Influence of Hybrid Fibre on the Mechanical Properties of Concrete

S.J. Princess Rosaline, R.Jayanthi

Abstract: This study presents the experimental investigation carried out to study the mechanical properties of concrete with and without the addition of fibres to it. Concrete is the most consumed material in the world which has the property of strong in compression and weak in tension. Also plain concrete possess very limited ductility and little resistance to cracking. Hence fibres are introduced in the concrete to improve the tensile strength & brittleness of the concrete. These fibres which are closely spaced and dispersed uniformly in the concrete arrest the micro and macro cracks and improve the tensile strength of concrete. Concrete admixed with such fibres are known as Fibre Reinforced Concrete. The combination of two (or) more fibres called as Hybridization is carried out in this work. M25 grade concrete is designed as per IS 10262:2009 with the volume fraction of 0-1.5%. The workability of the concrete is affected due to the addition of fibres and hence super plasticizers are added to the concrete. The fibres considered for the study are (i) Crimped Steel Fibre (0-1.5%) and (ii) Shortcut Glass Fibre (0.1-0.2%). The behaviour of the hybrid fibre reinforced concrete is investigated by conducting compressive strength test on cube specimen of size 150mmx150mmx150mm and split tensile strength test on cylinder specimen of size 150mm diameter and 300mm height. From the experimental results, the optimum fibre combinations for maximum compressive strength and split tensile strength of concrete are identified.

Keywords: Fibres, Hybrid Fibre Reinforced Concrete, Compressive Strength, Split Tensile Strength.

I. INTRODUCTION

Concrete which is the composition of cement, water, fine and coarse aggregate is the most consumed material in the construction world. As the concrete is weak in tension it behaves as a brittle material and due to this it cracks under minute loading. The formation of cracks is the major cause for the failure of the concrete as these cracks progressively promulgate to the compression end of the member. These cracks increase in size and scale as the time elapse and finally makes the concrete to fail and the member breaks. The formation of cracks in the concrete may also occur due to drying shrinkage, which is basically micro crack.

Thus to increase the tensile strength of concrete steel reinforcements are provided in the concrete and these steel bars take up the local tension alone. Hence multi directional closely spaced steel reinforcements are needed and it is achieved by introducing fibres into the concrete.

A. Fibres

Fibre is a small piece of reinforcing material which can be either circular or flat, possessing certain characteristics properties.

B. Fibre Reinforced Concrete

Fibre reinforced concrete (FRC) is a concrete that has fibrous material which improves structural integrity of a concrete. The amount of fibres added to a concrete mix is measured as a percentage of the total volume of the composite termed as fibres Volume Fraction (Vf). The fibre to be incorporated in the concrete is selected based on various factors such as Density, Modulus of Elasticity, Tensile Strength and Aspect Ratio.

The fibres are incorporated in the concrete to produce greater impact strength, bond strength, increase the tensile strength, toughness, ductility, energy absorption capacity and to improve the deformation characteristics of concrete. Due to this the use of FRC has increased during the last two decades and the application includes airport and highway pavements, earthquake resistant structures, mine and tunnel linings, bridge deck over lays, hydraulic structures.

Incorporating fibres into the concrete increases the cost of construction when compared to conventional concrete. This increase in cost is not a matter as the use of fibres into the concrete improves the characteristic of both fresh and hardened concrete.

C. Hybrid Fibre Reinforced Concrete

Hybrid is a cock tail of two or more type of fibres used in a combined form to produce a composite that will have the benefit of each of the individual fibre used. Such a composite of concrete is termed as the Hybrid Fibre Reinforced Concrete (HFRC).

Use of hybrid fibres in concrete arrests the micro cracks and control the formation of macro cracks. The mechanical properties of concrete is enhanced when both metallic and non-metallic type of fibres are introduced into the concrete.

D. Objective

The main objective of the work is to determine the optimum percentage of fibres to be added in the concrete to obtain the maximum Compressive strength and also the Split Tensile strength.

II. MATERIALS AND METHODOLOGY

A. Cement

Ordinary Portland Cement (OPC) manufactured by M/S Ultratech Cement confirming to IS.8112:1989 was used for this experimental study.
Table – I: Properties of Cement

| Physical Properties          | Test Results |
|-----------------------------|--------------|
| Specific Gravity of Cement  | 3.10         |
| Fineness of Cement (%)      | 2%           |
| Consistency of Cement       | 6mm for 35%  |
| Setting Time (Minutes)       |              |
| a) Initial                  | 35 min       |
| b) Final                    | 540 min      |

B. Aggregate

Aggregates are the granular materials like sand, gravel, crushed stone etc which are used along with cement to produce either mortar or concrete.

C. Fine Aggregate

Locally available natural sand which is clean, dry and passing through IS 4.75mm sieve is used as fine aggregate. Tests were carried out to determine the physical properties and are tabulated. The test result conforms to zone II of IS383-1970.

Table – II: Sieve Analysis of Fine Aggregate

| Sl. No | IS sieve number | Weight Retained in | % weight Retained | Cumulative % weight Retained | % of passing |
|--------|-----------------|--------------------|------------------|-----------------------------|--------------|
| 1.     | 4.75            | 10                 | 1                | 1                           | 99           |
| 2.     | 2.36            | 20                 | 2                | 3                           | 97           |
| 4.     | 1.18            | 60                 | 6                | 9                           | 91           |
| 5.     | 600             | 190                | 19               | 28                          | 72           |
| 6.     | 425             | 195                | 19.5             | 47.5                        | 52.5         |
| 7.     | 300             | 300                | 30               | 77.5                        | 22.5         |
| 8.     | 150             | 210                | 21               | 98.5                        | 1.5          |
| 9.     | 90              | 10                 | 1                | 99.5                        | 0.5          |
| 10.    | 75              | 5                  | 0.5              | 100                         | 0            |
| 11.    | pan             | 0                  | 0                | 0                           | -            |

Table – III: Properties of Fine Aggregate

| Properties          | Values Obtained |
|---------------------|-----------------|
| Specific Gravity    | 2.63            |
| Fineness Modulus    | 2.94            |
| Bulk Density        | 10%             |

D. Coarse Aggregate

Crushed granites passing through IS 20mm sieve and retained on IS 12.5mm sieve is used as coarse aggregate. Tests were carried out to determine the physical properties and are tabulated conforming to IS383-1970.

Table – IV: Properties of Coarse Aggregate

| Properties          | Values Obtained |
|---------------------|-----------------|
| Specific Gravity    | 2.69            |
| Fineness Modulus    | 7               |
| Water Absorption    | 0%              |

E. Water

Quality of water affects the strength and hence water which is suitable for drinking is used for mixing and curing of concrete.

F. Super plasticizers

As fibres are used in the concrete mix it affects the workability of concrete. Thus to improve the workability of concrete without increasing the water content, high performance super plasticising admixtures are used. In this work Conplast SP430 complies with BS5075 Part 3 and with ASTM C494 as Type A and Type F is used. It is a chloride free super plasticising admixture based on selected sulphonated naphthalene polymers. It is brown solution which disperses in water.

Table – V: Properties of CONPLAST SP430

| Properties         | Values Obtained |
|--------------------|-----------------|
| Appearance         | Brown liquid    |
| Specific gravity   | Typically 1.20 at 20ºC |
| Chloride Content   | Nil to BS 5075  |

G. Steel Fibres

In this experimental work crimped steel fibres are used to increase the tensile strength and also to control the crack width.

H. Glass Fibres

Chopped strands continuous glass fibres are also used in this work to enhance the mechanical properties of the concrete and to avoid the problem of plastic shrinkage crack which occurs in the early stage. The specification and properties of fibres used in this experimental work are tabulated below.

![Crimped Steel Fibre](Fig.1)

![Shortcut Glass Fibre](Fig.2)
Compressive Strength Test:

M25 grade of concrete is used for this experimental work and it is designed as per IS10262-2009. A mix proportion of 1:1.35:2.65 is obtained with a water cement ratio of 0.45. The quantities of various ingredients needed for this concrete are tabulated below.

| Properties          | Steel Fibre | Glass Fibre |
|---------------------|-------------|-------------|
| Length              | 30mm        | 6mm         |
| Diameter            | 0.5mm       | 0.01mm      |
| Aspect Ratio        | 60          | 600         |
| Density             | 7850 kg/m³ | 2580 kg/m³ |

I. Mix Proportion

Control concrete is prepared without the addition of fibres. Then the fibres are added to the concrete with the volume fraction varying from 0.35% to 1.70% by volume of concrete. The different proportions of fibres added to the concrete are tabulated below with designation for each mix proportion.

| S.No | Mix Proportion | Designation | Steel Fibre % | Glass Fibre % | Volume Fraction % |
|------|----------------|-------------|---------------|---------------|-------------------|
| 1.   | Control concrete | S           | 0             | 0             | 0                 |
| 2.   | S 0.25 G 0.1 | A           | 0.25          | 0.1           | 0.35              |
| 3.   | S 0.25 G 0.2 | B           | 0.25          | 0.2           | 0.45              |
| 4.   | S 0.50 G 0.1 | C           | 0.5           | 0.1           | 0.60              |
| 5.   | S 0.50 G 0.2 | D           | 0.5           | 0.2           | 0.70              |
| 6.   | S 0.75 G 0.1 | E           | 0.75          | 0.1           | 0.85              |
| 7.   | S 0.75 G 0.2 | F           | 0.75          | 0.2           | 0.95              |
| 8.   | S 1.00 G 0.1 | G           | 1.0           | 0.1           | 1.10              |
| 9.   | S 1.00 G 0.2 | H           | 1.0           | 0.2           | 1.20              |
| 10.  | S 1.25 G 0.1 | I           | 1.25          | 0.1           | 1.35              |
| 11.  | S 1.25 G 0.2 | J           | 1.25          | 0.2           | 1.45              |
| 12.  | S 1.50 G 0.1 | K           | 1.50          | 0.1           | 1.60              |
| 13.  | S 1.50 G 0.2 | L           | 1.50          | 0.2           | 1.70              |

J. Methodology

Compressive Strength Test: In order to determine the Compressive strength of the concrete, cube specimens of size 150mmx150mmx150mm were casted using M25 grade concrete. The moulds were filled with concrete containing various proportions of fibres. For each combination six moulds were casted to test them on 7th day and 28th day. The specimens were allowed to set under room temperature and after 24 hours they are demoulded. The demoulded specimens are then transferred to curing tank and allowed to cure for 7 days and 28 days. After the period of curing the specimens were tested on a 2000kN capacity Compression Testing Machine as per IS516-1959. Three cubes were tested for each category and their average value is calculated using the formula,

\[
\text{Compressive Strength (N/mm}^2\text{)} = \frac{\text{Load (N)}}{\text{Area (mm}^2\text{)}}
\]

Split Tensile Strength Test: In order to determine the Tensile strength of the concrete, cylinder specimens of size 100mm diameter and 200mm length were casted using M25 grade concrete. The moulds were filled with concrete containing various proportions of fibres. For each combination six moulds were casted to test them on 7th day and 28th day. The specimens were allowed to set under room temperature and after 24 hours they are demoulded. The demoulded specimens are then transferred to curing tank and allowed to cure for 7 days and 28 days. After the period of curing the specimens were tested on a 2000kN capacity Compression Testing Machine as per IS516-1959. Three cylinders were tested for each category and their average value is calculated using the formula,

\[
\text{Tensile Strength (N/mm}^2\text{)} = \frac{2P}{\pi DL},
\]

Where P = Failure load (N)

\[
D = \text{Diameter of the Cylinder (mm)}
\]

\[
L = \text{Length of the Cylinder (mm)}
\]

III. RESULT AND DISCUSSION

A. Compressive Strength

The results of the compressive strength of the specimen for M25 grade of concrete are shown in table and graph below.

| S.No | Designation | Compressive Strength (N/mm²) |
|------|-------------|-----------------------------|
|      |             | 7th day                     | 28th day                   |
| 1.   | S           | 20.51                       | 25.96                      |
| 2.   | A           | 22.85                       | 28.7                       |
| 3.   | B           | 24.67                       | 31.43                      |
| 4.   | C           | 25.82                       | 33.42                      |
| 5.   | D           | 27.67                       | 35.38                      |
| 6.   | E           | 29.45                       | 37.56                      |
| 7.   | F           | 31.52                       | 38.31                      |
| 8.   | G           | 32.58                       | 40.3                       |
| 9.   | H           | 33.67                       | 42.58                      |
| 10.  | I           | 34.51                       | 43.99                      |
| 11.  | J           | 35.71                       | 45.35                      |
| 12.  | K           | 37.79                       | 48.15                      |
| 13.  | L           | 34.66                       | 42.7                       |
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B. Split Tensile Strength

The results of the compressive strength of the specimen for M25 grade of concrete are shown in table and graph below.

| S.No | Designation | Split Tensile Strength (N/mm²) |
|------|-------------|--------------------------------|
|      |             | 7th day | 28th day  |
| 1    | S           | 2.06    | 2.59     |
| 2    | A           | 2.36    | 3.36     |
| 3    | B           | 2.56    | 3.58     |
| 4    | C           | 2.86    | 3.62     |
| 5    | D           | 3.22    | 3.88     |
| 6    | E           | 3.39    | 4.33     |
| 7    | F           | 3.57    | 4.78     |
| 8    | G           | 3.83    | 5.23     |
| 9    | H           | 4.25    | 5.78     |
| 10   | I           | 4.63    | 6.25     |
| 11   | J           | 5.05    | 6.78     |
| 12   | K           | 5.54    | 7.38     |
| 13   | L           | 4.73    | 6.53     |

IV. CONCLUSION

The effect of hybridization of fibres in concrete on the strength characteristics is experimented and the summary of conclusion is presented in this chapter.

i  Addition of different types of fibres reduces the workability of fresh concrete and hence it is improved by adding super plasticizers.

ii  The maximum compressive strength of 37.79N/mm² on 7th day and 48.15N/mm² on 28th day was obtained for the proportion designated as K which has the hybridization of Steel fibre 1.50% and Glass fibre 0.1% by volume of concrete (S1.50G0.1).

iii The maximum Split Tensile strength of 5.54N/mm² on 7th day and 7.38N/mm² on 28th day was obtained for the proportion designated as K which has the hybridization of Steel fibre 1.50% and Glass fibre 0.1% by volume of concrete (S1.50G0.1).

iv  The increase in tensile strength is due to the high tensile strength of the steel fibre.

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AUTHORS PROFILE

Ms. S.J. Princess Rosaline is working as Assistant Professor in the department of Civil Engineering at Periyar Maniammai Institute of Science and Technology, Vallam, Thanjavur. She completed her Master of Engineering in the field of Structural Engineering from Regional Engineering College, Trichy and Bachelor of Engineering in Civil Engineering from Periyar Maniammai College of Technology for Women, Vallam, Thanjavur, Tamil Nadu. Currently she is doing her research in the area of Hybrid Fibre Reinforced Concrete. She has attended various seminars, workshops and conferences in the field of Structural Engineering.

Dr. R. Jayanthi is Professor & Head of the Department of Civil Engineering at Periyar Maniammai Institute of Science and Technology, Vallam, Thanjavur. She obtained her Doctorate in the field of Geo Environmental Engineering from NIT, Trichy. She completed her Master of Engineering in the field of Geotechnical Engineering from Annamalai University, Chidambaram and Bachelor of Engineering in Civil Engineering from Regional Engineering College, Trichy. Her research area includes Geotechnical Engineering, Ground Water Quality Modeling. She has organized and attended various seminars, workshops and conferences in the field of Environment and Sustainable Technologies. She has also published in reputed international and national journals.