AIJREAS VOLUME 2, ISSUE 2 (2017, FEB) (ISSN-2455-6300) ONLINE
ANVESHANA'S INTERNATIONAL JOURNAL OF RESEARCH IN ENGINEERING AND APPLIED SCIENCES

HYBRID FIBER REINFORCE CONCRETE WITH LATEX AS POLYMER MATRICES

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INTRODUCTION

Concrete is acknowledged to be a relatively brittle material when subjected to normal stresses and impact loads, where tensile strength is approximately just one tenth of its compressive strength. As a result for these characteristics, concrete flexural members cannot support such loads that usually take place during their service life. Historically, concrete came to be reinforced with continuous reinforcing bars to withstand tensile stresses and to compensate for the lack of ductility and strength.

When the concrete is being stressed, the individual cracks tend to grow and it will result in the extensive cracking of concrete. The strain energy applied to the hardened concrete dissipates by opening up of the cracks and creating new surfaces. The cracks in the concrete are very sharp and there will be stress concentration at the end of the tips. More energy is required for propagation of cracks into the hardened cement paste than around the coarse aggregate. Due to the sharpness of the cracks in the concrete the rate of propagation of the cracks is higher than ductile material. That is why the concrete possesses lower strain level at failure.

The propagation of the crack in the concrete is perpendicular point to the principal tensile stress acting at that point .This is the case both in compression and tension. In the direct tension, cracks open up in a plane perpendicular to the direction the load applied. In the compression, the cracks open up due to lateral strain which induces the tensile stress. With increasing compressive stress, the lateral strain increases and the energy gets dissipated by the propagation of cracks creating new surfaces. Then the failure takes place by splitting of the concrete.

There are strong indications that it is not a limiting stress but the limiting tensile strain that determines the strength of the concrete under static loading. Due to this reason the concrete reaches limiting tensile strain much earlier in direct tension test than in compression .this is how the concrete possess lower tensile strength which is about 8 to 10% of compressive strength. Therefore the ductility and tensile strength of concrete are the two major draw backs in the concrete.

A significant consideration that may have to be added to strength and serviceability is ductility. It is important to ensure that in the extreme event of a structure being loaded to failure, it will behave in a ductile manner. This means ensuring that the structure will not fail in a brittle fashion without warning but will be capable of large deformations at near maximum load carrying capacity. The ductile behavior of members enables the use in design of distributions of bending moments that take into account the redistribution possible from the elastic bending moment pattern.

Ductility becomes an important consideration in areas requiring design for seismic loading. This is because the present philosophy of codes for seismic loading is to design structures to resist only relatively moderate earthquakes elastically; in the case of a severe earthquake, reliance is placed on the availability of sufficient ductility after yielding to enable a structure to survive without collapse. Hence the recommendations for seismic loading can be justified only if the structure has sufficient ductility to absorb and dissipate energy by post elastic deformations when subjected to several cycles of loading well into the yield range.

To ensure ductile behavior designers should give special attention to details such as longitudinal reinforcement contents, anchorage of reinforcement and confinement of compressed concrete, ensuring that all brittle types of failure are avoided.

The ductility of concrete can be improved by various methods

1. Confinement of concrete using tie stirrups.
2. Mechanical method by adding fibers to concrete to arrest the crack propagation.
3. Chemical method by adding polymers to the concrete to delay the crack propagation.
4. by adding fibers and polymers to the concrete to improve toughness and strain capacity.

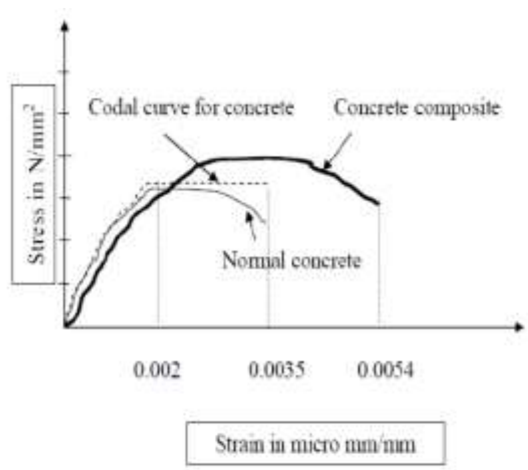


Fig: Sample stress-strain curve of normal concrete and fiber reinforced concrete

LITERATURE REVIEW

M.C. Nataraj, N. Dhang, A.P. Gupta [1999] an attempt has been made to generate the complete stress-strain curve experimentally for steel-fiber reinforced concrete for compressive strength ranging from 30 to 50 MPa. Round crimped fibers with three volume fractions of 0.5%, 0.75% and 1.0% (39, 59, and 78 kg/m3) and for two aspect ratios of 55 and 82 are considered. The effect of fiber addition to concrete on some of the major parameters namely peak stress, strain at peak stress, the toughness of concrete and the nature of the stress-strain curve is studied. A simple analytical model is proposed to generate both the ascending and descending portions of the stress-strain curve. There exists a good correlation between the experimental results and those calculated based on the analytical model.

Addition of crimped steel-fibers to concrete increases the toughness considerably. The increase in toughness is directly proportional to the reinforcing index. Increase in toughness is marginally higher for lower grade of concrete compared to higher grade of concrete. A marginal increase in compressive strength, strain at peak stress is also observed. This increase is directly proportional to the reinforcing index.

By Jean-Francois Trottier and Nemkumar Banthia[2002] an experimental program in which four deformed commercial fibers with widely different geometries was investigated in steel fiber reinforced concrete. Three matrices with compressive strength of 42, 52, and 85 MPa were reinforced with fibers at a dosage rate of 40 Kg/m3. Compressive and flexural strength are measured were studied for different geometries along with elastic modulus. For the fibers and the matrices investigated, a strong influence of both geometry and matrix strength on toughness characteristics of fiber reinforced concrete were observed. End deformed bars were in general found to be superior to deformed bars throughout the length.

S. A. MAHADIK, S. K. KAMANE, A. C. LANDE [2014] studied the effect of steel fibers on compressive strength and flexural strength of concrete by varying percentages of steel fibers.

An experimental program includes two phases. The first consists of high strength concrete mix design for grade of M40 by using IS 10206-1982 whereas the second phase consists of casting and testing of 15 concrete beam specimens with different percentage of steel fibers (0%, 0.5%, 0.75% & 1% by volume of concrete) for flexural strength of concrete and it also consists of casting and testing of 15 concrete cubes with different percentage of steel fibers (0%, 0.5%, 0.75% & 1% by volume of concrete) for compressive strength of concrete. For each percentage of steel fiber three beams and three cubes were casted.

It has been observed that the flexural strength of concrete for the beams with steel fibers 0.25%, 0.50%, 0.75% and 1% is more than that of beam without steel fibers. This may be due to the fact that the steel fibers will effectively hold the micro cracks in concrete mass. The percentage increase in the flexural strength for the beams with steel fibers 0.25%, 0.50%, 0.75% and 1% compared to the beams without steel fibers are +27.92%, +38.33%, +43.29%, and +34.19% respectively. The percentage increase in the compressive strength for the cubes with steel fibers 0.25%, 0.50%, 0.75% and 1% compared to the cubes without steel fibers are 11.56%, 21.05%, 24.15% and 10.52% respectively.

It can be concluded that the use of steel fibers is an effective method to improve the flexural & compressive strength of concrete. To get the maximum benefit it is recommended to use steel fibers 0.75% by volume of concrete. More percentage of steel fibers will have the workability problem & also air cavities are left in the system.

C.X. Qian, P. Stroeven[2000] To provide a hybrid reinforcement, in which the durability of fiber types is different. The presence of the durable fiber can increase the strength and/or toughness retention after age while another type is to guarantee the short-term performance during transportation and installation of the composite elements. The different sizes of steel fibers contributed to different mechanical properties, at least to a different degree. Additions of a small fiber type had a significant influence on the compressive strength, but the splitting tensile strength was only slightly affected. A large fiber type gave rise to opposite mechanical effects, which were further fortified by optimization of the aspect ratio. This effect of (steel) fiber size is due to the different cracking densities provoked by the different testing modes.

Chunxiang Qian, Piet Stroeven[2000] discusses polypropylene fibers and three sizes of steel fibers reinforced concrete. The total fiber content ranges from 0% to 0.95% by volume of concrete. A four-point bending test is adopted on the notched prisms with the size of 100 *100* 500 mm3 to investigate the effect of hybrid fibers on crack arresting. The research results show that there is a positive synergy effect between large steel fibers and polypropylene fibers on the load-bearing capacity and fracture toughness in the small displacement range. But this synergy effect disappears in the large displacement range. The large and strong steel fiber is better than soft polypropylene fiber and small steel fiber in the aspect of energy absorption capacity in the large displacement range.

N. Banthia, M. Sappakittipakorn[2007] An experimental program was carried out to investigate if the toughness of FRC with long fibers can be enhanced by hybridization with smaller fibers while maintaining workability, fiber dispensability and low cost. The results show that such hybridization indeed is a promising concept and replacing a portion of the large fibers with smaller fibers can significantly enhance toughness. One type of fiber is stronger and stiffer and provides reasonable first crack strength and ultimate strength, while the second type of fiber is relatively flexible and leads to improved toughness and strain capacity in the post-crack zone.

Glavind and Aarre[1991] tested steel and polypropylene fiber hybrids and reported that hybridization of these two fibers increased the ultimate compressive strain of the composite. Larsen and Krenchel combined steel and polypropylene fibers in cementitious composites and found that after 10 years of outdoor exposure the fracture energy of composites containing two fibers increased by approximately 40%.

Feldman and Zheng[1993] combined steel and polypropylene fibers and noted that a stronger and stiffer steel fiber improved the ultimate strength, while the more flexible and ductile polypropylene fibers improved toughness and strain capacity in the post-crack zone.

Machine Hsie, Chijen Tu, P.S. Song [2008] there are two forms of polypropylene fibers including coarse monofilament, and staple fibers. The content of the former is at 3 kg/m3, 6 kg/m3, and 9 kg/m3, and the content of the latter is at 0.6 kg/m3. The experimental results show that the compressive strength, splitting tensile strength, and flexural properties of the polypropylene hybrid fiber-reinforced concrete are better than the properties of single fiber-reinforced concrete. These two forms of fibers work complementarily. The staple fibers have good fineness and dispersion so they can restrain the cracks in primary stage. The monofilament fibers have high elastic modulus and stiffness. When the monofilament fiber content is high enough, it is similar to the function of steel fiber. Therefore, they can take more stress during destruction. In addition, hybrid fibers disperse throughout concrete, and they are bond with mixture well, so the polypropylene hybrid fiber-reinforced concrete can effectively decrease drying shrinkage strain.

G. Barluenga, F. Hernandez-Olivares [2004] deals with the influence of water-to-cement ratio (W/C) and percentage of polymer in the setting time, rheology and physical and mechanical properties of a Styrene–Butadiene–Rubber (SBR) Latex Modified Mortar. The consistency of SBR Latex Modified Mortar (LMM) depends on both water-to-cement ratio (W/C) and percentage of latex (PL). The parametric study presented allows prediction of the consistency as a function of both dosage parameters. The SBR experimental results showed that the mechanical properties depend also on dosage parameters and the results obtained by keeping constant W/C or consistency cannot be compared.

Ru Wang, Pei-Ming Wang, Xin-Gui Li [2005] studies the physical and mechanical properties of styrene-butadiene rubber emulsion modified cement mortars were prepared by varying polymer/cement mass ratio with a constant water/cement mass ratio of 0.4.with p/c ratio below 10%, the toughness of the modified mortars enhances with the increase of p/c. when p/c ratio is above 10% the flexural and compressive strength of the mortars are not improved further with more polymer. The authors concluded that the properties of the polymer modified mortars are influenced by the polymer film, cement hydrates and the combined structure between the organic and inorganic phases.

RESEARCH METHODOLOGY

To achieve the objectives stated above a detailed a detailed experimental investigation has been planned and work has been divided into five phases

PHASE-1: Evaluation of the mechanical properties of plain concrete

PHASE-2: Studying the mechanical properties of steel fiber reinforced concrete with various proportions and optimization of steel fiber content based on mechanical properties.

PHASE-3: Developing hybrid fiber reinforced concrete keeping steel fiber content and SBR latex content constant and varying the polyester fiber content. Evaluate the properties of hybrid fiber concrete.

PHASE-4: Developing stress-strain curves and load-deflection curves for various proportions of hybrid fiber reinforced concrete.

PHASE-5: Casting the beams with plain, mono fiber and hybrid fibers to know its structural behavior in flexure with reinforcement.

EXPERIMENTAL PROGRAM

Preparation of the specimens

The standards moulds are fitted such that there are no gaps between the plates of the moulds. If there small gaps they are filled with plaster of Paris. The moulds are then oiled and kept ready for casting. The entire casting is done in three stages one each corresponding to M30 grades with/without steel fibers and with hybrid fibers (steel and polyester). A standard concrete mixer of Pan Mixer type of half bag capacity is used for mixing concrete. Needle vibrator is used for casting the concrete in moulds. At the end of casting the top surface is made plane using trowel and a hacksaw blade to ensure a top uniform surface. After 24 hrs of a casting the specimens are kept for wet curing for the required number of days before testing.

Fig: Casting the cubes, cylinders and prisms

Fig: Slump cone test

Fig: Cubes testing in universal testing machine for compressive strength

Mould and Equipment's

The moulds used for casting the beam consisted of two channel sections placed back to back such that the space between the channels is equal to the width of the beam to be cast. Wooden pieces of required width of required width were kept in between the two channels to maintain the spacing (equal to the width of beam). The whole casting was done on a level platform. So, no base plate was provided for the moulds. The ends of the moulds were provided with holes of 8 mm diameter for providing bolts and nuts to keep the channels in position. In addition, two C – clamps were used to avoid any bulging of the sides. For casting the control cubes, standard cast iron cube moulds were used

Fig: Moulds for casting beams

Measurement of Curvature

The curvature is measured by knowing the strain profile of the beam along the depth. The curvature is nothing but the slope of the strain profile. To measure the strain along the depth of beam the Demec gauge is used. The points are selected along the depth of beam to calculate the strains. For equal intervals of time the readings are taken using demec gauge. The curvature is obtained by adding strain at top and bottom there by dividing the strain with depth of beam.

Measurement of deflections

The deflections were measured at three points i.e., the midpoint of the beam and the points midway between the midpoint and the supports by using dial gauges with least count of 0.01 mm and 50 mm travel. The schematic sketch of the test set-up is shown in fig

Fig: Test set up of a beam testing under flexure

RESULTS AND DISCUSSIONS

The details of the results obtained from the tests conducted on the specimens are presented in this section. In this chapter we will discuss the properties of plain concrete, mono steel fiber concrete and hybrid fiber concrete and the properties of hybrid fiber concrete are compared with respect to plain and mono steel fiber concrete. Similarly the compressive stress-strain curve and load-deflection curves under flexure are studied. Based on the optimum dosage of steel and polyester fiber content flexural studies on beam were studied.

Table: Compressive loading test results of plain concrete

S.No	Load(lbs)	Compressive strength(MPa)
1	180000	35.59
2	185000	36.58
3	205000	40.54
Average		37.57

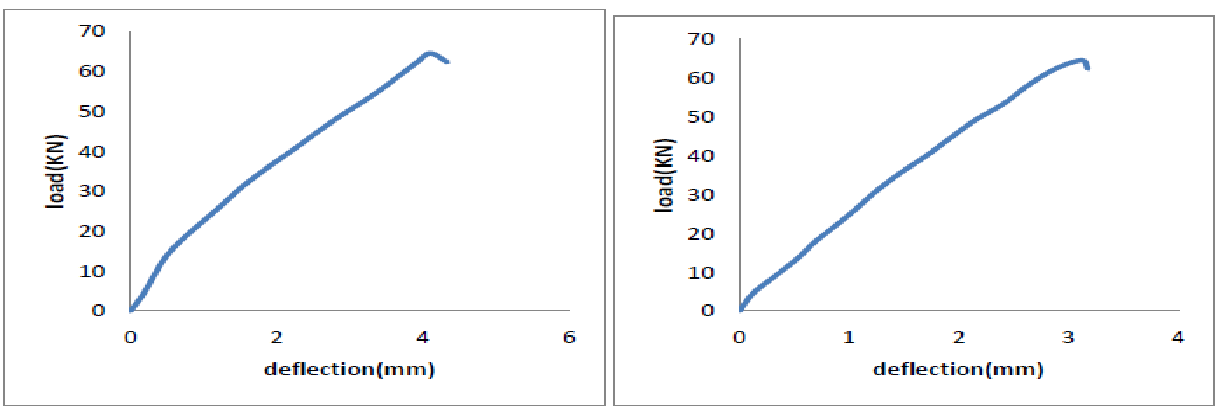


Fig: Load vs. deflection curves for reinforced beam without fibers at middle and l/4 from support

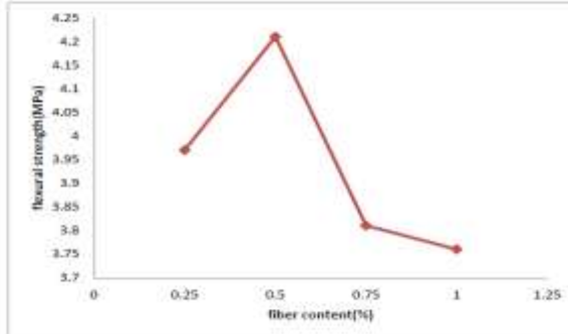


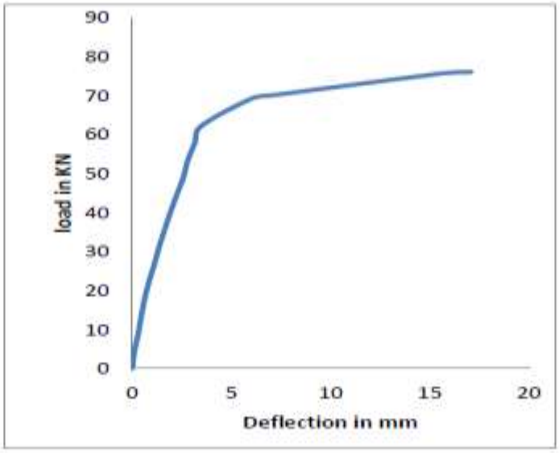
Fig: Flexural strength for various proportions of steel fiber content

As from the graphs it is clear that at 0.5% steel fiber content the concrete shown better mechanical properties compared to the remaining proportions. So therefore the optimum dosage of steel fiber content based on the mechanical properties is 0.5% by volume of concrete.

Flexural studies on beams

In this section, the behavior of simply supported under reinforced beams tested is discussed.

The term under reinforced mean that the unconfined reinforced concrete sections are designed to fail in tension. The longitudinal percentage of steel was provided such that the above criterion is realized.



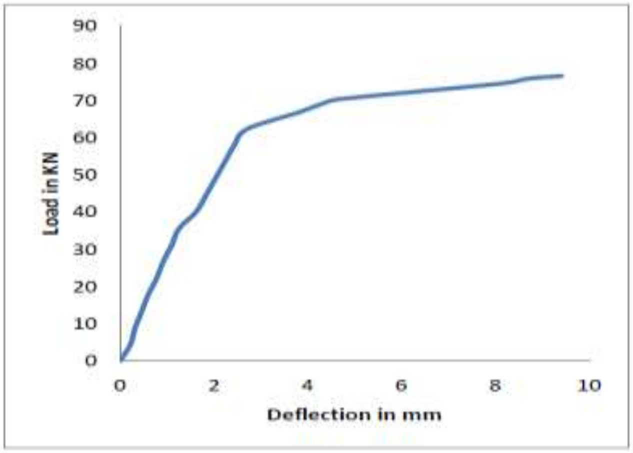


Fig: load vs. deflection curves for hybrid fiber reinforced beam at middle and l/4 from support mono steel fibers (c) hybrid fibers (steel and polyester)

Table: Load@ first crack, ultimate load, moment and curvature values for beams

Beam	Load@ first crack(KN)	Ultimate load(KN)	Ultimate moment (KN-m)	Ultimate curvature
Without fibers	44.5	64.52	32.26	0.000327
Mono steel fiber	49.83	72.08	35.37	0.000481
Hybrid fibers	51.17	76.09	38.1	0.000627

The behavior of beams with fibers was similar to the behavior of beam without fibers up to 75 to 80 percent of the ultimate load of the beam without fibers. The visible cracks developed at 60 to 75 percent of ultimate load of each beam. From the load-deflection it is observed that the energy absorption capacity of hybrid fibers increases when compared to beams without fibers and with mono steel fibers.

From the table5.13 it indicates that as fiber index increases the ultimate capacity increases in all types of beams. This is because of the increase in ultimate strain capacity of concrete and the increase in strain in steel at ultimate stage due to fiber confinement. The increase in capacity is also due to the randomly distributed fiber in fibrous concrete improves the strength of concrete. The increase in moments is in the range of 18% for hybrid fibers and 10% for mono steel fiber concrete compared to beams without fibers. Similarly the curvature at ultimate moment increases with fiber index. The increase in curvature is represented by the ratio of ultimate curvature, with hybrid fibers and steel fibers to the ultimate curvature, without fiber. The increase in ratios is 1.91 and 1.47. The increase in curvature of beams with hybrid fibers and mono steel fibers is due to the increase in failure strain in concrete due to continuous confinement and reduction in depth of neutral axis due to additional confinement provided by the fibers. As the curvature increases it allows more rotation so that redistribution of moments takes place.

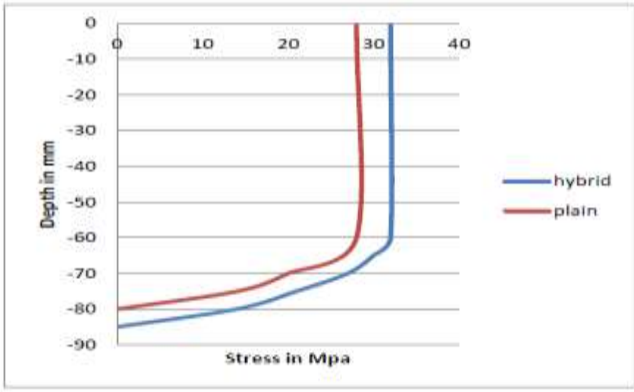


Fig: Comparison of stress block of hybrid fiber and plain concrete

From the stress profile it is observed that the synergy is more for the beam with fibers compared to the beam without fibers. It indicates that there is enhancement in the ductility of concrete by addition of two types of fibers.

CONCLUSIONS

The conclusions from the present study are

1. It is possible to produce hybrid fiber polymer concrete composites using polyester fibers in combination with steel fibers with an enhancement in the mechanical properties of concrete, toughness and ductility of the concrete
2. The increase in the compressive strength, split tensile strength and flexural strength of hybrid fiber polymer concrete compared to plain concrete are 25%, 45% and 41% respectively. Similarly the percentage increase of compressive, split tensile and flexural strength of hybrid fiber compared to mono steel fiber are 1.4%, 25% and 15% respectively.
3. Increased fiber availability of polyester fibers in bridging smaller micro cracks could be the reason for the enhancement in split and flexural properties.
4. Due to SBR latex addition, there is good bonding between polyester fibers and cement matrix which enhances the tensile strength of concrete mainly.
5. Among all hybrid fiber combinations, only SP2 Mix combination (with 0.5% steel and 0.2% polyester fiber) performed better in all respects compared to mono steel fiber and plain concrete.
6. The post peak behavior mainly depends on the steel fibers as the polyester fibers are inability to sustain high crack widths resulting at large deflections.
7. In beams due to fiber addition the ultimate moment increases in the range of 18% for hybrid fibers and 10% for mono steel fibers compared to beams without fibers and similarly the first crack moment and curvatures increases these is due to increase in strain of concrete and steel due to additional confinement provided by fibers.
8. There is enhancement in energy absorption capacity due to addition of fibers and polymer which indicates the increase in ductility of concrete.
9. A major significance of these findings is that steel fibers in concrete could be replaced to a small extent with polyester to provide better properties of the concrete.

Future Scope

1. The study can expand to Study of behavior of hybrid fibers in self-compacting concrete, high strength, self-compacting/curing and other modern type of concretes to observe the influence and improvement in the behavior of concrete in terms of its energy absorption and fracture.
2. There is need to Study of hybrid fibers with latex as polymer under torsion and shear.
3. The study of behavior of hybrid fiber polymer concrete for high strength concretes
4. The study of different type of hybrid fiber combinations like steel- glass fiber, steel-polypropylene fiber with different types of polymers.

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