Study On The Effect Of Fibres On Flexural Behaviour Of Concrete

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***Abstract* - Fibre reinforced concrete is a composite material consisting of cement based matrix having ordered or random distribution of fibre which can be steel, nylon, polypropylene etc. Low tensile strength and low strain at fracture were the major problem of plain concrete. Intrusion of fibres in concrete helps to increase the bridging effect, which results in enhancing tensile strength. By the use of fibres in concrete optimum utilization of materials are achived and also cost reduction is possible. A number of papers have already published on the use of fibres in concrete. This paper represents a review on the influence of both steel and polypropylene fibres on the flexural behavior of concrete**

***keywords* - High performance concrete, flexural strength, steel fibres, polypropylene fibres**

INTRODUCTION

The tensile strength is one of the basic and important properties of concrete. Determination of tensile strength of concrete is necessary because it helps to estimate the load at which the concrete members may crack. The absence of cracking has considerable importance concrete structures. Because it helps in maintain the continuity of concrete structure and in many cases in prevention of corrosion of reinforcement. Usually unreinforced concrete structures such as dams under earthquake conditions other structures such as highway and airfield pavement are designed on the basis of flexural strength. So the flexural behavior of concrete should be studied in detail even though concrete is not expected to resist the direct tension.

Fibres in concrete

Conventional concrete has low ductility, low impact and abrasion resistance and little resistance against cracking. Hence short discontinuous and discrete fibres are added to plain concrete to improve the post cracking behavior. The random distribution results in a loss of efficiency as compared to conventional reinforced concrete, but the closely spaced fibres improve toughness and tensile properties of concrete and help to control cracking. Thus the weakness of plain concrete can be removed by inclusion of fibres in concrete. Addition of fibres increases ductility, tensile strength, fatigue performance, fracture strength, toughness, impact resistance etc. The fibres help to transfer loads at the internal micro cracks. When concrete cracks, the randomly oriented fibres arrest crack formation and propogation, and thus improve strength and ductility. When the deflection corresponding to ultimate flexure strength exceeded, plain concrete fails suddenly. On the other hand, fibre reinforced concrete continue to sustain considerable loads even at deflections. Fibres are produced from different materials in various shapes and size. Commonly used fibres are steel fibres (straight, crimped, twisted, hooked, ringed and paddled ends), glass fibres (straight), synthetic fibres (Kevlar, nylon and polyester), natural fibres (wood, asbestos, cotton and bamboo) and polypropylene fibres (plain, twisted fibrillated and with buttoned end). Among these steel fibres and polymeric fibres are widely used.

Steel fibres

The use of steel fibres over past few decades has been so widespread. The most common applications are pavement, tunnel linings, bridge decks and slab repairs etc. Normally steel fibre reinforced concrete cannot be regarded as a direct replacement of longitudinal reinforcement in reinforced and prestressed structural members, but the presence of fibre in the body of concrete can be expected to improve the resistance of conventionally reinforced structural members to cracking, deflection and other serviceability conditions. Certain benefits of using steel fibres are as follows.

- Improve structural strength
- Reduce steel reinforcement requirements
- Improve ductility
- Reduce crack widths and thus improving durability
- Improve impact and abrasion resistance
- Improve freeze thaw resistance

Types of steel fibres are as shown below

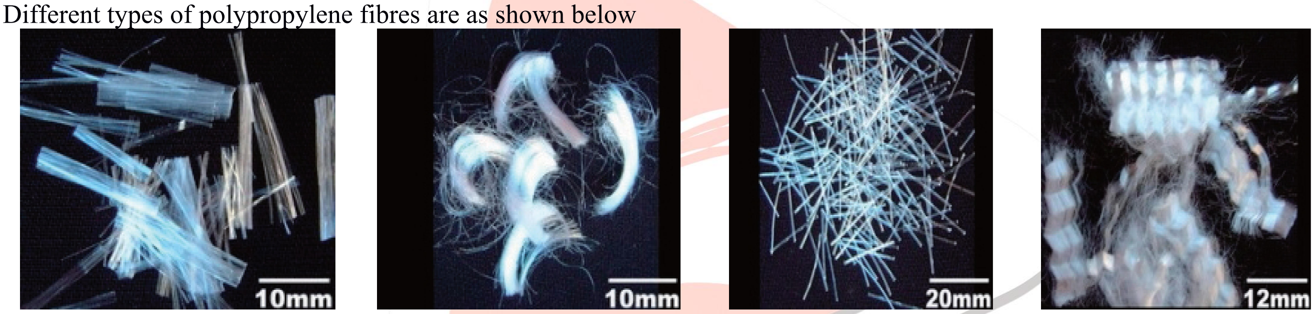
a) Undulated steel fibre b) Hooked end fibres c) Straight fibres d) Crimped steel fibres

Polypropylene fibres

When polypropylene fibre is added to concrete during mixing, thousands of individual fibres are evenly dispersed throughout the concrete creating a matrix like structures. These fibres are mainly used in the construction of slabs, roads, pavements, driveways, kerbs, water retaining structures and marine applications. The application of these fibres in construction increased largely because addition of fibres in concrete improves tensile strength, toughness, impact strength and also failure mode of concrete. Polypropylene fibres have following advantages such as

- Improve mix cohesion, improving pumpability over long distances
- Improve freeze thaw resistance
- Improve resistance to explosive splling in case of a severe fire
- Improve impact resistance
- Increase resistance to plastic shrinkage during curing
- Reduced bleeding
- Non-magnetic, rust free, alkali resistant, safe and easy to use.

Different types of polypropylene fibres are as shown below



a) Fibrillated b) Staple fiber c) Monofilament d) Staple fiber with crimp

Holschemacher et al. studied the role of steel fibres having different configuration in combination with steel bar reinforcement. It reports on results of an experimental research program that was focused on the influence of steel fibre types and amounts on flexural tensile strength, fracture behaviour and workability of steel bar reinforced high-strength concrete beams. In the frame of the research different bar reinforcements (2nos of 6 mm and 2nos of 12 mm) and three types of fibres configurations (two straight with end hooks with different ultimate tensile strength and one corrugated) were used. Three different fibre contents were applied. Experiments show that for all selected fibre contents a more ductile behaviour and higher load levels in the post-cracking range were obtained. Strength and geometry of fibres have a direct influence on the load bearing capacity of High strength steel fibre reinforced concrete beams without bar reinforcement. Using high-strength fibres resulted in a clearly better ductile behaviour and higher load levels in the post-cracking range, compared to normal strength ones.[2]

Ziad et al. have conducted studies on the cracking behavior of steel fibre reinforced concrete. Concrete mixtures containing steel fibres in volume fractions of 0, 0.5, 1, 1.5 and 2 percent were investigated. Three beam specimens in each volume fractions were subjected to four point loading, utilizing linear variable differential transducers to measure deflections. Test results indicate that the incorporation of steel fibres significantly enchanced the cracking behavior of concrete. It was also found that flexural stress increased with an increase of fibre content which improved material tolerance.[3]

Talukdar et al. conducted studies to determine the compressive strength, modulus of rupture, split tensile and shear strength of concrete made using fibres of five different origins. The fibres used were steel fibre of two different sizes and other various types having a volume fraction ranging from 0.5% to 2%. From the research it is concluded that increase in flexural strength is as high as 48.38% in case of steel fibrous concrete and compressive strength of around 20% relative to plain concrete.[4]

Lin et al. conducted studies on the effect of steel fiber on the mechanical properties of cement-based composites containing silica fume. Test variables included water to cementitious ratio, dosage of silica fume and volume fraction of steel fibre. According to the results of the study, the designed direct tensile testing method was a suitable method to estimate the tensile strength of fibre cement based composites. Addition of fibres provided better performace for the cement based composites, while silica fume in the composites would help obtaining uniform fibre dispersion in the matrix and improve strength and the bonding between fiber and matrix. The 10% silica fume specimens with water cement ratios of 0.35 and 0.65 have 3% and 8% higher tensile strength.[5]

Kamura et al. studied the effect of steel fibre on concrete having different compressive strength. Experiments were done to study how the fibres affect the compressive strength, split tensile strength, modulus of elasticity and toughness. Experiments were conducted on RC beams designed as tension failure and having the same steel reinforcement, parameter varied were the percentage fibre. The load versus mid span deflection relationships of these entire RC beam under simple bending were recorded. Results concluded that both the ultimate load and flexural strength increases with increase in fibre content.[6]

Soong et al. studied the mechanical properties of high strength steel fibre reinforced concrete. From the study it is concluded that the low tensile strength concrete can be increased by addition of steel fibres this paper deals with the mechanical properties like compressive, splitting tensile strength, modulus of rupture and toughness index of high strength steel fibre reinforced concrete. Steel fibres having different percentage variation of 0.5%, 1, 1.5%, 2% of volume of concrete are added. Maximum compressive strength is obtained at 1.5% volume fraction having 15.3% improvement over noral high strength concrete. Splitting tensile strength and modulus of rupture of fibre reinforced concrete improved with increasing the volume fraction having 98.3% and 126.6% improvements at 2% volume fraction.[7]

Jyotsna et al. studied about flexural and split tensile strength is steel fibre reinforced concrete at high temperature. By adding 1% of steel fibres fracture resistance of concrete can be increased. High temperature induces high temperature gradients which in turn induces high tensile stresses. Fibres present in the concrete act as a bridge and helps in arresting cracks. The main application of steel fibre is its post cracking behavior and toughness. It is observed that at later ages for fibre reinforced high strength concrete the flexural strengths are increasing with temperature whereas for normal strength fibre reinforced concrete the values are decreasing with temperature. Also steel fibres helps in decreasing the internal pressures and also helps in improved flexural and split strengths. The geometry of steel fibres helps in better bonding of concrete, it also helps the fibre to act more efficiently as a bridge in reducing fracture of concrete.[8]

Ahmed et al. studied about the factors affecting flexural tensile strength of concrete. The deflection and cracking behavior of concrete structure depend on the flexural tensile strength of concrete. Many factors which influence the flexural tensile strength of concrete are level of stress, size, age and confinement to concrete flexure member, etc. The large continuous size concrete members having confining reinforcement increases ductility and large deflections in structures provide a good warning of failure prior to complete failure of the flexure member and also for efficient use of constructional material. It is concluded that the factors like confinement conditions and age of concrete should be given due consideration in deriving the flexural tensile strength and compressive strength proportionality equations. The flexural tensile strength increases with increase of age and strength of concrete. The proportional increase in the flexural tensile strength at same age of concrete goes on decreasing with increase of level of concrete strength. The flexural tensile strength increases many folds under confinement confining condition of concrete. [9]

Choi et al studied the effect of fiber reinforcement on all-lightweight concrete in which both fine and coarse aggregates are artificially lightweight and the results were investigated experimentally. Using 1.5% vinylon fibers significantly improved the flexural strength of the all-lightweight concrete 234% higher than that of normal concrete. Vinylon fibers improved the splitting tensile strength of the all-lightweight concrete most efficiently followed by steel and polyethylene fibers. However, the fibers had a marginal effect on the compressive strengths of both the all-lightweight and normal concrete, as expected. Adding fibers improved the flexural strength even more significantly than the splitting tensile strength. Vinylon fibers improved the flexural strength of the all-lightweight concrete most efficiently followed by polyethylene and steel fibers. The flexural strength of the normal concrete was also improved with the addition of fibers, but the strength increase was around 60%, which was less efficient than for the all-lightweight concrete.[10]

Pliya carried out a study to understand the influence of a polypropylene and steel fibres on the behaviour of high strength concretes subjected to high temperature. Concrete mixes were studied by adding polypropylene fibres, steel fibres and cocktail of fibres. Different concretes compositions with various amounts of polypropylene and steel fibres were tested. There is a significant improvement of the residual mechanical properties of concretes containing the cocktail of fibres compared to concretes without fibres. After the heating at 300^0C and 600^0C, the relative flexural tensile strength decrease of concrete having a combination of steel and polypropylene fibre was about 10% compared with that of concrete having steel fibre only. The flexural tensile strength decreases gradually with the rise in temperature for all the concretes groups. The addition of polypropylene fibres involves a reduction of the residual flexural tensile strength, in particular at 450^0C. With Steel fibre, an important gain in flexural tensile strength is observed regardless the temperature.[11]

Sivakumar and Santhanam focuses on the experimental investigation on high strength concrete reinforced with hybrid fibres (combination of hooked steel and a non-metallic fibre) up to a volume fraction of 0.5%. Fibre addition was seen to enhance the pre-peak as well as post-peak region of the load–deflection curve, causing an increase in flexural strength and toughness, respectively. Increased fibre availability in the hybrid fibre systems (due to the lower densities of non-metallic fibres), in addition to the ability of non-metallic fibres to bridge smaller micro cracks, is the reasons for the enhancement in mechanical properties. Among all fibre concretes, the hybrid combination of steel and polyester showed the maximum flexural strength. The reason could be due to smaller length and high aspect ratio of polyester fibres, which gives high reinforcement index. In addition, the increased fibre availability makes it more efficient in delaying the growth of micro cracks and thereby improving the ultimate tensile stress capacity. The steel polypropylene hybrid combination showed the maximum residual load among all hybrid fibre concretes, while the concretes with glass fibres performed the worst. [12]

Kamal studied about Ultra-high performance concrete with different types of fibres. The main variables taken into consideration in this research were the type of fibers and the percentage of longitudinal reinforcement as well as the existence or absence of the web reinforcement. Increased number of cracks was observed at the end of loading due to the use of fibers, which led to the reduced width of cracks. The use of polypropylene and steel fibers increased the 28 day compressive strength by 2.5 and 6 percent compared to the counterpart mixes without fibers. Independent of the longitudinal steel reinforcement ratio, the steel fibers were more efficient in increasing both initial and ultimate loads. The increase in the ultimate loads was as high as 48 and 15 percent where steel and polypropylene fibers were used, respectively in test beams with the lower reinforcement ratio. When the reinforcement ratio increased the percentage increase was only 22 percent for both steel and polypropylene fibers.[13]

Afroughsabet et al. investigates the effect of the addition of steel and polypropylene fibers on the mechanical and some durability properties of high-strength concrete. Hooked-end steel fibers with a 60-mm length were used at four different fiber volume fractions of 0.25%, 0.50%, 0.75%, and 1.0%. Polypropylene fibers with a 12-mm length were used at the content of 0.15%, 0.30%, and 0.45%. Some mixtures were produced with the combination of steel and polypropylene fibers at a total fiber volume fraction of 1.0% by volume of concrete, in order to study the effect of fiber hybridization. All the fiber-reinforced concretes contained 10% silica fume as a cement replacement. The results also indicate that incorporation of steel and polypropylene fibers improved the mechanical properties of HSC at each volume fraction considered in this study. Furthermore, it was observed that the addition of 1% steel fiber significantly enhanced the splitting tensile strength and flexural strength of concrete. Among different combinations of steel and polypropylene fibers investigated, the best performance was attained by a mixture that contained 0.85% steel and 0.15% polypropylene fiber. The higher tensile strength and modulus of elasticity of steel fibers are the two main factors that contribute toward the better performance of steel fiber-reinforced concretes.[14]

Anbuvelan et al. studied on the influence of polypropylene fibres, steel fibres and re-engineered plastic shred with 0.1% and 0.5% by volume of concrete mix, respectively with the same aspect ratio of 80. Three grades of concrete M30, M50, M70 with and without addition of fibres were considered for investigation. From the studies carried out it is found out that the addition of polypropylene fibre to plain concrete increases the strength to 4-17% and steel fibres increases the strength to 4-49% and addition of re-engineered plastic fibres to plain concrete increases the strength to 20-60%. [15]

CONCLUSIONS

- The strength and geometry of fibres have a direct influence on the load bearing capacity of High Strength Steel Fibre Reinforced Concrete beam without bar reinforcement. It gives better ductile behavior and higher load levels in the the post cracking range.
- Incorporation of steel fibres significantly enhanced the cracking behavior of concrete.
- As the percentage volume fraction of steel fibre is varied from 0.5% to 2%, the flexure strength is increased upto 48.38% and compressive strength is increased upto 20% relative plain concrete.
- Addition of silica fume in composites helps in obtaining uniform fibre dispersion and improve strength and bonding between fibre and matrix.
- Both ultimate load and flexure strength increases with increase in fibre content.
- Splitting tensile strength and modulus of rupture of fibre reinforced concrete improved with increasing the volume fraction of fibres.
- For fibre reinforced high strength concrete the flexural strengths are increasing with temperature whereas for normal strength fibre reinforced concrete the values are decreasing with temperature. Fibres help in decreasing internal pressure in improving flexural and split strength
- Factors like confinement conditions and age of concrete have certain influence in flexure and compressive strength. Flexural tensile strength increases with increase of age.
- Vinylon fibres improved the splitting tensile strength of light weight concrete, but this fibres had a marginal effect on compressive strengths of both light weight and normal concrete.
- The flexural strength decreases gradually with rise in temperature. For polypropylene fibres there is a reduction of residual flexural tensile strength at 450^0C, but for steel fibres an important gain in strength is observed regardless the temperature.
- Hybrid fibre addition was seen to enhance the pre-peak as well as post-peak region of load-deflection curve. Increased fibre availability in hybrid fibre systems helps to bridge smaller micro cracks is the reason for enhancement in mechanical properties.
- Incorporation of steel and polypropylene fibres improved the mechanical properties of high strength concrete at each volume fraction. The best performance of concrete was attained by a mixture that contain 0.85% of steel and 0.15% of polypropylene fibre.
- Addition of polypropylene fibres to concrete decreases the compressive strength, but both splitting tensile and flexural strength increases first and then decreases with higher amount of fibre.

REFERENCES

[1] Dr. T. Ch. Madhavi, L. Sway Raju, Deepak Mathur, Polypropylene Fibre Reinforecd Concrete- A Review, International Journal of Emerging Technology and Advanced Engineering, Vol 4, 2014, pp. 114-119

[2] K. Holschemacher, T. Mueller, Y. Ribakov, Effect of steel fibres on mechanical properties of high-strength concrete, Materials and Design, Vol 31, 2010, pp 2606-2615

[3] Ziad Bayasi, Henning Kaiser, Steel Fibres as Crack Arrestors in Concrete, The Indian Concrete Journal, Vol 4, 2001, pp. 215-219

[4] P. Baruah and S. Talukdar, A Comparative Study of Compressive, Flexural, Tensile and Shear Strength of Concrete with Fibres of Different Origins, Indian Concrete Journal, Vol 8, 2007, pp. 19-23

[5] Wei-Ting Lin, Ran Huang, Chin-Lai Lee, Hui-Mi Hsu, Effect of Steel Fibre on the Mechanical Properties of Cement Based Composites Containing Silica Fume, Journal of Marine Science and Technology, Vol 16, 2008, pp. 214-221

[6] Kamura Ari, Tefaruk Haktanir, Faith Altun, Effect of Steel Fibre Addition on Mechanical Properties of Concrete and RC Beams, Construction and Building Materials, Vol 21, 2006, pp. 654-661

[7] P.S. Song, S. Hwang, Mechanical Properties of High-Strength Steel Fiber-Reinforced Concrete, Construction and Building Materials, Vol 18, 2004, pp. 669–673

[8] P. Jyotsna Devi, Dr. K. Srinivasa Rao, A Study on the Flexural and Split Tensile Strengths of Steel Fibre Reinforced Concrete at High Temperatures, International Journal of Education and applied research, Vol 4, 2014, pp. 49-53

[9] Mohd. Ahmed, Javed Mallick, Mohd. Abul Hasan, A Study of Factors Affecting the Flexural Tensile Strength of Concrete, Journal of King Saud University–Engineering Sciences, 2014

[10] Jisun Choi, Goangseup Zi, Shinichi Hino, Kohei Yamaguchi, Soye Kim, Influence of Fiber Reinforcement on Strength and Toughness of All-Lightweight Concrete Construction and Building Materials, Vol 69, 2014, pp. 381–389

[11] P. Pliya, A. L. Beaucour, A. Noumowe, Contribution of Cocktail of Polypropylene and Steel Fibres in Improving the Behaviour of High Strength Concrete Subjected to High Temperature, Construction and Building Materials, Vol 25, 2011, pp. 1926–1934

[12] A. Sivakumar, Manu Santhanam, Mechanical Properties of High Strength Concrete Reinforced with Metallic and Non-Metallic Fibres, Cement and Concrete Composites, Vol 29, 2007, pp. 603–608

[13] M.M. Kamal, M.A. Safan, Z.A. Etman, R.A. Salama, Behavior and Strength of Beams Cast with Ultra High Strength Concrete Containing Different Types of Fibers, Housing and Building National Research Center, Vol 10, 2014, pp. 55–63

[14] Vahid Afroughsabet, Togay Ozbakkaloglu, Mechanical and Durability Properties of High-Strength Concrete Containing Steel and Polypropylene Fibers, Construction and Building Materials, Vol 94, 2015, pp .73–82

[15] K. Anbuvelan, M. M Khadar, M. Lakhmipathy, K.S Sathyanarayanan, Studies on Properties of Concretes Containing Polypropylene, Steel and Reengineered Plastic Shred Fibre, Indian Concrete Journal, Vol 81, 2007, pp. 17-24