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# PERFORMANCE OF HIGH STRENGTH CONCRETE WITH FIBRE REINFORCEMENT & SILICA FUME

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**Abstract**— The construction industry is facing with increasing demand for the construction of special structures like high-rise buildings, nuclear power plant structures, long-span bridges, offshore drilling platforms, missile launching pads, very deep underground structures etc. For these structures, advanced concrete composites which possess superior performance like high compressive strength, tensile strength, impact resistance, heat resistance and superior durability properties have to be used. With the development of high grade cement and availability of proper mineral admixtures and chemical admixtures it has been made possible to manufacture concrete with compressive strength of 60MPa and this concept has given rise to high-strength concrete [HSC].

In the present study the addition of silica fume and super plasticizers such as Steel fibers and Polyester fibers are used to make M60 Grade concrete and the properties are tested with different test procedures as per IS recommendations.

**Index Terms**— Concrete, Polyesters, Silica fume, Super plasticizers, Steel fibers.

## INTRODUCTION

### General

Concrete is one of the most versatile building materials. It can be cast to fit any structural application. It is readily available in urban areas at relatively low cost. Concrete is characterized by excellent load carrying behavior in compression but also by brittle failure in tension. The advantages to using concrete include high compressive strength, good fire resistance, high water resistance, low maintenance and long service life.

Concrete possesses a very low tensile strength and almost no ductility. Therefore, the utilisation of steel reinforcement is always required, to bridge the cracks and to cope with the tensile forces larger than the tensile capacity of concrete. Use of reinforced concrete makes for a good composite material with extensive applications.

Fiber reinforced concrete is a concrete mix that contains short discrete fibers that are uniformly distributed and randomly oriented. Fiber material can be steel, cellulose, carbon, polypropylene, glass, nylon, and polyester. The amount of fibers added to a concrete mix is measured as a percentage of the total volume of the composite (concrete and fibers) termed volume fraction Vf. Vf typically ranges from 0.1 to 3%.

A composite can be termed as hybrid, if two or more types of fibers are rationally combined in a common matrix to produce a composite that derives benefits from each of the individual fibers and exhibits a synergetic response. This thesis focuses on hybridization of steel and polyester fibers. The main reason for adding steel and polyester fibers is to improve the tensile behavior and to obtain a ductile material in tension.

Concrete is defined as “High strength” solely on the basis of compressive strength at a given age. In the 1970s, before the advent of super plasticizers, concrete mixtures that showed 40MPa or more compressive strength at 28 days were called high strength concrete(HSC). Later, when 60 to120MPa concrete mixtures became commercially available.

In 2002 the ACI Committee on high Strength concrete revised the definition to cover mixtures with a specified design strength of 55MPa or more. Although conventional practice is to specify concrete strength based on the 28 day test result. There is a growing movement to specify the 56 or 90 day strength because many structural elements are not fully loaded for periods as long as two to three months or even longer. When high strength is not needed at an early age.

It is best not to specify it so as to achieve a number of benefits such as cement saving, ability to use relatively large proportions of mineral admixtures and a more durable product.

## HISTORICAL DEVELOPMENT OF HIGH STRENGTH CONCRETE

### General

The problem of construction of structures that are strong as well as durable under water was faced from early times during the progress of human civilization. The Romans used brick dust and volcanic ash with lime to produce hydraulic mortar. Portland cement as is known today was however first visualized by John Smitten who developed a hydraulic mortar by burning a mixture of lime and clay. This took place in about 1756. In the year 1776, James Parker got a patent for producing hydraulic cement by burning modules of clay containing veins of calcareous matter. This was called natural cement. In the year 1816, an unreinforced concrete was developed.

In the year 1824, Joseph Aspden of United Kingdom patented the process to producing cement from lime and clay which when set resembled Portland stone in appearance and this was called Portland cement. In the year 1861, Francis Coignet published a book describing the many application and uses of reinforced concrete. Thus, it is important to note that there was a rapid development in concrete construction and from 1900; steady development took place in concrete construction. Though, in 1930 high strength concrete with 28 days compressive strength of 102MPa was obtained by a combination of compression and vibration process without chemical or mineral admixtures and this isolated development was not followed by systematic development in the production and use of high strength concrete till the mid 1960s and the first exposure to high strength concrete dates back to 1970, when John Binger, of materials service, made a presentation on the high strength concrete, which was delivered in Chicago area. So, in the 1970s, when the compressive strength of the concrete used in the structural members of some high rise buildings was higher than that of the usual concretes used in construction, there is no doubt that it was legitimate to call these new concretes "**High Strength Concretes**".

**Properties of High Strength Concrete**

The properties of high strength concrete are significantly different from those of normal strength concrete. When the concrete is setting and hardening as well as in the hardened state. These properties should be taken in to account while designing structures using high strength concrete

- Setting and hardening
- Heat development
- Shrinkage
- Elastic deformation and crack growth characteristics

**Advantages of using High Strength Concrete**

The main advantages of using high strength concrete are the following:

- Reduction in member size resulting in an increase in the usable floor space, a reduction in the quantity of concrete and consequent reduction construction cost.
- Reduction in self weight and consequent reduction in foundation cost.
- Reduction in the area of the form work and time required for stripping forms.
- The ability to withstand large column loads with reasonable sizes of columns.
- Reduction in axial shortening effect in columns.
- Reduction in floor thickness and beam height
- Lower creep and shrinkage.
- Reduced maintenance cost
- Higher resistance to crack propagation chemical, attack etc.

## PRODUCTION OF HIGH STRENGTH CONCRETE

**Introduction:**

Currently, concretes in practice are produced with more compressive strength. They are made using the same technology as that is normally used to make concretes except that the materials used to make them are carefully selected and controlled cements, aggregates, mineral admixtures and chemical admixtures combined with low water cementitious materials ratios and strict in-situ quality control during production, transportation and placement. A specified workability of concrete can be obtained by adding super plasticizers.

**Classification of Concrete**

The advent of concrete technology techniques has given impetus for making concrete of higher strength. As per our IS 456: 2000 concretes are grouped as ordinary concrete, standard concrete and high strength concrete as given in Table 1.

**Table 1 Group of Concrete as per IS 456: 2000**

| Sl.No | Name of Group of Concrete | Grade Designation |
|---|---|---|
| 1 | Ordinary concrete | M10 to M20 |
| 2 | Standard concrete | M25 to M55 |
| 3 | High strength concrete | M60 to M80 |

## TYPES OF MIXES

### Nominal Mixes

In the past the specifications for concrete prescribed the proportions of cement, fine and coarse aggregates. These mixes of fixed cement aggregate ratio which ensures adequate strength are termed nominal mixes. These offer simplicity and under normal circumstances, have a margin of strength above that specified. However, due to the variability of mix ingredients the nominal concrete for a given workability varies widely in strength.

### Standard Mixes

The nominal mixes of fixed cement aggregate ratio (by volume) vary widely in strength and may result in under or over rich mixes. For this reason, the minimum compressive strength has been included in many specifications. These mixes are termed standard mixes. IS 456: 2000 has designated the concrete mixes into a number of grades as M10, M15, M20, M25, M30, M35 and M40. In this designation the letter M refers to the mix and the number to the specified 28 day cube strength of mix in $N/mm^2$. The mixes of grades M10, M15, M20 and M25 correspond approximately to the mix proportions (1:3:6), (1:2:4), (1:1.5:3) and (1:1:2) respectively.

### Designed Mixes

In designed mixes the performance of the concrete is specified by the designer but the mix proportions are determined by the producer of concrete, except that the minimum cement content can be laid down. This is most rational approach to the selection of mix proportions with specific materials in mind possessing more or less unique characteristics.

The approach results in the production of concrete with the appropriate properties of most economically. However, the designed mix does not serve as a guide since this does not guarantee the correct mix proportions for the prescribed performance.

For the concrete with undemanding performance nominal or standard mixes (prescribed in the codes by quantities of dry ingredients per cubic meter and by slump) may be used only for very small jobs, when the 28 day strength of concrete does not exceed 30 $N/mm^2$.

### Selection of materials

It is necessary to get the maximum performance out of all of the materials involved in producing HSC. It must, however, be remembered that prediction with any certainty as to how they will behave when combined in a concrete mixture is not feasible. Particularly while attempting to produce HSC, any material incompatibilities will be highly detrimental to the finished product. Thus, again the culmination of any mix design process must be the extensive testing of trial mixes.

### Types of Fibers:

Concrete is the most widely used structural material in the world is prone to cracking for a variety of reasons These reasons may be attributed to structural, environmental or even economics factors. The most of the cracks are formed due to the weakness of the material to resist tensile forces. When concrete shrinks and it is restrained, it will crack. Steel fiber reinforcement offers a solution to the problem of cracking by making concrete tougher and more ductile. The addition of steel fibers to conventional plain or reinforced and prestressed concrete member at the time of mixing production in parts strength, performance and durability of concrete.

The weak matrics when reinforced with steel fibers uniformly distributed in its entire mask, render the matrix to behave as a composite material with properties significantly different from conventional concrete. The randomly oriented steel fibers assist in controlling the propagation of micro-cracks present in the matrix. First by improving the overall cracking resistance of the matrix and later by bridging across even smaller cracks formed after the application of load on to the member, preventing the major cracks.

### Steel Fibers

Steel fibers uses in concrete are available in a variety of shapes, sizes and metal types. Many fibers with round, rectangular and crescent shaped cross sections are commercially available. They range in ultimate strength from 345 to 2070 MPa. Fiber sizes range from 13 mm x 0.25 mm to 64 x 0.76 mm. Fibers with hooked or deformed ends could be used in smaller quantities because they develop higher pullout resistance. Fibers with large surface area, square or rectangular as compared to round, have more concrete bonding area. Fiber contents in construction projects have typically ranged from 0.5% to 2.0% by volume. Higher percentages of fibers have been generally used with straight fibers.

### Acrylic Fibers

Acrylic fibers contain at least 85% by weight of acrylonitrile units. Generally, acrylic fibers used in the textile industry have a tensile strength ranging from 207 to 245Mpa. These fibers have tensile strengths of up to 1000MPa.

### Carbon Fibers

Carbon fibers were developed primarily for their high strength and stiffness for applications in aerospace industry. These fibers are manufactured as either high modulus fibers or high tensile strength fibers. Carbon fibers help to increase the tensile strength and elastic modulus of concrete. These fibers are inert in aggressive environments, abrasion resistant and stable at high temperatures with relatively high stiffness. The uniform dispersion of carbon fibers in concrete is more difficult than the other fiber types.

**Aramid Fibers**

Aramid fibers have relatively high tensile strength and a high tensile modulus. The strength of aramid fiber is unaffected by temperature up to 200º C and creep resistant.

**Glass Fibers**

Commonly used glass fibers are round and straight and have diameters of 0.005 to 0.015 mm, but these fibers may be bonded together to produce glass fiber elements with diameters of 0.013 to 1.3 mm. The strength of glass fiber is comparable to that of steel fiber, its density is lower, and its elastic modulus is about one third of steel. The major application of glass fiber has been the spray-up process in which the glass fibers and a cement rich mortar are sprayed simultaneously on a surface.

**Polyolefin Fibers**

Synthetic polymeric fibers are derived from organic polymers. The common forms of fibers are smooth monofilament, twisted, fibrillated and three dimensional mat. The monofilaments were of geometry, size and shape similar to that of which were commercially available in steel and glass; approximate diameter of 0.25 mm and 12 to 50 mm long, with an aspect ratio of 50 to 100. Dosage rates varied from 0.1 to 2.0% by volume. Polyolefin fiber is produced in mono filament form from a homo polymeric resin and a hydrophobic special surface treatment has been given to improve to mechanical bond between the polyolefin fiber and the concrete matrix. These fibers are available in various lengths and diameters and they are added to improve the structural properties of concrete like steel fibers.

**Polyester Fibers**

A polyester fiber in the compressive region of reinforced concrete beams provides high strength, ductile concrete at reasonable cost. Polyester prevents the micro shrinkage cracks developed during hydration, making the structure/plaster/component inherently stronger. Further, when the loads imposed on concrete approach that of failure cracks will propagate, sometimes rapidly. Commonly used polyester fiber available in market is 6mm and 12mm fibers. 6mm is used for plastering works and 12mm fibers are used for concrete and reinforced concrete works.

**Supplementary cementing materials**

**Silica fume**

Silica fume, also referred to as micro silica or condensed silica fume, is another material that is used as an artificial pozzolanic admixture. Silica fume as an admixture in concrete has opened up one more chapter on the advancement in concrete technology. The use of it, in conjunction with super plasticizer has been the backbone of modern HSC. Though it is possible to make high strength concrete without silica fume at compressive strengths up to about 95 MPa, beyond this strength level, however, silica fume becomes essential, and even at lower strength (65-95 MPa) it is easier to make HSC with silica fume than without it. Thus when it is available at a reasonable price, silica fume should generally be a component of the HSC mix.

**Super Plasticizer**

In modern concrete practice, it is essentially impossible to make HSC adequate workability in the field without the use of super plasticizers. There is no a priori way of determining the required super plasticizers dosage; it must be determined, in the end, by some sort of trail and error procedure. Unfortunately, different super plasticizers will behave quite differently with different cements (Even cements of normally the same type). This is due in part to the variability in the minor components of the cement, (which are not generally specified), and in part to the acceptance standards for super plasticizers themselves are not very clearly written.

Most of the commercial formulations belong to one of four Families:

- Sulfonated melamine-formaldehyde condensates (SMF)
- Sulfonated naphthalene-formaldehyde condensates (SNF)
- Modified lignosulfonates (MLS)
- Polycarboxylate derivative super plasticizers.

## MATERIALS USED AND WORK METHODOLOGY

**General**

In the results of an experimental investigation which carried out on the effect of fibers on high strength concrete interms of compressive, split tensile, flexural properties and ductility and improvement by testing control specimens. The performance of high strength reinforced concrete beam with and without fibers by flexure test, under two point loading. Two types of steel fibers are used in high strength concrete beams are steel fiber and polyester fiber.

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## Materials Used

### Cement

In entire investigation Ordinary Portland Cement (OPC 53 grade) was used**.** The physical properties of cement tested according to Indian standards procedure confirm to the requirements of IS: 12269. Its physical properties are given in table 5.1.

The specific gravity of cement was found in the laboratory by using Pyconometer and other accessories the test was done on the sample thrice the average of which reported the result as 3.15

**Table 2 Physical Properties of Cement**

| Sl. No. | Descriptions | Results obtained |
|---|---|---|
| 1. | Fineness (retained on 90-mm sieve) | 4.5 |
| 2. | Normal consistency | 32% |
| 3. | Initial setting time(min) | 120 |



### Fine Aggregate

River sand, (Grading zone-II conforming to IS: 383-1987) was used as fine aggregates in the experimental investigation. The specific gravity (G) of soil grains (or solids) usually called soil is the ratio of the weight in air of the given volume of dry soil solids at a stated temperature to the weight in air of an equal volume of distilled water at a stated temperature.

The specific gravity of sand was found in the laboratory by using Pyconometer and other accessories the test was done on the sample thrice the average of which reported the result as 2.56

### Coarse Aggregates

Two sizes of coarse aggregates were used in this project i.e. 20mm graded aggregate as per IS: 383, and 10mm graded aggregate as per IS: 383 was used. The specific gravity (G) of Coarse aggregate usually called Coarse aggregate is the ratio of the weight in air of the given volume of dry Coarse aggregate at a stated temperature to the weight in air of an equal volume of distilled water at a stated temperature.

The specific gravity of coarse aggregate was found in the laboratory by using Pyconometer and other accessories the test was done on the sample thrice the average of which reported the result as 2.6

### Water

Water is an important ingredient of concrete as it's actively participates in chemical reactions with concrete. Since it helps to form the strength giving cement gel. The quantity of water added carefully.

### Silica Fume

Silica fume, also referred to as microsilica or condensed silica fume, is another material that is used as an artificial pozzolanic admixture. The use of silica fume with super plasticizer has been the backbone of modern HSC. Though it is possible to make high strength concrete without silica fume at compressive strengths up to about 95MPa, beyond this strength level, however, silica fume becomes essential. Even at lower strength (65-95MPa) it is easier to make HSC with silica fume than without it. Thus when it is available at a reasonable price, silica fume should generally be a component of the HSC mix. Its physical and chemical properties are given Table 5.2.

**Fig. 1 Silica Fume**

**Table 3 Properties of Silica Fume**

| Sl.No | Mandatory Chemical and Physical Requirements | Standard Value |
|---|---|---|
| 1 | Silicon dioxide($SiO_2$) | min. 85.0% |
| 2 | Loss on ignition (LOI) | max. 2.0% |
| 3 | Moisture content % | max. 2.0% |
| 4 | Percent retained on 45μm | max. 3.0% |
| 5 | Pozzolanic activity index - 7days accelerated curing<br>Bulk density | min. 105%<br>650kg/m³ |

### Superplasticizer

Sulphonated Naphthalene Formaldehyde (SNF) based in a liquid form was used in all the concrete mixtures. This superplasticizer ideally used for ready mix concrete industries. Reduction of water cement ratio of the order of 20-25% can results in high early compressive strength and workability.

**Fiber**

In this investigation two types of fiber was used its namely steel fiber and polyester fiber. The fibers are added in concrete at volume fraction of 1.5% with combination of steel-polyester at 100%-0%, 0%-100%, 70%-30% and 30%-70%. The properties of steel fibers and polyester fibers are shown in Table 5.3 and 5.4 respectively.

**Fig. 2 Steel Fiber**

**Table 5 Properties of Steel Fiber**

| SI.NO | Properties | Steel Fiber |
|---|---|---|
| 1 | Length(mm) | 30 |
| 2 | Diameter(mm) | 0.5 |
| 3 | Aspect ratio (l/d) | 60 |
| 4 | Specific gravity | 7.8 |
| 5 | Tensile strength(MPa) | 1009.02 |
| 6 | Elastic modulus(GPa) | 200 |

**Fig. 3 Polyester Fiber**

**Table 4 Properties of Polyester Fiber**

| SI.NO | Properties | Polyester |
|---|---|---|
| 1 | Length(mm) | 12 |
| 2 | Diameter(mm) | 0.05 |
| 3 | Aspect ratio (l/d) | 240 |
| 4 | Specific gravity | 1.35 |
| 5 | Tensile strength(MPa) | 970 |
| 6 | Elastic modulus(GPa) | 15 |

**Reinforcement Details for Beam**

The size of the beam is 1000 x 150 x 250mm and the beam designed as singly under reinforced section and the reinforcement provided is 2 nos. of 12mm diameter at bottom as main reinforcement and 2 nos. 10mm diameter at top and the grade of steel used Fe 415. The minimum shear reinforcement provided as 8mm diameter stirrups at spacing of 120mm centre to centre. The reinforcement rods confirming to IS: 432 and IS: 1786-1985 for mild steel and for Tor steel had been used respectively. The reinforced beams where analyzed by limit state method.

**Mix Proportion**

Advanced concrete composites which possess superior performance like high compressive strength, tensile strength, impact resistance, heat resistance and superior durability properties. With the development of high grade cement and availability of proper mineral admixtures and chemical admixtures it has become made possible to manufacture concrete with compressive strength of 60MPa. The mix proportion was shown in Table 5.5 and the mix ratio is **1: 1.35 :2.19 :0.29.**

**Table 6 Concrete Mix Proportions used in the Testing Program**

| Sl.NO | Material | Quantity (Kg/m3) |
|---|---|---|
| 1 | 53 Grade Cement | 478 |
| 2 | Sand | 683.24 |
| 3 | Coarse aggregate<br>20 mm size<br>10 mm size | 664<br>443 |
| 4 | Water | 141.6 |
| 5 | Silica fume | 26 |
| 6 | Hyper plasticizer | 12 |

**Experimental Procedure**

**Preparation and Casting of Test Specimens**

The concrete mix proportions used in the testing program. In the preparation of concrete pan mixer is used and the constituent materials were initially mixed without fibers. The fibers were then added in small amounts to avoid balling of fibers and to produce concrete with uniform material consistency and good workability. The steel fiber reinforced concrete and hybrid fiber reinforced concrete (combination of steel and polyester fibers) at volume fraction of 1.5% specimen were placed into moulds and a vibrator was used to decrease the amount of air bubbles. The specimens were demolded after 24 hours and then placed in a curing tank for 28 days and the specimens were removed from curing tank and allowed to air dry 12 hours prior to test.

For 150 mm x 300 mm cylindrical specimen, 150 mm cubes and 100 mm x 100 mm x 500 mm beams 1000 x150 x 250mm were prepared and tested for there strength properties. The compressive strength test was carried out in a standard manner in compression testing machine as shown in Fig. 5.7. The split tensile test on the cylinder specimens was conducted as shown in Fig. 5.5. The flexural strength test was conducted on prismatic beam specimens under two point loading as shown in Fig.4 .

**Fig. 3 Test Setup for Split Tensile Strength**

**Fig. 4 Test Setup for Flexural Strength**



**Fig. 5 Test Setup for Compressive Strength**

**RESULTS AND DISCUSSIONS**

**STRENGTH OF CONCRETE**

The strength of concrete is very important factor. Concrete is used as a structural element, and all structural uses are associated with compressive strength. The strength of concrete is defined as the resistance that concrete provides against load so as to avoid failure. The strength depends on the

i. Water-cement ratio
ii. Aggregate size
iii. Compaction
iv. Curing etc…

**COMPRESSIVE STRENGTH**

Fig. 5.7 shows effect of fibre volume on compressive strength of HSC of 60MPa. The compressive strength development of HSC and of steel fibre and polyester fibre provided an improvement at 1.5% volume fraction. From the strength effectiveness in Table 6.1 The compressive strength of steel fibre is 13.79% and in combination of steel and polyester of 70-30 is 16.93%.

**Table 8 Compressive Strength for Fibre Reinforced Concrete**

| Designation | Fibre Volume (%) | | | Compressive Strength (MPa) | |
|---|---|---|---|---|---|
| | Steel Fibre | Polyester Fibre | Total | Measured Value | Strength Effectiveness (%) |
| S0P0 | 0 | 0 | 0 | 68 | 0 |
| S0P100 | 0 | 1.50 | 1.5 | 69.01 | 1.49 |
| S30P70 | 0.45 | 1.05 | 1.5 | 74.32 | 9.29 |
| S100P0 | 1.5 | 0 | 1.5 | 77.38 | 13.79 |
| S70P30 | 1.05 | 0.45 | 1.5 | 79.51 | 16.93 |



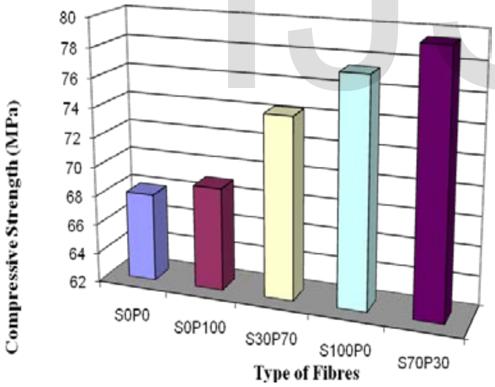


**Fig. 6 Effect of Fiber on Compressive Strength**

**SPLIT TENSILE STRENGTH**

The split tensile strength of all the fibrous concrete in this investigation was significantly higher than of plain concrete. The development of split tensile strength is shown in Fig.6.2 and the strength effectiveness in Table 6.2, the improvement started from 6.12 % to 27.04 %. The polyester fibre has the maximum value of 9.95% and whereas the steel with polyester showed (S70P30) 27.04%.

**Table 7 Spilt Tensile Strength for Fibre Reinforced Concrete**

| Designation | Fibre Volume (%) | | | Splitting Tensile Strength (MPa) | |
|---|---|---|---|---|---|
| | Steel Fibre | Polyester Fibre | Total | Measured Value | Strength Effectiveness (%) |
| S0P0 | 0 | 0 | 0 | 3.92 | 0 |
| S0P100 | 0 | 1.5 | 1.5 | 4.31 | 9.95 |
| S30P70 | 0.45 | 1.05 | 1.5 | 4.67 | 19.13 |
| S100P0 | 1.50 | 0 | 1.5 | 4.16 | 6.12 |
| S70P30 | 1.05 | 0.45 | 1.5 | 4.98 | 27.04 |

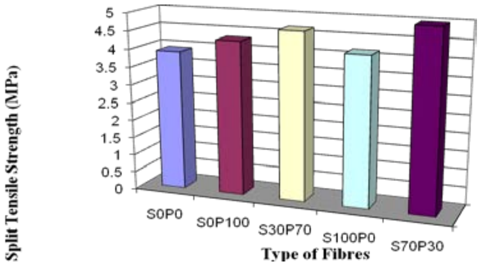


**Fig. 7 Effect of Fiber on Split Tensile Strength**

**Flexural Strength**

The flexural strength for HSC is shown in Fig.6.3 The strength effectiveness are presented in Table 6.3 indicates that the values of all fibrous concrete were significantly higher than of high strength control concrete. From the strength effectiveness in Table 6.3, the improvement started from 15.58% to 37.54%. The polyester fibre (S70P30) shows 37.54% increase in strength effectiveness.

**Table 9 Flexure Strength for Fibre Reinforced Concrete**

| Designation | Fibre Volume (%) | | | Flexural Strength (MPa) | |
|---|---|---|---|---|---|
| | Steel Fibre | Polyester Fibre | Total | Measured Value | Strength Effectiveness (%) |
| S0P0 | 0 | 0 | 0 | 6.74 | 0 |
| S0P100 | 0 | 1.5 | 1.5 | 7.79 | 15.58 |
| S30P70 | 0.45 | 1.05 | 1.5 | 8.75 | 29.82 |
| S100P0 | 1.50 | 0 | 1.5 | 8.18 | 21.36 |
| S70P30 | 1.05 | 0.45 | 1.5 | 9.27 | 37.54 |

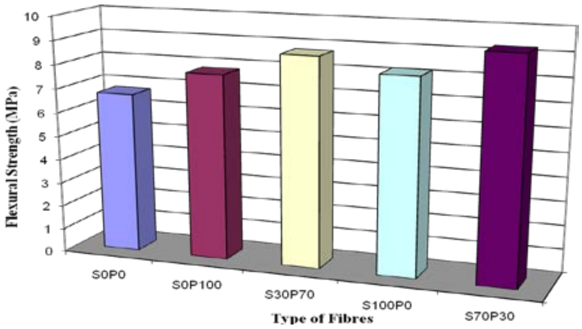


**Fig 8 Effect of Fibre on Flexure Strength**

**Beam Results**

The data obtained from experimental investigations on the ultimate load, yield load, ultimate, yield deflection and ductility are presented in the following sections for beams with and without fibers. The load deflection behaviour of the beam specimens and the effect of fibre material on its flexural behaviour for HSC are also presented.

The performance parameters of yield and ultimate load, yield and ultimate deflection, presented in Tables 6.4 & 6.5.

**Yield Load and Yield Deflection**

The experimental yield loads were obtained (by inspection) corresponding to the stage of loading beyond which the load-deflection response was not linear. It can be inferred from the test results furnished in Table 6.4 and Figs. 6.4 and 6.5 that the load carrying capacity increases with increase in fibre content. The high strength hybrid fibre reinforced concrete beams show fairly high yield loads with reasonable yielding plateaus when compared to the steel fibre reinforced concrete as well as conventional beam. The yield load for beams ranges from 21.52 kN to 36.67 kN. The maximum yield load was found to be 70.40% with 1.50% high strength hybrid fibre content when compared to the conventional beam and 57.90% when compared with specimens consisting of 100% steel fibers.

The deflection characteristics of the reinforced concrete beams improved much with the addition of fibers. These influences were more pronounced for reinforced concrete beams with high strength hybrid fibers. From the test results, it can be observed that the high strength hybrid fibre reinforced concrete beams exhibit increase in deflection with increase of fibre content at all load levels when compared to the conventional beam. The increase in yield deflection was found to be 41.37% with 1.50% high strength hybrid fibre content when compared to the conventional beam and 29.67% when compared with specimens consisting of 100% steel fibers.

**Table 10 Yield Load and Yield Deflection**

| Sl. No. | Specimen Designation | Yield Load (kN) | Deflection (mm) |
|---|---|---|---|
| 1. | S0P0 | 21.52 | 16.75 |
| 2. | S0P100 | 31.09 | 17.84 |
| 3. | S30P70 | 32.80 | 18.89 |
| 4. | S100P0 | 33.98 | 21.72 |
| 5. | S70P30 | 36.67 | 23.68 |

**Ultimate Load and Ultimate Deflection**

The experimental ultimate loads were obtained corresponding to the stage of loading beyond which the beam would not sustain additional deformation at the same load intensity. It can be inferred from the test results furnished in Table 6.5 that the load carrying capacity increases with increase in fibre content. The increase in ultimate load was found to be 50.51% with 1.50% hybrid fibre content when compared to the conventional beam and 30.98% when compared with specimens consisting of 100% steel fibers. The experimental results clearly indicate that the addition of fibers considerably enhances the load carrying capacity of the beams.

The increase in ultimate deflection was found to be 59.93% with 1.50% hybrid fibre content when compared to the conventional beam and 41.02% when compared with specimens consisting of 100% steel fibers.

**Table 11 Ultimate Load and Ultimate Deflection**

| Sl. No. | Specimen Designation | Ultimate Load (kN) | Ultimate Deflection (mm) |
|---|---|---|---|
| 1. | S0P0 | 32.41 | 16.87 |
| 2. | S0P100 | 38.29 | 20.19 |
| 3. | S30P70 | 40.37 | 22.57 |
| 4. | S100P0 | 42.45 | 23.79 |
| 5. | S70P30 | 48.78 | 26.98 |

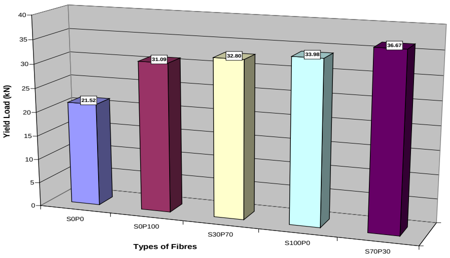


**Fig.9 Yield Load**

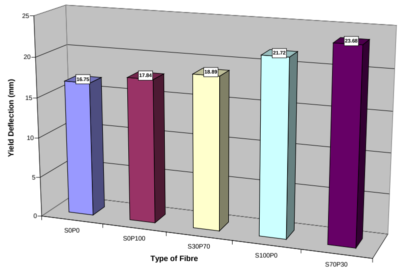


**Fig.10 Yield Deflection**

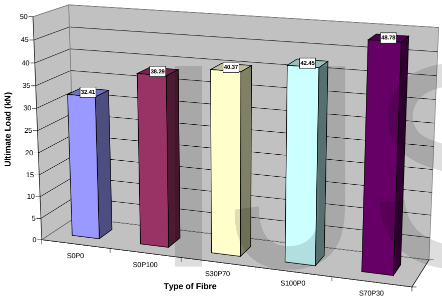


**Fig.11 Ultimate Load**

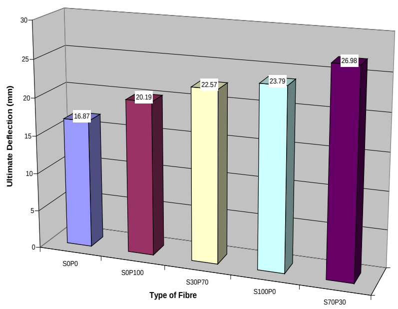


**Fig 12 Ultimate Deflection**

**LOAD DEFLECTION RESPONSE**

Load deflection curves are a standardized method of quantifying the energy which a beam absorbs during its load induced flexural deflection. The area under the curve represents the energy absorbed by the beam. These curves were drawn using the data from static flexure test. A significant difference in the behaviour of plain and fibre reinforced concrete beams is found in the flexure test. When the fibre concrete beams are loaded in flexure, two stages of behaviour have been observed in the load-deflection curve (Figs. 6.8 to 6.12). These curves show a linear variation in the initial stages of loading and then the curves are significantly non-linear and reach its peak at the ultimate strength or at the maximum sustainable load.

Two factors that significantly influence the flexural strength are the fibre type and fibre volume.The steel fibers effectively arrest large deformations and crack widths where as polyester fibers control crack initiation and propagation of small cracks. The mode of failure was a simultaneous yielding of the fibers and the matrix. Fibers, when added in significant volume fraction increase the strength and ductility of concrete. In all the fibre reinforced concrete beams, deflections were increased at all stages of loading.

The final failure of the beam was characterized by large strains in the steel reinforcement and substantial deflection near collapse accompanied by extensive cracking. An overall evaluation of the flexural test results and load-deflection curves indicate that hybrid fibre reinforced concrete exhibit higher load carrying capacity and ductility.

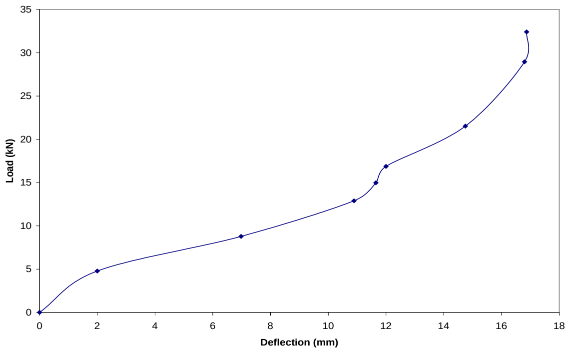


**Fig.13 Load Deflection Behaviour of S0P0**

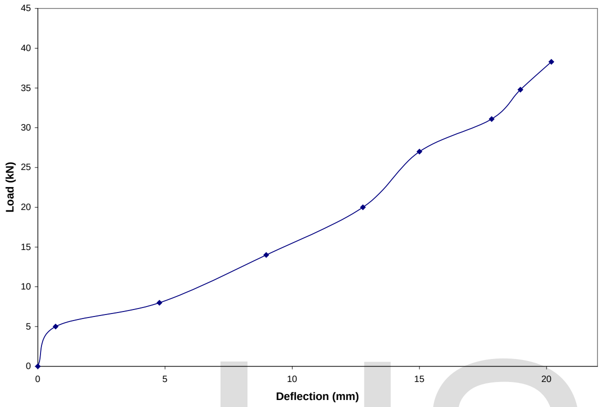


**Fig.14 Load Deflection Behaviour of S0P100**

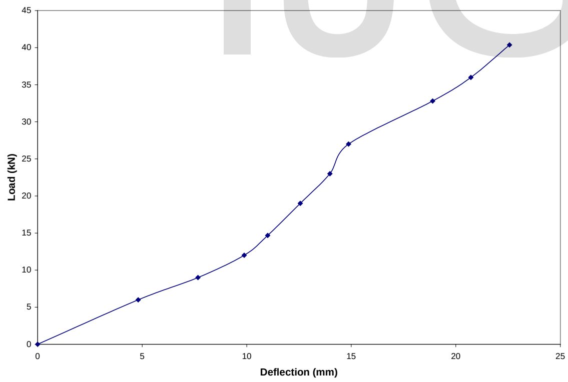


**Fig.15 Load Deflection Behaviour of S30P70**

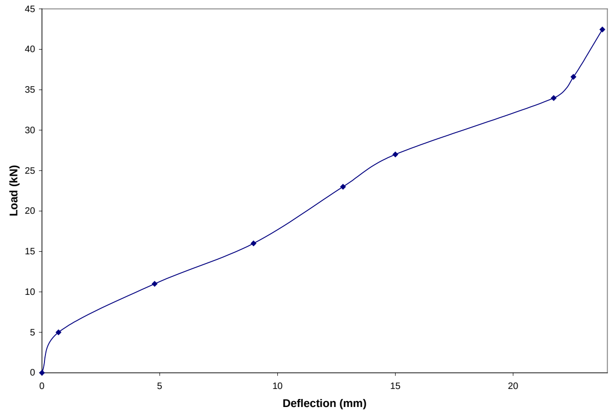


**Fig 16 Load Deflection Behaviour of S100P0**

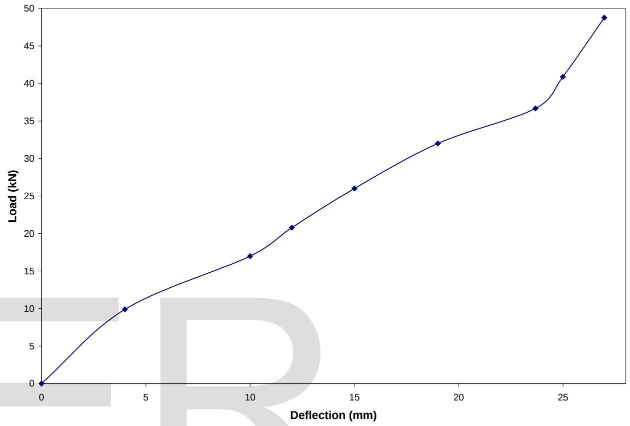


**Fig.17 Load Deflection Behaviour of S70P30**



## CONCLUSION

Based on the test results of this investigation, the following conclusions are drawn:

1. Addition of fibers in concrete improves strength when compared to the plain concrete.
2. The overall performances of reinforced concrete improved by adding of 1.50% with 70-30 steel polyester when compare with other proportions and conventional concrete.
3. An overall evaluation of the flexural test results and load deflection curves indicate that hybrid fiber reinforced concrete exhibit higher load carrying capacity.
4. The maximum yield load was found to be 70.40% with 1.50% high strength hybrid fiber S70P30 and 57.90% are found to be S100P0 mix when compare with conventional beam.
5. The increase in yield deflection was found to be 41.37% with 1.50% high strength hybrid fiber content when compared to the conventional beam and 29.67% when compared with specimens consisting of 100% steel fibers.
6. Ultimate load was found to be 50.51% with 1.50% hybrid fibre content when compared to the conventional beam and 30.98% when compared with specimens consisting of 100% steel fibers.
7. Ultimate deflection was found to be 59.93% with 1.50% hybrid fibre content when compared to the conventional beam.
8. The strength effectiveness at volume fraction of 1.5% for S70P30 showed a maximum for flexural strength, followed by split tensile strength and compressive strength.
9. From the experimental results clearly indicates that the addition of fibers enhances the load carrying capacity of beam when compared to the conventional beam. In that fiber mix particularly, S70P30 produces enhanced upshot.

**SCOPE FOR FURTHER STUDY**

1. The Ultra high strength concrete beam with fibre volume fraction can be optimized for steel and polyester fibre.
2. The different types and different combination of fibers can be analyzed.

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