

Experimental Study on Compressive Strength of Concrete by using Different Fibres at various Replacement Levels

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Abstract

Concrete is most widely used construction material in the world. Fiber reinforced concrete (FRC) is a concrete in which small and discontinuous fibers are dispersed uniformly. The fibers used in FRC may be of different materials like steel, G.I., carbon, glass, Aramid, asbestos, polypropylene, jute etc. The addition of these fibers into concrete mass can dramatically increase the compressive strength, tensile strength, flexural strength and impact strength of concrete. In this study the results of strength properties of steel, glass, and polypropylene fiber reinforced concrete have been presented the compressive strength of concrete samples made with different fiber amounts varies from 0%, 0.25%, 0.5%, and 1% were studied. The samples with the addition of the different fibers showed better results with increase of fiber content.

Keywords: Concrete, Fiber Reinforced Concrete, Fibers

I. INTRODUCTION

A. Introduction to Fiber Reinforced Concrete

Deterioration of concrete structures is one of the major problems of the construction industry today. So we can reduce this problem by using different fibers. The application of cement concrete is limited due to the characteristics of brittle failure; this can be overcome by the inclusion of a small amount of short and randomly distributed fibers such as steel, glass, synthetic and natural. The primary role of fibers in cementations composite is to control cracks, increase the tensile strength, toughness and to improve the deformation characteristics of the composite and also improve the flexural toughness, shear strength, durability and resistance to impact. Generally Steel, Carbon, Aramid, and glass fibers are the most commonly used fibers in manufacturing FRC strengthening systems. Steel fibers are the most commonly used man-made metallic fibers generally made of carbon or stainless steel; these are used for crack control. The quality and quantity of steel fibers influence the mechanical properties of concrete. The most common reinforcing fiber is E-Glass, which derives its name from its electrical resistance. Glass fibers are cheaper than carbon fibers so they have a wider utilization in the world. Application of glass fiber composite materials depends on proper utilization of glass composition, size chemistry, fiber orientation, and fiber volume in the appropriate matrix for desired mechanical, electrical, thermal, and other properties. Polypropylene fibers are thermo plastics produced from Propylene gas. Propylene gas is obtained from the petroleum by products or cracking of natural gas feed stocks. Concrete develops micro cracks with curing and these cracks rapidly under applied stress resulting in low tensile strength of concrete. Hence addition of polypropylene fibers improves the strength of concrete. Polypropylene fibers are also compatible with all concrete chemical admixtures and can be handled with ease.

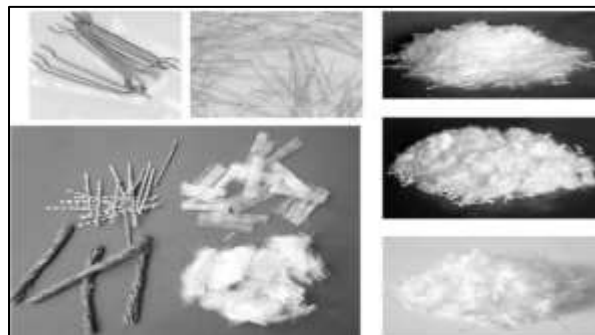


Fig. 1: Different types of fibers

Table – 1
Mechanical properties of Different fibers

| Fiber material | Tensile strength (N/mm ²) | Young's modulus (10 ³ N/mm ²) | Specific Gravity |
|----------------|---------------------------------------|--|------------------|
| Steel | 275-2758 | 200 | 7.86 |
| Glass | 1034-3792 | 69 | 2.5 |
| Carbon | 600-3690 | 120-580 | 1.65 |
| Armed | 1720-2540 | 41-125 | 1.44 |
| Polypropylene | 3000 | 95 | 0.97 |

II. EXPERIMENTAL WORK

The experimental work was carried out to study the effect of strength of concrete is usually defined and determined by the crushing strength of 150mm x 150mmx150mm, at an age of 7, 14 and 28days. It is most common test conducted on hardened concrete as it is an easy test to perform and also most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength. Steel mould made of cast iron dimension 150mm x 150mmx150mm used for casting of concrete cubes filled with steel glass, polypropylene fibers 0%, 0.25%, 0. 5%, 1% by volume of concrete. The mould and its base rigidly damped together so as to reduce leakages during casting. The sides of the mould and base plates were oiled before casting to prevent bonding between the mould and concrete. The cube was then stored for 24 hours undisturbed at room temperature.

A. Materials and Properties

The materials used in this project are given as follows

- 1) A 53 grade ordinary Portland cement
- 2) Fine aggregates (Natural sand)
- 3) Coarse aggregates
- 4) Water (fresh water)
- 5) Fresh concrete
- 6) Fibers used
 - Steel fibers
 - Glass fibers
 - Polypropylene fibers

B. Cement

A 53 grade ordinary Portland cement is used in this work .The raw materials used in manufacture of cement is lime, silica, alumina, iron oxide. These interact in kiln at high temperatures to form more complex compounds.



Fig. 2: Cement

C. Tests Performed to find out Properties of Cement

- Specific gravity of cement
- Fineness of cement
- Standard consistency test
- Setting time test (initial & final setting)

D. Procedure and Results

1) Specific gravity of cement

- Weight of empty dry bottle, W1=25 gm.
- Weight of bottle + water, W2 = 79.5 gm.
- Weight of bottle + kerosene, W3= 65 gm.

- Weight of bottle +kerosene + 25 gm. cement, W4=84 gm.
- Weight of cement, W5=25 gm.
- Specific Gravity of Cement= $W5*(W3-W1) / ((W2-W1) * (W3 +W5-W4))$
- Specific Gravity of Cement obtained was 3.15

2) *Fineness of Cement*

- Weight of cement taken in IS 90u sieve, W1=100gm
- Weight of residue left on the sieve W2 = 6 gm.

Fineness of the cement = $(W2/W1) \times 100$

$$= (6/100) \times 100$$

Fineness of cement obtained was 6%.

3) *Normal Consistency Test*



Fig. 3: Weight of cement

Weight of cement taken =300 gm.

Table – 2
Determination of Consistency of Cement

| Trial no | % of water added | Height not penetrated in Vicat's mould(in mm) |
|----------|------------------|---|
| 1 | 24 | 09 |
| 2 | 26 | 06 |

Standard consistency of cement =26%

Table – 3
Physical Properties cement

| Sr. No | Property | Test results |
|--------|----------------------|--------------|
| 1 | Specific gravity | 3.15 |
| 2 | Fineness of cement | 6% |
| 3 | Normal consistency | 26% |
| 4 | Initial setting time | 30 min |
| 5 | Final setting time | 6 hrs. |

Physical Properties of OPC 53 Grade

Tests performed to find out the properties of Fine aggregate (Natural sand)

4) *Specific gravity of fine aggregates*



Fig. 4: Specific gravity of fine aggregates

- Weight of empty Pycnometer (W1) = 65gm.
- Weight of Pycnometer with sand (W2) = 1501gm
- Weight of Pycnometer with sand and water (W3) = 2114gm
- Weight of Pycnometer with water (W4) = 1523gm

$$\text{Specific Gravity} = (W2 - W1) / ((W4 - W1) - (W3 - W2)) = 2.68$$

Therefore the Specific Gravity Of fine aggregate obtained was 2.68

5) *Fineness modulus of fine aggregate*



Fig. 5: Fineness modulus of fine aggregate

Table – 4
Fineness modulus of fine aggregate

| Sieve size(mm) | mass retained (gm.) | % mass retained | Cumulative %retained | % passing |
|----------------|---------------------|-----------------|----------------------|-----------|
| 4.75 | 6 | 0.3 | 0.3 | 99.7 |
| 2.36 | 9 | 0.45 | 0.75 | 99.25 |
| 1.18 | 88 | 4.4 | 5.15 | 94.85 |
| 0.6 | 495 | 24.75 | 29.9 | 70.10 |
| 0.3 | 1111 | 55.55 | 85.45 | 14.55 |
| 0.15 | 254 | 12.7 | 98.15 | 1.85 |
| 0.075 | 26 | 1.3 | 99.45 | 0.55 |

$$\text{Fineness modulus of fine aggregate} = \text{sum of \% of cumulative mass retained} / 100$$

$$= 246.5 / 100 = 2.46$$

6) *Bulking of Sand*

Table – 5
Bilking of sand

| S. No | Volume of dry loose sand V1 | % moisture content added | Volume of wet loose sand v2 | % Bulking V2 – V1 / V1 |
|-------|-----------------------------|--------------------------|-----------------------------|------------------------|
| 1 | 500 | 2 | 520 | 4 |
| 2 | 500 | 4 | 600 | 20 |
| 3 | 500 | 6 | 700 | 40 |
| 4 | 500 | 8 | 530 | 6 |
| 5 | 500 | 10 | 500 | 0 |

Bulking of sand is 8%

Tests performed to find out the properties of coarse aggregates

7) *Finess modulus of coarse aggregate*

Table – 6
Fitness modulus of coarse aggregate

| Sieve size (mm) | mass retained | % mass retained | Cumulative % retained | %passing |
|-------------------|---------------|-----------------|-----------------------|----------|
| 40 | - | - | - | 100 |
| 20 | 205.5 | 20 | 20.55 | 79.45 |
| 16 | 248.5 | 24.85 | 45.4 | 54.6 |
| 12.5 | 513.5 | 51.35 | 96.75 | 3.25 |
| 10 | 32.0 | 3.2 | 99.95 | 0.05 |
| 4.75 | 5 | 0.05 | 100 | 0 |

$$\text{Fineness modulus} = \text{sum of \% of cumulative mass retained} / 100 = 8.62$$

8) Specific gravity of coarse Aggregates

Table – 7
Specific gravity of coarse Aggregates

| Size of aggregates | 20 mm | 10 mm |
|--|--------|--------|
| Weight of specific gravity bottle (W1) in mg | 625 | 625 |
| Weight of specific gravity bottle with 3/4 th of C.A (W2) in mg | 1619 | 1693 |
| Weight of specific gravity bottle with 3/4 th of C.A and Water (W3) in mg | 2314.5 | 2349.5 |
| Weight of specific gravity bottle with Water (W4) | 1668.5 | 1668.5 |
| Sp. Gravity of C.A | 2.85 | 2.76 |

III. MIX DESIGN

In this chapter, the concrete mix design is presented. The following mix design for grade M35 is based on Indian standard recommended method of concrete mix design IS: 10262-2009. In this introduced the methods of concrete mix design, factors to be effected on mix design and the outline procedure of the mix design.

Design of concrete mix involves determination of the properties of the given constituents namely cement, water, coarse aggregate, and fine aggregate with add mixtures if any. Workability is specified as the important property of concrete in fresh state. For hardened state, compressive strength and durability will be considered.

A. Mix Design for M35 Grade

1) Stipulations for Proportioning

- Grade designation : M35
- Type of cement : OPC 53 Grade
- Maximum nominal size of aggregate : 20 MM, 10MM
- Minimum cement content : 340 kg/m³
- Maximum water-cement ratio : 0.42
- Workability (slump value) : 100mm
- Exposure condition : severe
- Method of concrete placing : pumping
- Degree of supervision : good
- Type of aggregate : crushed angular
- Maximum cement content : 470kg/m³

2) Test data for materials:

- Cement used : OPC 53 grade
- Specific gravity of cement : 3.15

3) Specific gravity of:

- Coarse aggregate : 2.74
- Fine aggregate : 2.55

4) Water absorption:

- Coarse aggregate : 0.5 %
- Fine aggregates : 1.0 %

5) Free (surface) moisture

- Coarse aggregate : Nill
- Fine aggregate : Nill

B. Target Strength for Mix Proportioning

$$f'_{ck} = f_{ck} + 1.65 s \quad (\text{From table 1, IS 10262:2009 standard deviation, } S=5\text{N/mm}^2)$$

$$\text{Target strength} = 35 + 1.65 * 5 = 43.25 \text{ N/mm}^2$$

C. Selection of Water-Cement Ratio

From table 5, of IS 456, maximum water- cement ratio = 0.45
Based on experience adopt water-cement ratio = 0.35, 0.35 < 0.42, Hence ok.

D. Selection of Water Content

From table 2, maximum water content for 20mm aggregates = 186litre
10mm aggregates = 208liter
Estimated water content for 100 mm slump = (60/100)186+ (40/100)208 = 195litres

E. Calculation of Cement Content

- Water – cement ratio = 0.42
 - Cement content = $195/0.42 = 470 \text{ kg/m}^3$
- From table 5 of IS 456, minimum cement content for ‘severe’ exposure condition = 340 kg/m^3
 $470 \text{ kg/m}^3 > 340 \text{ kg/m}^3$. Hence, ok.

F. Properties of Volume of Coarse and Fine Aggregate Content

Volume of coarse aggregate = $(60/100)0.64 + (40/100)0.48 = 0.576$
 Volume of fine aggregate = $1 - 0.576$

IV. MIX CALCULATIONS

- 1) Volume of concrete = 1 m^3
- 2) Volume of cement = mass of cement/specific gravity of cement*1/1000 = $470/3.1*1/1000 = 0.1516 \text{ m}^3$.
- 3) Volume of water = mass of water/specific gravity of water*1/1000 = $195/1*1/1000 = 0.195 \text{ m}^3$
- 4) Volume of all in aggregates = $(a-(b+c+d)) = 1 - (0.1516 + 0.195) = 0.6534 \text{ m}^3$
- 5) Mass of coarse aggregate =
 $e*\text{volume of coarse aggregate}*specific gravity of coarse aggregate*1000 = 0.6534*0.57*2.74*1000 = 1025 \text{ kg}$
- 6) Mass of fine aggregate =
 $e*\text{volume of fine aggregate} * specific gravity of fine aggregate*1000 = 0.6534*0.42*2.55*1000 = 700 \text{ kg}$.

A. Mix Proportions Required for Combined Mix

- Cement: 470 kg/m^3
- Water: 195 kg/m^3
- Fine aggregate: 760 kg/m^3
- Coarse aggregate: 1170 kg/m^3
- Water-cement ratio: 0.42

Table – 8
Mix design

| Grade | Proportions | Cement(Kg/M ³) | F.A(Kg/M ³) | C.A(Kg/M ³) | Water(Lt) |
|-------|-------------|----------------------------|-------------------------|-------------------------|-----------|
| M35 | 1:1.61:2.48 | 470 | 760 | 1170 | 195 |

Table – 9
Quantities of materials

| Grade | Type of Fiber | Proportions | Cement (Kg/m ³) | F.A (Kg/m ³) | C.A (Kg/m ³) | | %Water | %fiber (kg) |
|-------|---------------|-------------|-----------------------------|--------------------------|--------------------------|-------|--------|-------------|
| | | | | | 20mm | 10mm | | |
| M35 | Normal | 0% | 14.32 | 23.04 | 21.33 | 14.22 | 5.92 | 0 |
| M35 | Steel | 0.25% | 14.32 | 23.04 | 21.33 | 14.22 | 5.92 | 0.595 |
| | | 0.5% | 14.32 | 23.04 | 21.33 | 14.22 | 5.92 | 1.191 |
| | | 1% | 14.32 | 23.04 | 21.33 | 14.22 | 5.92 | 2.384 |
| M35 | Glass | 0.25% | 14.32 | 23.04 | 21.33 | 14.22 | 5.92 | 0.140 |
| | | 0.5% | 14.32 | 23.04 | 21.33 | 14.22 | 5.92 | 0.280 |
| | | 1% | 14.32 | 23.04 | 21.33 | 14.22 | 5.92 | 0.561 |
| M35 | Polypropylene | 0.25% | 14.32 | 23.04 | 21.33 | 14.22 | 5.92 | 0.073 |
| | | 0.5% | 14.32 | 23.04 | 21.33 | 14.22 | 5.92 | 0.147 |
| | | 1% | 14.32 | 23.04 | 21.33 | 14.22 | 5.92 | 0.294 |

B. Different Tests on Concrete (Workability Tests)

1) Slump Cone Test

Table – 10
Slump cone test results

| S.no | W/c Ratio | Slump Fall Ht (mm) |
|------|-----------|--------------------|
| 1 | 0.5 | 0 |
| 2 | 0.6 | 17 |

Table – 11
Compaction factor test

| S.no (1) | W/c Ratio (2) | Cylinder wt with partially compacted concrete wt (w ₂) kg (3) | Cylinder wt with fully compacted concrete wt (w ₃) kg(4) | Weight of partially compacted concrete (w ₂ -w ₁) (5) | Weight of fully compacted concrete (w ₃ -w ₁)(6) | Compaction factor (5)/(6) |
|----------|---------------|---|--|--|---|---------------------------|
| 1 | 0.5 | 15.940 | 18.17 | 10.24 | 12.47 | 0.82 |
| 2 | 0.6 | 16.609 | 18.30 | 10.90 | 12.6 | 0.86 |
| 3 | 0.7 | 16.935 | 18.60 | 11.194 | 12.864 | 0.87 |



Fig. 10: Compaction factor test results



Fig. 11: Tested samples

V. RESULTS AND DISCUSSIONS

Table – 12
Compressive strength of different cubes

| S.no | Mix | % of fibers added | 7 days | 14 days | 28 days |
|------|---------------------|-------------------|-------------------------|-------------------------|-------------------------|
| 1 | Normal mix | 0% | 28.56 N/mm ² | 33.35 N/mm ² | 38.96 N/mm ² |
| 2 | Steel fibre | 0.25% | 35.65 N/mm ² | 40.43 N/mm ² | 46.26 N/mm ² |
| | | 0.5% | 38.5 N/mm ² | 43.60 N/mm ² | 50.25 N/mm ² |
| | | 1% | 42.85 N/mm ² | 46.87 N/mm ² | 55.36 N/mm ² |
| 3 | Glass fibre | 0.25% | 33.35 N/mm ² | 38.52 N/mm ² | 42.80 N/mm ² |
| | | 0.5% | 36.53 N/mm ² | 40.85 N/mm ² | 45.65 N/mm ² |
| | | 1% | 39.46 N/mm ² | 43.45 N/mm ² | 49.83 N/mm ² |
| 4 | Polypropylene Fibre | 0.25% | 30.55 N/mm ² | 35.45 N/mm ² | 40.23 N/mm ² |
| | | 0.5% | 32.65 N/mm ² | 38.21 N/mm ² | 42.85 N/mm ² |
| | | 1% | 35.34 N/mm ² | 39.35 N/mm ² | 45.65 N/mm ² |

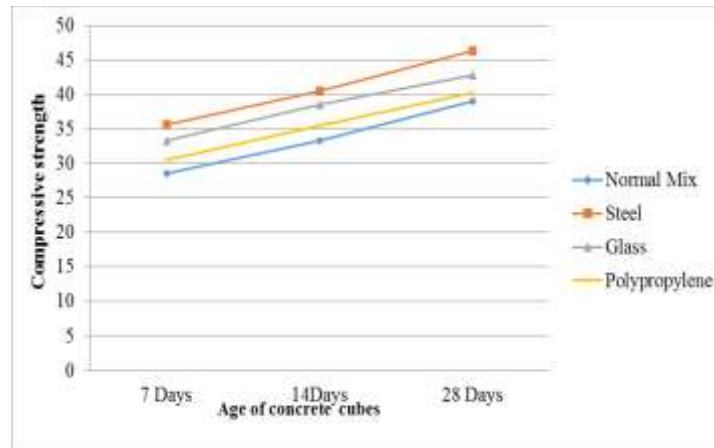


Fig. 12: Compressive strength -Age of concrete cubes for 0.25% of fiber content

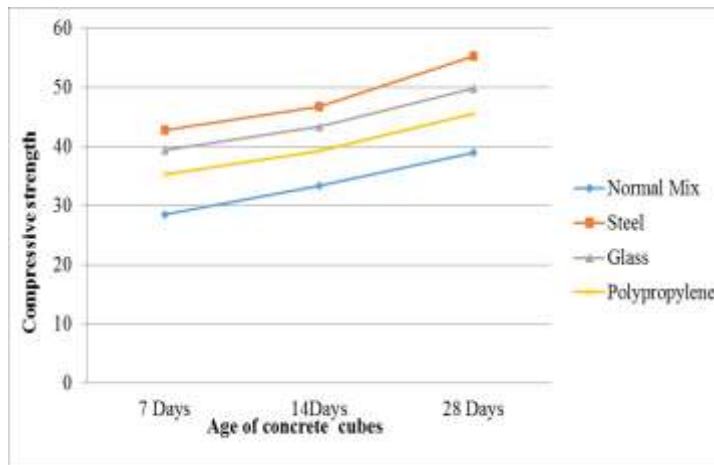


Fig. 13: Compressive strength -Age of concrete for cubes of 0.5% of fiber content

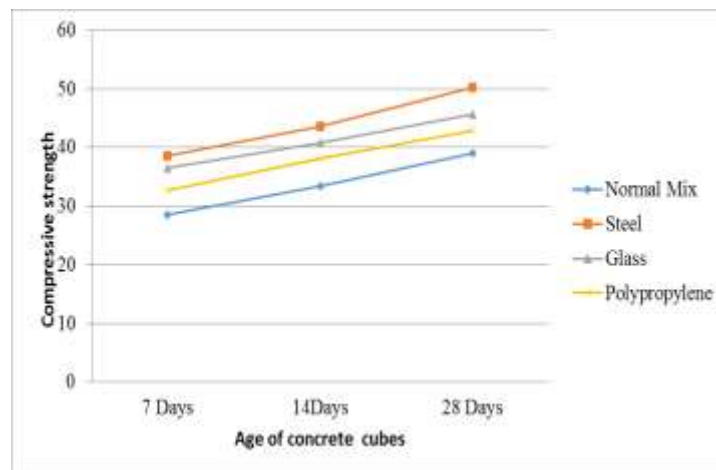


Fig. 14: Compressive strength -Age of concrete for cubes of 1% of fiber content

VI. CONCLUSIONS

- With the increase of fibre content the compressive strength increases.
- The ultimate load behaviour is also improved due to the addition of fibres.
- Steel fibres give more strength when compared to glass and polypropylene fibres.

The steel fiber reinforced concrete gives 29.61% with addition of 1% steel fiber volume of concrete with compared with normal mix.

- 1) The glass fiber reinforced concrete gives 21.8% with addition of 1% glass fiber volume of concrete with compared with normal mix.
- 2) The polypropylene fiber reinforced concrete gives 14.65% with addition of 1% polypropylene fiber volume of concrete with compared with normal mix.
- 3) The steel fiber reinforced concrete gives 22.48% with addition of 0.5% steel fiber volume of concrete with compared with normal mix.
- 4) The glass fiber reinforced concrete gives 14.65% with addition of 0.5% glass fiber volume of concrete with compared with normal mix.
- 5) The polypropylene fiber reinforced concrete gives 9.05% with addition of 0.5% polypropylene fiber volume of concrete with compared with normal mix.

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