or crushed stone in these mixtures. When water is added to cement, a chemical process known as hydration begins. During hydration, compounds in the cement react with water to produce calcium silicate hydrate (C-S-H) gel, which is responsible for the hardening and strength development. This gel forms the internal structure that binds the components together. Typically, concrete achieves around 70% of its final strength within the first 7 days and reaches its full design strength after approximately 28 days.
4.2 Water: Water plays a vital role in construction, yet it often receives less focus compared to materials like cement, steel, or aggregates. The quality, quantity, and method of its use have a direct impact on the strength, durability, and overall performance of concrete and mortar structures.

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- **Mixing of Concrete and Mortar:** Water initiates the hydration of cement and imparts the necessary workability to the mix, making placement and compaction possible.
- **Curing of Concrete:** Adequate water supply during curing ensures complete hydration of cement, minimizes shrinkage cracking, and helps the concrete achieve its desired strength and durability.

4.3Fine aggregate: Fine aggregate includes granular materials such as natural sand or finely crushed stone that pass through a 4.75 mm sieve. It is an essential ingredient in both concrete and mortar, typically making up about 25–30% of the overall concrete volume. Fine aggregate fills the voids between coarse particles, improves workability, and contributes to the strength and finish of the final mix.

Key Properties

Gradation: A well-graded fine aggregate consists of a mix of different particle sizes, which helps achieve maximum packing density and reduces voids.

- **Fineness Modulus:** The fineness modulus of fine aggregates generally falls between 2.3 and 3.1, reflecting the overall average particle size.
- **Shape and Texture**: Aggregates with angular shapes and rough textures develop stronger interlocking and better bonding with cement paste compared to smooth, rounded particles.

FIG NO. 1 FINE AGGREGATE

4.4 Coarseaggregate: Coarse aggregate consists of granular materials like crushed stone, gravel, or broken brick that are retained on a 4.75 mm sieve. It plays a crucial role in concrete by forming its structural core and typically makes up 60–75% of the total

Common Aggregate Sizes and Their Uses:

- Up to 20 mm: Most widely used in standard construction projects.
- 40 mm: Suitable for large-scale applications such as foundations, dams, and mass concrete.
- 10 mm: Preferred for thinner sections and in the production of precast elements.

FIG NO.2 COARSEAGGREGATE

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4.5Glass fibre: Glass fiber is produced from very fine strands of glass, usually ranging between 5 and 25 micrometers in diameter. When incorporated into concrete, these fibers act as reinforcement, improving tensile strength, minimizing cracking, and enhancing the long-term durability of the composite.

Forms and Dimension

- **Chopped Strands:** Short fibers cut to lengths between 6 mm and 50 mm, commonly used for reinforcing concrete**.**
- **Continuous Rovings**: Long, unbroken strands of glass fiber applied in specialized reinforcement techniques.
- **Fiber Diameter:** Generally, ranges from 10 to 20 micrometers**.**
- **Aspect Ratio:** The ratio of length to diameter typically falls between 150 and 1000, influencing fiber performance in composites.

FIG NO.3 GLASS FIBRE

4.6 Different Type of Curing:

4.6.1 STEAM CURING:

Steam curing is a method of accelerated concrete curing in which heat and moisture are applied under controlled conditions to hasten cement hydration. Rather than waiting several weeks for concrete to develop its required strength naturally, this technique allows substantial strength to be achieved within a much shorter period—often in just hours or days. The process typically involves subjecting fresh concrete to steam at temperatures ranging from 45°C to 80°C with relative humidity levels above 90%. The combination of elevated temperature and high moisture content speeds up the chemical interaction between cement and water, leading to quicker setting and hardening.

PROCEDURE:

- First, the concrete prism will be cast and kept for 1 day for initial setting.
- The prism will be kept with its mold and placed into a hot water tank.
- The sample will be steam cured for 3.5 hours at a temperature of 100 degrees Celsius.
- The sample will be removed and normally cured for 2 hours

4.6.2 NORMAL CURING

Normal curing, also known as standard or ambient curing, is the traditional method of allowing concrete to harden and gain strength under natural environmental conditions without external heat application. Concrete is kept moist and at ambient temperature (typically 20-25°C) to allow the cement hydration process to occur naturally. The chemical reaction between cement and water proceeds at its natural pace, gradually developing strength over time.

Standard Process:

- Concrete is placed and finished
- Surface is kept continuously moist through water spraying, wet coverings, or curing compounds
- Temperature remains at ambient levels
- Duration typically extends 14 days for full strength development.

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FIG NO.4 STEAM CURING TANK WITH PRISM

FIG NO.5 NORMAL CURING TANK WITH PRISM

V. TEST RESULTS

5.1Test on coarse aggregate:

TABLE NO.1 Results of coarse aggregate Material Tests

Test Description	Results	Standard value
Specific gravity of course aggregate	2.9	2.5 And 3.0.
Sieve analysis	20mm	>4.75mm-80mm
Water absorption	1%	<2%

The coarse aggregate used in the mix has a specific gravity of 2.9, which falls within the standard range of 2.5 to 3.0, a water absorption of 1% which is less than the permissible limit of 2%, and the sieve analysis confirms that the 20 mm aggregate passes the 80 mm sieve and is retained on the 4.75 mm sieve, there by meeting standard requirements.

5.2 Test on fine aggregate:

TABLE NO.2 Results of Practical Material Tests

Test Description	Results	Standard value
Specific gravity of course aggregate	2.5	2.3-2.7
Sieve analysis	4.75mm	150micron<4.75mm
Water absorption	1%	<3%

The test results indicate that the coarse aggregate possesses a specific gravity of 2.9, which lies within the standard range of 2.5 to 3.0. The water absorption value is 1%, well below the maximum permissible limit of 2%. In addition, the sieve analysis shows that the 20 mm aggregate passes through the 80 mm sieve and is retained on the 4.75 mm

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sieve, confirming compliance with the required grading standards.

5.3 Test on cement:

Table No.3 Results of Practical Material Tests

Test	Result	Standard value
Specific gravity of cement aggregate	2.70	2.4 to 2.9.
Consistency of cement	28%	30%
Initial setting time of cement	27min	30min
Final setting time of cement	4hr 10min	7hr

The specific gravity of cement aggregate was found to be 2.70, which lies within the standard range of 2.4 to 2.9, confirming the material's suitability. The standard consistency of cement was measured at 28%, slightly lower than the typical value of 30%, but still acceptable for normal use. The initial setting time was recorded as 27 minutes, which is close to the standard 30 minutes, ensuring sufficient time for handling and placing. The final setting time was observed at 4 hours 10 minutes, well below the permissible limit of 7 hours, indicating timely hardening. Overall, the test results suggest that the cement used meets standard requirements and is appropriate for construction applications.

5.4 Test on Fresh Concrete:

Table No.4 Results of Fresh Concrete Tests

Tests	Result	Standard value
Slump test	140mm	(100-150mm)
Compaction test	0.85	0.85-0.92
Vee bee test	7sec	5-10sec

The workability of concrete was assessed using slump, compaction factor, and Vee-Bee tests. The slump test gave a value of 140 mm, which lies within the standard range of 100–150 mm, indicating medium to high workability. The compaction factor was found to be 0.85, also within the acceptable range of 0.85–0.92, confirming good consistency and ease of placement. The Vee-Bee time recorded was 7 seconds, which fits within the standard limit of 5–10 seconds, suggesting balanced workability suitable for reinforced concrete. Overall, the results show that the mix has desirable workability properties for construction use.

5.5 Flexural Strength Test:

It indicates its ability to resist bending or tensile stresses.In this test the prism is placed on two supports and load is applied either at the mid span (center point loading) or (third point loading).as the load increases the prism bends and cracks form on the tension face.

UNIVERSAL TESTING MACHINE (UTM): It is a mechanical testing device used to perform different strength tests such as tensile, compressive, and flexural test on materials. It's can apply controlled loads and measure the corresponding deformation or failure load.

MIX DESIGN:

- As per code (IS 10262:2019) & (IS 456-2000)
- Water / Cement Ratio = 0.35-0.45
- Grass fibre = 1.5% used for M30
- Mix design: 1:1.73:3.08(cement: sand: aggregate)

Test specifications:

- Grade of concrete: M30
- Glass fibre replacement: 1.5% by the weight of cement
- Size of sample: 100*100*500CM
- Steam Curing 5.5 hr (3.5 hours in steam and 2hr normal)
- Normal Curing= 14 days
- Testing machine: Universal Testing Machine.

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FORMULA FOR FINDING DISPLACMENT

Fb= PL^3 / 48EI

EI= 5000*SQRT (Fck)

FIG NO.6 UTM MACHINE

FIG NO.7 UTM MACHINE WITH SAMPLE

FIG NO.8 NORMAL CONCRETE MIXIN &

FIG NO.9 FIBRE CONCRETE MIXING

FIG NO.10 BROKEN SAMPLE

FIG NO.11 STEAM CURIED SAMPLE

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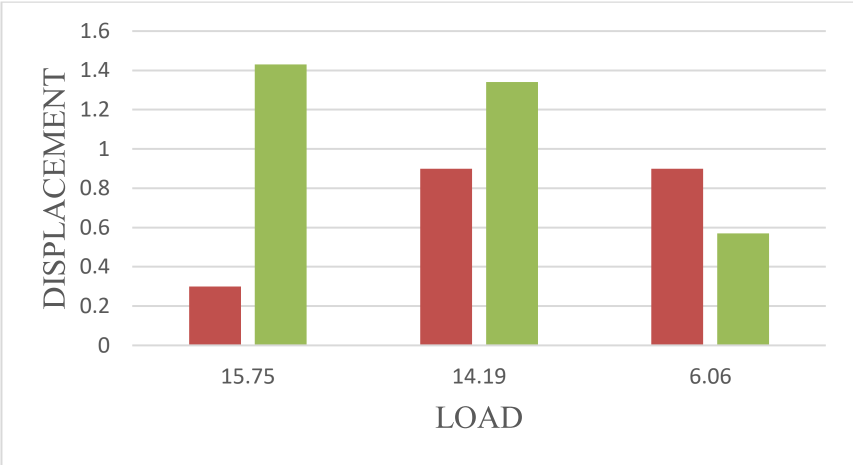
6.Comparison Of Displacement Between Experimental And Theoretical Results

1. Comparison between experi and theor Normal curing with normal concrete sample:

Table No 29 Comparison Displacement form Exp & theo

Sl no.	Load kN	Exp Disp(mm)	Theo Disp. mm
1	15.75	0.3	1.43
2	14.19	0.9	1.34
3	6.06	0.9	0.57



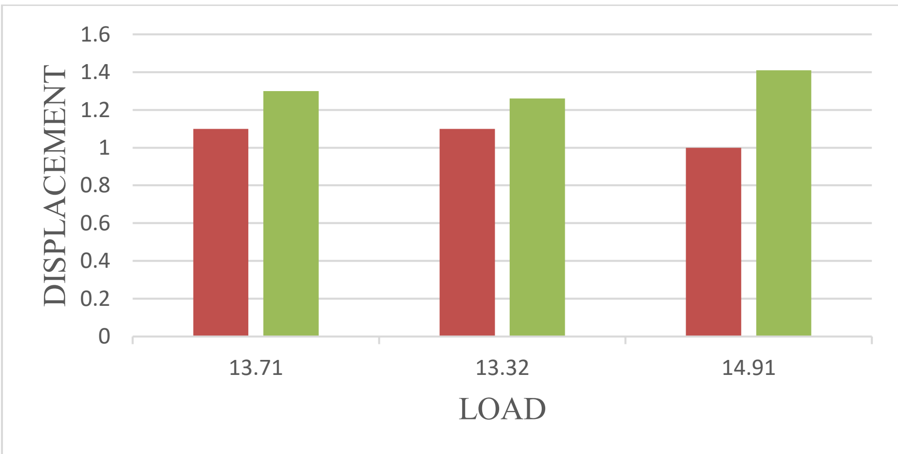
Graph No 25 Comparison of Exp and Theo Displacement under Applied Load

The M30 concrete specimen without fibre was subjected to normal curing and tested using a Universal Testing Machine (UTM). At a high load of 15.75kN, the experimental displacement was 0.3 mm compared to the theoretical 1.43 mm, indicating that the specimen was stiffer than predicted. At 14.19kN, the experimental displacement increased to 0.9 mm, still lower than the theoretical 1.34 mm, showing reasonable agreement. Interestingly, at a low load of 6.06kN, the experimental displacement (0.9 mm) exceeded the theoretical 0.57 mm.

2.Comparison between experi and theor Normal curing with fibre mix concrete sample:

Table No 30 Comparison Displacement form Exp & theo

Sl no.	Load kN	Exp Disp(mm)	Theo Disp. mm
1	13.71	1.1	1.3
2	13.32	1.1	1.26
3	14.91	1	1.41



Graph No 26 Comparison of Exp and Theo Displacement under Applied Load

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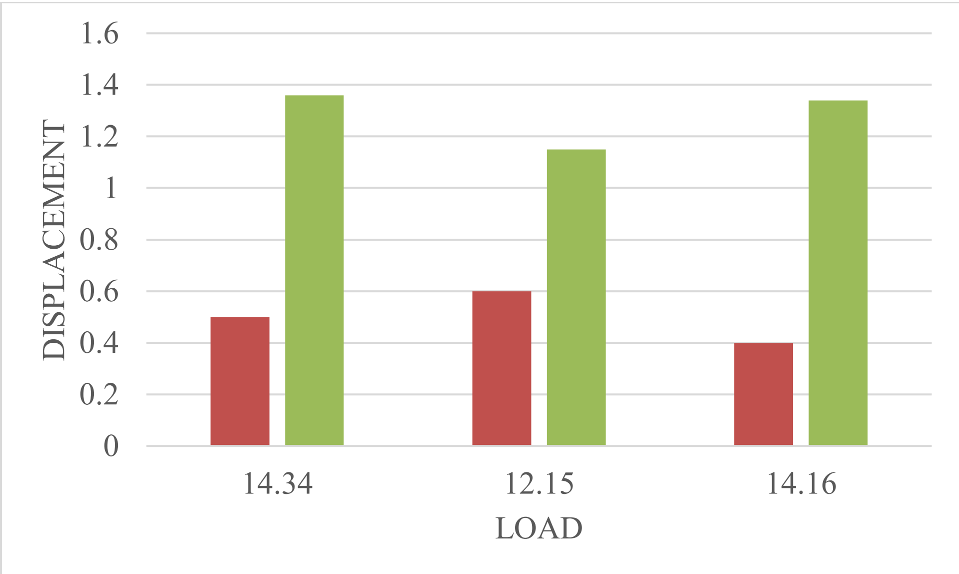
The normally cured M30 concrete specimen with 1.5% glass fibre was tested using a Universal Testing Machine (UTM) to measure load versus displacement. The experimental displacements were consistently slightly lower than the theoretical predictions—1.1 mm compared to 1.3 mm at 13.71kN, 1.1 mm compared to 1.26 mm at 13.32kN, and 1.0 mm compared to 1.41 mm at 14.91kN. This indicates that the actual fibre-reinforced specimen exhibited slightly higher stiffness and better load-carrying behavior than predicted, likely due to the added fibre reinforcement and improved bonding in the concrete matrix. Overall, the results show good agreement with theory while highlighting the beneficial effect of fibres in controlling deformation.

3.Comparison between experi and theor steam curing with normal concrete sample:

Table No 31 Comparison Displacement form Exp & theo

Sl no.	Load kN	Exp Disp(mm)	Theo Disp. mm
1	14.34	0.5	1.36
2	12.15	0.6	1.15
3	14.16	0.4	1.34



Graph No 27 Comparison of Exp and Theo Displacement under Applied Load

The M30 concrete specimen without fibres was subjected to steam curing and tested using a Universal Testing Machine (UTM). At a load of 14.34kN, the experimental displacement was 0.5 mm compared to the theoretical 1.36 mm, showing higher stiffness due to accelerated strength gain from steam curing. At 12.15kN, the displacement was 0.6 mm versus the theoretical 1.15 mm, indicating good resistance to deformation. At 14.16kN, the experimental displacement was 0.4 mm compared to 1.34 mm theoretical, again reflecting the enhanced early-age strength provided by steam curing. Overall, steam curing improved the load-carrying capacity and limited the deflection of the normal concrete specimen compared to theoretical predictions.

4. Comparison between experi and theor steam curing with fibre mix concrete sample:

Table No 32 Comparison Displacement form Exp & theo

Sl no.	Load kN	Exp Disp(mm)	Theo Disp. mm
1	12.57	0.9	1.19
2	7.83	0.4	0.8
3	12.57	1	1.2

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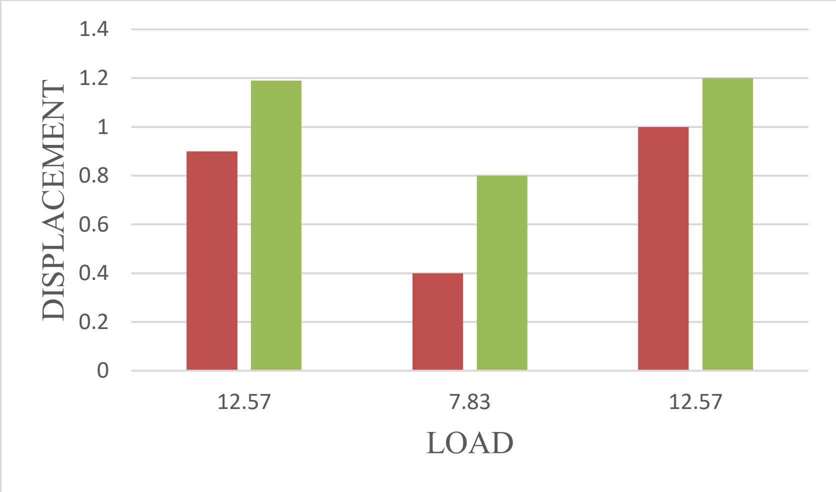

Graph No 28 Comparison of Exp and Theo Displacement under Applied Load

The M30 concrete specimen with 1.5% glass fibre was subjected to steam curing and tested using a Universal Testing Machine (UTM). At a load of 12.57kN, the experimental displacement was 0.9 mm compared to the theoretical 1.19 mm, showing the specimen was stiffer than predicted. At 7.83kN, the experimental displacement was 0.4 mm, lower than the theoretical 0.8 mm, indicating that steam curing enhanced early-age strength and limited deformation. At 12.57kN again, the displacement increased slightly to 1.0 mm compared to 1.2 mm theoretically, confirming that fibre reinforcement combined with steam curing effectively controlled cracking. Overall, the experimental displacements were consistently lower than theoretical predictions, highlighting the combined benefits of steam curing and fibre addition on stiffness and load-carrying capacity.

VI. CONCLUSION

- Glass fibers did not show significant improvement in compressive strength. Tensile and flexural capacity, on the other hand, were significantly enhanced. This is a result of the glass fibers' ability to resist cracking.
- M30 concrete with 1.5% glass fiber shows improved tensile and flexural performance compared to plain M30 concrete.
- The percentage increase of flexural and split tensile strength of various grades of glass fibre concrete mixes compared with 28 days is observed from 10 to 20%.
- Steam curing is Rapid strength development (often 70-80% of 28-day strength in 24 hours).
- Steam curing is faster production cycles in precast manufacturing.
- Normal curing of glass fiber reinforced M30 also improved performance, but less effectively than steam curing.

VII. RECOMMENDATIONS FOR FUTURE STUDY

- Glass fibre reinforced concrete be used for high construction.
- Steam curing can be preferred for precast construction.
- According to some research, glass fibers do not considerably improve the compressive capacity of concrete. As a result, further research using various pozzolanic materials is needed to increase the compressive capacity of glass fiber-reinforced concrete. etc.

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