

Partial Replacement Of Cement By Glass Fiber

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ABSTRACT

The growing demand for sustainable construction materials has led to extensive research on incorporating alternative materials that can enhance the mechanical performance and durability of concrete. One such promising material is glass fiber, which, when partially used as a replacement or additive to cement, improves the overall properties of concrete. This study examines the effect of replacing a portion of cement with glass fiber in varying proportions to evaluate its impact on compressive strength, tensile strength, workability, and durability of concrete.

Concrete is one of the most widely used construction materials; however, its inherently low tensile strength and brittle nature often limit its performance. To overcome these drawbacks and improve sustainability, the partial replacement of cement by glass fibres has emerged as a promising technique. Glass fibres possess high tensile strength, low density, and superior crack-resistance properties, which significantly enhance the mechanical performance of concrete. In this study, glass fibres are added as a partial replacement of cement at varying proportions to evaluate their effects on workability, compressive strength, tensile strength, and durability characteristics.

The inclusion of glass fibres helps to control micro-cracks, improve post-cracking behaviour, and reduce the overall cement consumption, thereby lowering carbon emissions. However, excessive fibre content may reduce workability and lead to fibre dispersion issues. The results indicate that optimal dosages of glass fibres can successfully improve the strength and service life of concrete, making it a more durable and sustainable construction material.

Keywords –Cement, Glass Fiber, Compressive Strength

I.INTRODUCTION

Concrete is a composite construction material that has become fundamental to modern infrastructure. It is primarily composed of cement, fine aggregates (sand), coarse aggregates (gravel or crushed stone), and water. When these ingredients are mixed together, a chemical reaction known as hydration occurs, causing the mixture to harden and gain strength over time. Concrete is widely valued for its versatility, durability, and ability to be molded into any desired shape before setting.

The performance of concrete can be modified by adding various admixtures and supplementary materials such as fly ash, silica fume, and fibres. Because of its high compressive strength and resistance to environmental effects, concrete is extensively used in buildings, roads, bridges, dams, and other construction works. However, conventional concrete has low tensile strength and is susceptible to cracking, which has led to the development of advanced forms like reinforced concrete, pre-stressed concrete, and fibre-reinforced concrete. Overall, concrete remains the most essential and economical material for structural applications worldwide.

II. LITERATURE REVIEW

1. Enhancing the fracture toughness of eco-friendly self-compacting concrete with waste glass coarse aggregates and steel fibers: A mixed-mode I/II fracture analysis using SCB specimens Morteza Ghodrattnama, Arash Rajaei, Amir R. Masoodi, Saeed Abrishami. Amirhossein Davarpanah T.Q., Pooyan Pournoori

This research explores the combined effects of utilizing waste glass coarse aggregates (WGCA) and hooked-end steel fibers (SFs) on the fracture behavior and mechanical properties of SCC subjected to complex loading scenarios (WGCA was incorporated to replace natural coarse aggregates (NCA) at replacement levels of 15%, 30%, and 45%, while SFs were introduced at volume fractions of 0.1 %, 0.3 %, and 0.5 %. A total of 240 semi-circular bending (SCB) specimens were evaluated under four distinct loading modes (I, I/II, II/1, and II) after curing for 28 and 56 days, in addition to 60 cubic samples for assessing compressive strength.

The findings indicate that substituting NCA with WGGA-up-to-30% improves both fracture toughness and compressive strength, attributed to enhanced matrix densification resulting from the pozzolanic activity of glass particles. However, exceeding this percentage leads to a decline in performance due to inadequate bonding at the interface between the aggregate and matrix. The inclusion of SFs effectively addresses this limitation by improving crack-bridging mechanisms, stiffness, and ductility.

The most favorable outcomes were observed with 30% WGCA and 0.5% SF, which provided exceptional resistance to crack propagation across all loading modes. This extensive study offers valuable insights into the sustainable use of WGCA and SFs in SCC, tackling both environmental and structural issues. The results highlight the potential benefits of integrating recycled materials and fiber reinforcement to enhance the performance of SCC under practical loading conditions.

2.Comprehensive analysis of mechanical characteristics in self-compacting concrete (SCC) with aluminum oxide (Al₂O₃) nanoparticles and glass fibers: An experimental and analytical investigation(Hamed Heidarzad Moghaddam, Mohammad Ali Lotfollahi-Yaghin Ahmad Malek

This research investigates the synergistic effects of aluminum oxide (Al₂O₃) nanoparticles and glass fibers on the mechanical and durability properties of self- compacting concrete (SCC) using an experimental and analytical approach.

The experimental analysis involved assessing fresh concrete properties and mechanical performance through tests such as compressive strength, splitting tensile strength, slump flow, L-box, V-funnel, T50, ultrasonic pulse velocity, and bond strength. Durability was evaluated using water absorption, water penetration depth, and electrical resistance test

Glass fibers were added at volumes of 0%, 0.5%, 1.0%, and 1.5%, while Al₂O₃ nanoparticles were incorporated at weight percentages of 0%, 0.5%, 1.0%, 1.5%, 2.0%, and 3.0%. The optimal mix, comprising 2.0% Al₂O₃ nanoparticles and 1.5% glass fibers, resulted in a 61 % increase in compressive strength and a 107.6% increase in tensile strength Water absorption was reduced by up to 46%, while electrical resistance increased by 265%, demonstrating improved durability. The combination also enhanced bond strength by 39 %, providing better adhesion between rebars and concrete. Analytical correlations between mechanical and bond properties were established.

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3.Axial compressive and long-term shrinkage behaviors of self-compacting recycled concrete reinforced with recycled glass fiber

Fubin Zhang, Rujun Zheng, Gaoyu Liao, Dianchao Wang, Zhengyi Lu, Haining Meng, Zheng Lu

Incorporating waste glass fiber effectively inhibits the long-term shrinkage rate of RGF-SCRC and improves its axial compressive strength, with the improvement of 2.2-15.3% in axial compressive strength and a reduction of 17.9-66.5% in the long-term shrinkage rate. However, excessive fiber addition shows a negatively effect on the performance of RGF-SCRC.

The optimum addition was concluded as 7.5 kg/m³. On the other hand, the waste alkali-resistant glass fiber showed a higher improvement than waste glass fiber. Moreover, microstructure analysis reveals that the waste fibers could be uniformly dispersed within the investigated specimen, effectively bridging gaps and significantly enhancing the concrete's strength and toughness.

Based on experimental results, the axial compression stress-strain relationship and long-term shrinkage curves of RGF-SCRC were fitted and modified, and proposed an axial compression constitutive relationship and a long-term shrinkage theoretical analysis model which are applicable to RGF-SCRC. The models' correctness was verified by comparing them with experimental results. These research outcomes offer valuable insights for the future practical implementation of RGF-SCRC.

4.Working and mechanical properties of waste glass fiber reinforced self- compacting recycled concrete Fubin Zhang, Zhengyi Lu, Dianchao Wang...

This paper uses waste glass fiber in self compacting recycled concrete (SCIRC), forming a kind of

waste glass fiber reinforced self-compacting recycled concrete (RGF-SCRC). The effects of recycled coarse aggregate (RCA) replacement ratio, water to binder (W/B) ratio, the content and type of glass fiber on the working and mechanical properties of RGF-SCRC were investigated.

The results showed that the specimens could meet the requirements of self-compacting concrete (SCC) in terms of working performance, but the addition of RCA and glass fiber could reduce the workability of RGF SCRC, when RCA is replaced with 100% and the fiber content reaches 10 kg/m³, the slump expansion is reduced by 9.5 % and 12.4%, respectively.

The mechanical force and friction force anchored at the fiber end at the interface with the concrete matrix increase the bonding strength, thereby enhancing the mechanical properties of RGF-SCRC. This study achieves the resource utilization of waste glass fiber and improves the mechanical properties of concrete and the research results can provide a reference for the practical application of RGF-SCRC in civil engineering.

5. Fracture and permeability properties of glass fiber reinforced self-compacting concrete Yahya R. Atewi", Mustafa F. Hasan b., Erhan

This article studied the influence of utilizing glass fiber (GF) on mechanical and permeability properties of self-compacting concrete (SCC) with fly-ash blended. There were three SCC series designed.

These percentages were 0%, 2%, and 4% by weight, respectively. The incorporation of fly ash (FA) was done by using 25% of total binder content by weight in all the SCC mixtures. Moreover, glass fiber was used as an additive material with levels of 0%, 0.35%, 0.70%, 1.0%, and 1.5%, respectively.

To experimentally evaluate mechanical properties; compressive strength; static modulus of elasticity; splitting tensile strength; fracture energy, and the permeability properties of the mixtures; sorptivity index; rapid chloride permeability test (RCPT); gas permeability test were done. The results showed that with utilizing nanosilica which ranged from 0% to 4% with replacement up until 0.7% glass fiber, indicated to enhance the mechanical and permeability properties of self-compacting concrete.

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III. OBJECTIVES

- To study the properties of Glass Fiber and properties with the cement.
- To study the properties of fresh concrete with replacement of Glass Fiber.
- To study the properties of hardened concrete with the replacement of cement by Glass Fiber
- To study the cost-reduction,
- To find the optimum replacement of cement.

IV. METHODOLOGY

4.1 METHODOLOGY

The methodology for incorporating glass fibres into cement involves a structured sequence of material preparation, mix proportioning, casting and testing. The process begins by selecting alkali-resistant glass fibres of suitable length and percentage to prevent deterioration in the cement's high-alkali environment. Cement, fine aggregates and water are first dry-mixed to form a uniform base matrix. The glass fibres are then sprinkled gradually into the mix to avoid clumping, allowing them to disperse through the fresh paste like tiny reinforcing threads that strengthen the internal structure. The fibre-reinforced mix is cast into moulds and compacted carefully to remove trapped air. After demoulding, the specimens are cured under controlled conditions so the cement matrix can gain strength while the fibres lock into place. Finally, standard laboratory tests such as compressive, flexural and water-absorption tests are performed to evaluate the influence of the glass fibre content. This methodology ensures consistent, reliable results and helps understand how the fibres enhance the performance of the cement composite.

4.2 MATERIALS USED:

- Cement – OPC 43
- Fine Aggregate
- Coarse Aggregate
- Glass Fiber
- Water

HARDENED CONCRETE TESTS

1. Compressive strength test

4.1.1 COMPRESSIVE STRENGTH TEST

The compressive test, also known as the compressive strength test, is a fundamental procedure used to determine the capacity of a material or structure to withstand loads that tend to reduce size. This test is widely used in construction to assess the strength and durability of concrete, bricks, and other materials.

Aim: To determine the maximum compressive load a material can bear before failure. To ensure materials meet the required strength specifications for construction projects.

Equipment:

Compression Testing Machine: A device that applies a compressive force to the material sample. **-Test Specimens:** Standard-sized samples, typically in the form of cubes, cylinders, or prisms.

Procedure:

1. Preparation: Mold and cure the concrete or material sample according to standard specifications.
2. Positioning: Place the cured specimen on the compression testing machine's platen.
3. Loading: Gradually apply compressive force at a uniform rate until the specimen fails.
4. Recording: Record the maximum load applied at the point of failure.

Interpretation:

The compressive strength is expressed in units of stress, such as megapascals (MPa) or pounds per square inch (psi).

It is a crucial indicator of the material's ability to perform under load-bearing conditions. Higher compressive strength values indicate stronger and more durable materials.

Applications:

Concrete Testing: Ensuring concrete mixtures meet the required strength for structural applications.

Brick and Block Testing: Evaluating the load-bearing capacity of masonry units.

Material Quality Control: Verifying the strength and consistency of various construction materials safety, reliability, and durability of structures.

THEORY AND CONCEPTS OF MIX DESIGN FOR SELF-COMPACTING CONCRETE USING GLASS FIBRES



FIG:4.5: COMPRESSIVE TEST

The mix design of concrete using glass fibres is based on the principle of producing a composite material with enhanced mechanical performance and durability compared to ordinary concrete. Glass fibres act as discontinuous micro-reinforcement, effectively controlling the development and propagation of cracks, improving tensile and flexural strength, and increasing impact resistance. During mix design, suitable proportions of cement, water, fine aggregate, coarse aggregate, and admixtures are selected to meet the desired strength and workability criteria. The addition of glass fibres generally increases internal friction and reduces workability; therefore, water content or superplasticizers must be adjusted to maintain consistency. Alkali-resistant (AR) glass fibres are commonly recommended due to the highly alkaline environment of cement paste. The fibre content is typically kept between 0.5% and 2% by weight of cement to achieve optimum performance without causing fibre balling or segregation. By following the standard guidelines of IS 10262 or ACI mix design methods and conducting trial mixes, a well-designed glass fibre reinforced concrete can deliver superior performance in terms of toughness, durability, and crack resistance, making it suitable for both structural and architectural applications.

1. Mix Design Process

The mix design of concrete using glass fibres follows the standard design method (as per IS 10262:2019 or ACI 211.1) with necessary adjustments for fibre inclusion. The procedure is given below:

1. Determine the Grade of Concrete

Select the characteristic compressive strength (e.g., M20, M30, M40) based on structural requirements.

2. Identify Exposure Conditions and Workability

Specify durability requirements, maximum water–cement ratio, and expected slump, as fibres reduce workability.

3. Select Water–Cement Ratio (w/c)

Choose based on strength and durability needs. Use lower w/c ratios to achieve desired strength while incorporating admixtures to improve slump.

4. Calculate Target Mean Strength

Target strength = $f_{ck} + 1.65 \times \text{standard deviation}$

5. Select Cement Content

Determine minimum cement content from durability requirements and the selected w/c ratio.

6. Proportioning of Aggregates

Fix quantities of fine and coarse aggregates using IS guidelines or aggregate grading curves.

7. Incorporate Glass Fibre Content

Typical addition = 0.5% to 2% by weight of cement, depending on desired mechanical properties.

Use Alkali-Resistant (AR) fibres to resist concrete alkalinity.

8. Adjustment for Workability

Because fibres decrease slump, add superplasticizers or slightly increase water content while maintaining the w/c ratio constraint.

V. RESULTS AND DISCUSSION

TABLE 5.1 BASIC TESTS ON MATERIALS

SL NO.	TEST	RESULT OBTAINED	RANGE
1	Normal consistency	32%	26%-35%
2	Initial setting time of cement	30 Min	30 min
3	Final setting time of cement	310 min	4-5 hours
4	Specific gravity of cement	3.14 g/cc	3.1-3.16
5	Sieve analysis of fine aggregate	F.M= 4.37 kg/m ²	-
6	Specific gravity of fine aggregate	2.88	2.5-3.0
7	Sieve analysis of coarse aggregate	F.M-9.23mm	-
8	Specific gravity of Coarse aggregate	2.65	2.5-3.0
9	Flakiness index	14.2%	-
10	Elongation index	16%	-

The range of normal consistency of cement is between 26% to 35% by weight of dry cement & in our case we have got the normal consistency of cement is to be 34% hence satisfy.

The initial setting of cement is 30 mins & in our case we have obtained the initial setting time of cement as 30 mins, hence ok.

As per Indian Standard, the final setting time of cement is 4-5 hours and in our case we have

got the final setting time of cement is to be 310 mins, hence Ok.

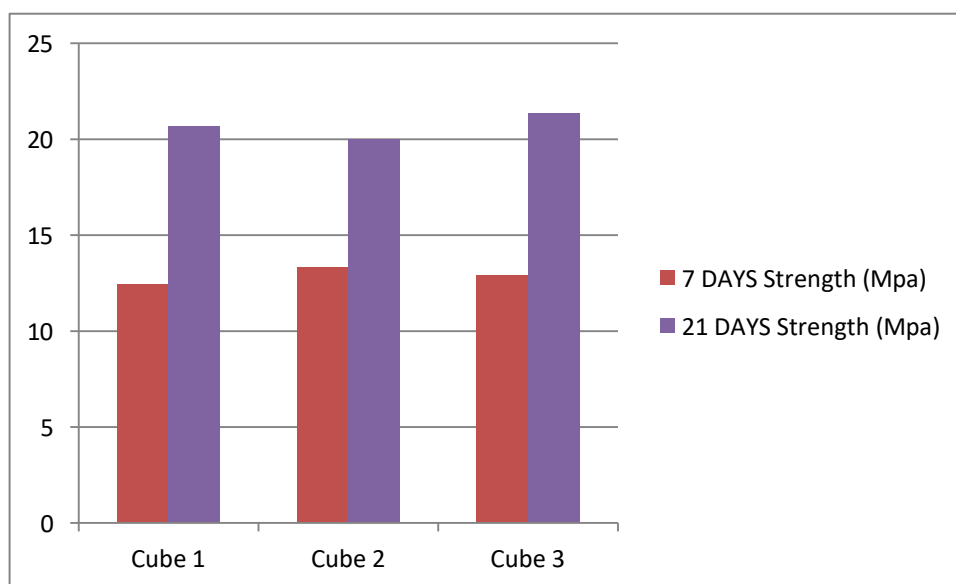
The specific gravity of cement generally ranges from 3.1 to 3.16, & in our case we have got the specific gravity of cement as 3.15, hence ok.

The specific gravity of fine aggregate generally ranges from 2.5 to 3.0, & in our case we have got the specific gravity of fine aggregate as 2.70, hence ok.

5.1 COMPRESSION TEST:

TABLE 5.2 Compression Test for 1% Glass Fiber:

SAMPLE	7 DAYS		21 DAYS	
	Load (KN)	Strength (Mpa)	Load (KN)	Strength (Mpa)
Cube 1	280	12.44	465	20.66
Cube 2	300	13.33	450	20
Cube 3	290	12.88	480	21.33
Average	290	12.88~13	465	20.66

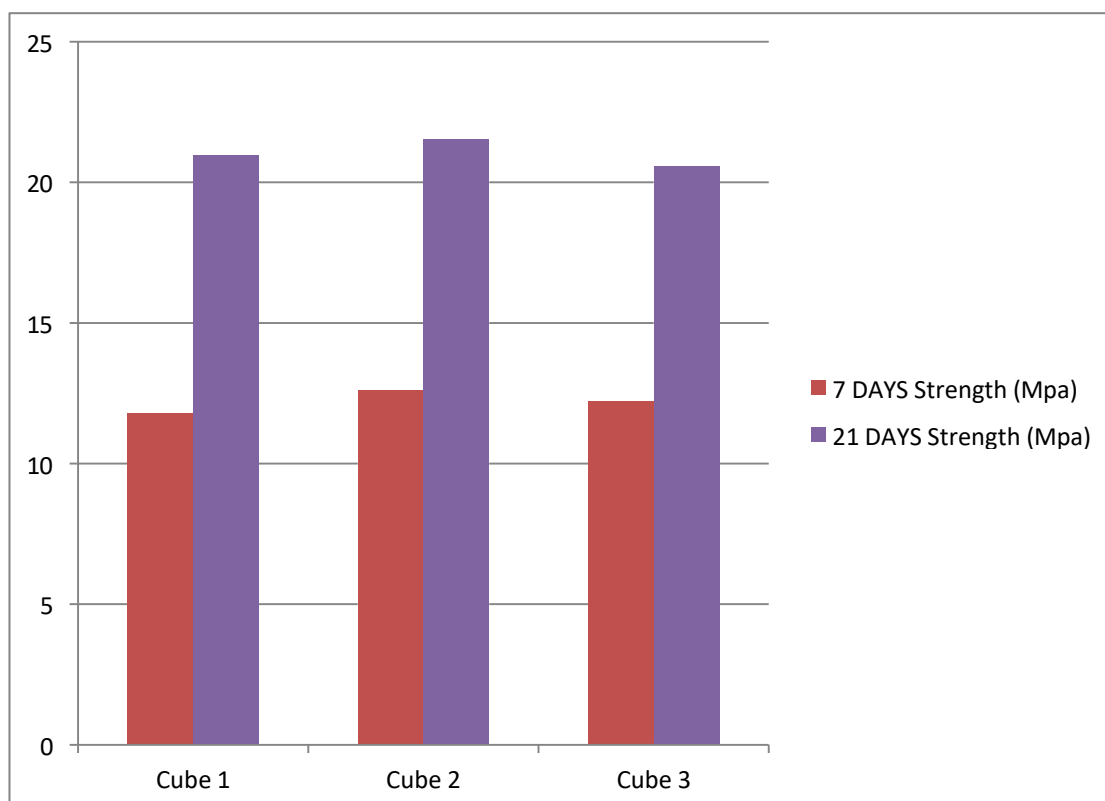


Graph 5.1 1% Glass Fibre

TABLE 5.3 Compression Test for 1.5% Glass Fiber:

	7 DAYS	21 DAYS

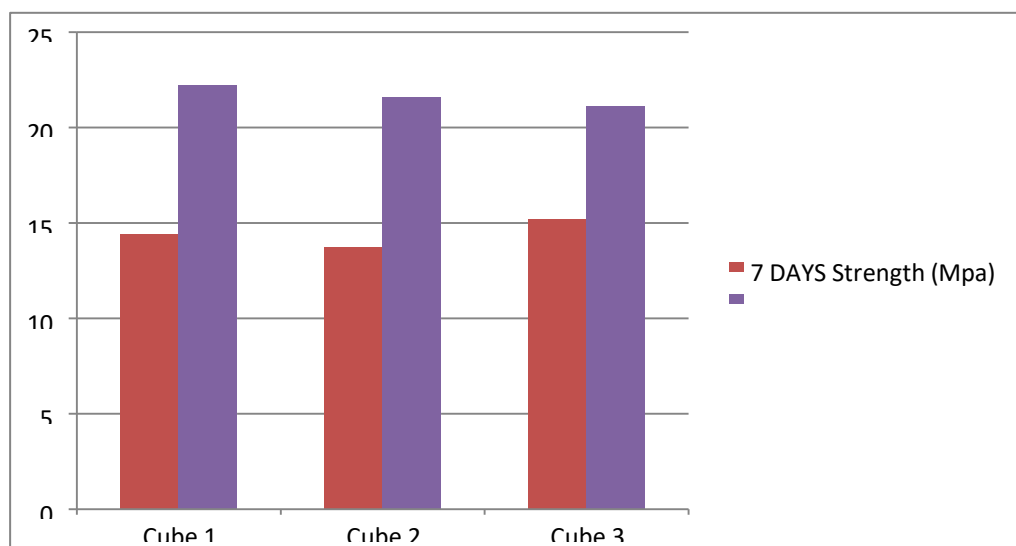
SAMPLE	Load (KN)	Strength (Mpa)	Load (KN)	Strength (Mpa)
Cube 1	265	11.77	472	20.97
Cube 2	284	12.6	484	21.52
Cube 3	276	12.2	463	20.57
Average	275	12.23	474	21.01



Graph 5.2 1.5% Glass Fiber
TABLE 5.4 Compression Test for 2% Glass Fiber:

SAMPLE	7 DAYS		21 DAYS	
	Load (KN)	Strength (Mpa)	Load (KN)	Strength (Mpa)
Cube 1	325	14.4	502	22.2

Cube 2	312	13.7	486	21.6
Cube 3	350	15.2	474	21.1
Average	328	14.4	487.3	21.72



Graph 5.3 2% Glass Fiber

5.2 WATER ABSORPTION TEST



FIG 5.1 WATER ABSORPTION TEST FOR CUBES REPLACEMENT WITH GLASS FIBER

5.2.1 METHODOLOGY

The methodology of the water absorption test for concrete involves determining how much water a hardened concrete specimen absorbs when submerged. First, the concrete specimen is oven-dried at a constant temperature (usually around 105°C) until it reaches a stable weight, ensuring all moisture is removed. After drying, the specimen is cooled to room temperature and its dry weight (W_1) is recorded. Then the specimen is fully immersed in clean water for a specified period, typically 24 hours. After soaking, the surface water is wiped off gently, and the wet weight (W_2) is measured. The water absorption is then calculated using the formula: Water absorption (%) = $[(W_2 - W_1) / W_1] \times 100$.

This procedure helps assess the porosity and durability of concrete, as lower water absorption indicates denser and more durable material.

5.2.2 PROCEDURE

The concrete specimens are first removed from the curing tank and gently wiped to remove any surface moisture. They are then placed in a hot air oven and dried at a temperature of about $105^\circ\text{C} \pm 5^\circ\text{C}$ until a constant mass is achieved, which ensures that all free moisture is removed. After drying, the specimens are allowed to cool at room temperature and their dry weight is recorded accurately. Next, the dried cubes are completely immersed in clean water for 24 hours to allow absorption to occur. After the immersion period, the specimens are taken out, the surface water is wiped off without applying pressure, and the saturated weight is recorded. Water absorption is calculated using the difference between the saturated weight and dry weight, expressed as a percentage of the dry weight. This procedure helps in determining the porosity and durability of concrete, including mixes containing glass fibres.

5.2.3 CALCULATION OF WATER ABSORPTION

TABLE 5.5 Water absorption test for 1% replacement of glass fiber

	7 Days		21 Days	
	Weight of dry cube $W_1(\text{kg})$	Weight of wet cube $W_2(\text{kg})$	Weight of dry cube $W_1(\text{kg})$	Weight of wet cube $W_2(\text{kg})$
Cube 1	8.925	9.21	9.2	9.33
Cube 2	9.1	9.40	8.9	9.12
Cube 3	8.5	9.0	9.1	9.25
Average	8.84	9.1	9.06	9.23

$$\% \text{ of water absorption for 7 days} = ((W_2 - W_1) / W_1) \times 100$$

$$= ((9.1 - 8.8) / 8.8) \times 100$$

$$= 3.8\%$$

$$\% \text{ of water absorption for 21 days} = ((W_2 - W_1) / W_1) \times 100$$

$$= ((9.23 - 9.06) / 9.06) \times 100$$

$$= 2.2\%$$

TABLE 5.6 Water absorption test for 1.5% replacement of glass fiber

	7 Days		21 Days	
	Weight of dry cube $W_1(\text{kg})$	Weight of wet cube $W_2(\text{kg})$	Weight of dry cube $W_1(\text{kg})$	Weight of wet cube $W_2(\text{kg})$
Cube 1	8.62	8.96	8.94	9.23
Cube 2	8.73	9.1	8.70	9.14

Cube 3	8.9	9.2	8.73	8.92
Average	8.75	9.08	8.8	9.09

$$\begin{aligned} \text{\% of water absorption for 7 days} &= ((W_2 - W_1) / W_1) \times 100 \\ &= ((9.08 - 8.75) / 8.75) \times 100 \\ &= 3.6\% \end{aligned}$$

$$\begin{aligned} \text{\% of water absorption for 21 days} &= ((W_2 - W_1) / W_1) \times 100 \\ &= ((9.09 - 8.8) / 8.8) \times 100 \\ &= 3.29\% \end{aligned}$$

TABLE 5.7 Water absorption test for 2% replacement of glass fiber

	7 Days		21 Days	
	Weight of dry cube W1(kg)	Weight of wet cube W2(kg)	Weight of dry cube W1(kg)	Weight of wet cube W2(kg)
Cube 1	8.75	8.92	8.98	9.2
Cube 2	8.82	9.23	8.84	9.1
Cube 3	8.96	9.14	9.12	9.23
Average	8.81	9.10	8.97	9.19

$$\begin{aligned} \text{\% of water absorption for 7 days} &= ((W_2 - W_1) / W_1) \times 100 \\ &= ((9.10 - 8.81) / 8.81) \times 100 \\ &= 3.8\% \end{aligned}$$

$$\begin{aligned} \text{\% of water absorption for 21 days} &= ((W_2 - W_1) / W_1) \times 100 \\ &= ((9.19 - 8.97) / 8.97) \times 100 \\ &= 2.5\% \end{aligned}$$

VI. CONCLUSION

The experimental study on M20 grade concrete with 1%, 1.5%, and 2% glass fibre added to 15 cm cubes shows that the inclusion of glass fibres improves the performance of concrete at both 7 days and 21 days. At 1% the compression strength is 13 Mpa in 7 days and 20.66 Mpa in 21 days. Similarly, at 1.5% the compression strength is 12.2 Mpa for 7 days and 20.1 Mpa for 21 days. At 2% the compression strength is 14.4 Mpa in 7 days and 21.7 Mpa in 21 days. The results indicate that 1% and 1.5% fibre content provide the most effective improvement, as the fibres help reduce micro-cracks, enhance bonding within the matrix, and increase overall strength. At 2% fibre content, the strength gain becomes comparatively lower because excess fibres reduce workability and create fibre clustering.

Overall, the tests confirm that optimum glass fibre dosage lies around 1%–1.5%, where the concrete shows noticeable improvement in compression strength and reduced water absorption compared to the control mix. By 21 days, all mixes show higher strength than at 7 days, demonstrating normal hydration development while still maintaining the benefits of fibre addition. Thus, glass fibres can be effectively used as a secondary reinforcement to enhance the durability and mechanical properties of M20 concrete when used in moderate percentages. The water absorption test conducted on 15 cm concrete cubes containing different percentages of glass fibres shows that the addition of fibres helps reduce the overall water absorption of the concrete. Mixes with 1% and 1.5% glass fibres recorded noticeably lower absorption compared to the control concrete, indicating improved density and reduced permeability. This improvement occurs because the fibres help control micro-cracks and create a more compact internal structure.

At 2% fibre content, the water absorption slightly increases compared to 1% and 1.5% mixes, mainly due to reduced workability and the possibility of fibre balling, which creates small voids. However, the absorption still remains comparable or lower than plain concrete.

Overall, the experiment shows that adding glass fibres up to an optimum level of 1%– 1.5%

enhances the durability of concrete by reducing water penetration. This confirms that glass fibres can be effectively used as a secondary reinforcement to improve the impermeability and long-term performance of concrete.

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