Introduction to Steel Fiber Reinforced Concrete on Engineering Performance of Concrete

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Abstract— Fiber reinforced concrete has been successfully used in slabs on grade, shotcrete, architectural panels, precast products, offshore structures, structures in seismic regions, thin and thick repairs, crash barriers, footings, hydraulic structures and many other applications. The usefulness of fiber reinforced concrete in various Civil Engineering applications is thus indisputable. This review study is a trial of giving some highlights for inclusion of steel fibers especially in terms of using them with new types of concrete.

Keywords — Compressive strength, ductility, flexural strength, Fibre Reinforced Concrete, Steel fiber, Split tensile strength, toughness, workability

1. INTRODUCTION:

Concrete is characterized by brittle failure, the nearly complete loss of loading capacity, once failure is initiated. This characteristic, which limits the application of the material, can be overcome by the inclusion of a small amount of short randomly distributed fibers (steel, glass, synthetic and natural) and can be practiced among others that remedy weaknesses of concrete, such as low growth resistance, high shrinkage cracking, low durability, etc. Steel fiber reinforced concrete （SFRC） has the ability of excellent tensile strength, flexural strength, shock resistance, fatigue resistance, ductility and crack arrest. Therefore, it has been applied abroad in various professional fields of construction, irrigation works and architecture. There are currently 300,000 metric tons of fibers used for concrete reinforcement. Steel fiber remains the most used fiber of all (50% of total tonnage used) followed by polypropylene (20%), glass (5%) and other fibers (25%) (Banthia ,2012). Steel fiber reinforced concrete under compression and Stress-strain curve for steel fiber reinforced concrete in compression was done by Nataraja.C. Dhang, N. and Gupta, A.P. They have proposed an equation to quantify the effect of fiber on compressive strength of concrete in terms of fiber reinforcing parameter. Mechanical properties of high-strength steel fiber reinforced concrete were done by Song P.S. and Hwang S. They have marked brittleness with low tensile strength and strain capacities of high strength concrete can be overcome by addition of steel fibers. Tdyhey investigated an experimental study were teel fibers added at the volume of 0.5%, 1.0%, 1.5% and 2.0%.

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The observation indicate that compressive strength of fiber concrete reached a maximum at 1.5%volume fraction, being 15.3% improvement over the HSC. The split tensile and Flexural Strength improved 98.3% and 126.6% at 2.0% volume fraction.

Reinforcement Mechanisms in Fiber Reinforced (FRC):

In the hardened state, when fibers are properly bonded, they interact with the matrix at the level of micro-cracks and effectively bridge these cracks thereby providing stress transfer media that delays their coalescence and unstable growth. If the fiber volume fraction is sufficiently high, this may result in an increase in the tensile strength of the matrix [1]. Indeed, for some high volume fraction fiber composite, a notable increase in the tensile/flexural strength over and above the plain matrix has been reported. Once the tensile capacity of the composite is reached, and coalescence and conversion of micro-cracks to macro-cracks has occurred, fibers, depending on their length and bonding characteristics continue to restrain crack opening and crack growth by effectively bridging across macro-cracks. This post peak macro-crack bridging is the primary reinforcement mechanisms in majority of commercial fiber reinforced concrete composites. (Banthia N. 2012) [1].

EFFECT ON WORKABILITY OF STEEL FIBER:

Slump tests were carried out to determine the workability and consistency of fresh concrete. The efficiency of all fiber reinforcement is dependent upon achievement of a uniform distribution of the fibers in the concrete, their interaction with the cement matrix, and the ability of the concrete to be successfully cast or sprayed (Brown J. & Atkinson T.2012) [05]. Essentially, each individual fiber needs to be coated with cement paste to provide any benefit in the concrete. Regular users of fiber reinforcement concrete will fully appreciate that adding more fibers into the concrete, particularly of a very small diameter, results in a greater negative effect on workability and the necessity for mix design changes. The slump changed due to the different type of fiber content and form. The reason of lower slump is that adding steel fibers can form a network structure in concrete, which restrain mixture from segregation and flow. Due to the high content and large surface area of fibers, fibers are sure to absorb more cement paste to wrap around and the increase of the viscosity of mixture makes the slump loss (Chen and Liu, 2000)[06].

EFFECT OF STEEL FIBER ON COMPRESSIVE, SPLITTING TENSILE AND MODULOUS OF RUPTURE OF CONCRETE:

Presently, a number of laboratory experiments on mechanical properties of SFRC have been done. Shah Suendra and Rangan [07], in their investigations conducted uni-axial compression test on fiber reinforced concrete specimens. The results shown the increase in strength of 6% to 17% compressive strength, 18% to 47% split tensile strength, 22% to 63% flexural strength and 8% to 25% modulus of elasticity respectively. Byung Hwan Oh [08], in their investigations, the mechanical properties of concrete have been studied, these results shown the increase in strength of 6% to 17% compressive strength, 14% to 49% split tensile strength, 25% to 55% flexural strength and 13% to 27% modulus of elasticity respectively. Barrows and Figueiras [09], in their investigations the mechanical properties of concrete have been studied, these results shown the increase in strength of 7% to 19% compressive strength, 19% to 48% split tensile strength, 25% to 65% flexural strength and 7% to 25% modulus of elasticity respectively. Chen S.[10] investigated the strength of 15 steel fiber reinforced and plain concrete ground slabs. The slabs were 2x2x0.12m, reinforced with hooked end steel fibers and mill cut steel fibers. Dwaraknath and Nagaraj [11] predicted flexural strength of steel fiber concrete by these parameters such as direct tensile strength, split cylinder strength and cube strength. James [12] stated that the minimum fiber volume dosage rate for steel, glass and polypropylene fibers in the concrete matrix is calculated approximately 0.31%, 0.40% and 0.75%. Patton and Whittaker [13] investigated on steel fiber concrete for dependence of modulus of elasticity and correlation changes on damage due to load. Rossi et. Al[14], analyzed that the effects of steel fibers on the cracking at both local level (behavior of steel fibers) and global level (behavior of the fiber/cement composite) were dependent to each other. Sener et. Al[15], calibrated the size effect of the 18 concrete beams under four-point loading. Swami and Saad[16], had done an investigation on deformation and ultimate strength of flexural in the reinforced concrete beams under 4 point loading with the usage of steel fibers, where consists of 15 beams (dimensions of 130x203x2500mm) with same steel reinforcement (2Y-10 top bar and 2Y-12 bottom bar) and variables of fibers volume fraction (0%, 0.5% and 1.0%). Tan et al [17] concluded some investigation on the shear behavior of steel fiber reinforced concrete. 6 simply supported beams were tested under two- point loading with hooked steel fibers of 30mm long and 0.5mm diameter, as the fiber volume fraction increased every 0.25% from 0% to 1.0%. Vandewalle [18], had done a similar crack behavior investigation, which based on combination of five full scale reinforced concrete beams (350x200x3600mm) with steel fibers (volume fraction of 0.38% and 0.56%).In this investigation, the experimental results and theoretical prediction on the crack width was compared. Pereira et al. [19] had an experimental research on the steel fiber-reinforced self-compacting concrete and numerical simulation of punching test. Using notched cylindrical specimens, fracture energy of steel fiber reinforced concrete was measured, and a new trilinear cohesive law was proposed by Kazemi et al. [20]. By testing the deformational behavior of conventionally reinforced steel fiber concrete beams in pure bending, Dwarakanath and Nagaraj [21] gave an economical and efficient use of steel fibers. The study results given by Thomas and Ramaswamy [22] indicate that the fiber and matrix interaction contributes significantly to enhancement of mechanical properties caused by the introduction of fibers. Numerical analysis and field test on performance of steel fiber reinforced concrete segment in subway tunnel were described by Zhu [23]. Bending and uniaxial tensile tests on hybrid fiber reinforced concretes combining fibers with different geometry and material have been done by Sorelli et al. [24].

EFFECT OF STEEL FIBER ON IMPACT CAPACITY AND TOUGHNESS OF CONCRETE:

Toughness is a measure of the ability of the material to absorb energy during deformation estimated using the area under the stress-strain curves. Luo et. al [25], studied and conducted test on the mechanical properties and resistance against impact on steel fiber reinforced high-performance concrete. Five different geometry of fibers included steel-sheet-cut fibers and steel ingot milled fibers with four fiber volume fractions (4%, 6%, 8% and 10%) were applied in to the mix. Eswari, P. et. al [26]studied and conducted test for fiber content dosage Vf ranged from 0.0 to 2.0 percent. Steel and Polyolefin fibers were combined in different proportions and their impact on strength and toughness studied. Addition of 2.0 percent by volume of hooked-end steel fibers increases the toughness by about 19.27%, when compared to the plain concrete. When the fibers were used in a hybrid form, the increase in above study parameters was about 31.42%, when compared to the plain concrete.

CONCLUSIONS:

The study on the introduction of effect of steel fibers can be still promising as steel fiber reinforced concrete is used for sustainable and long-lasting concrete structures. Steel fibers are widely used as a fiber reinforced concrete all over the world. Lot of research work had been done on steel fiber reinforced concrete and lot of researchers work prominently over it. This review study tried to focus on the most significant effects of addition of steel fibers to the concrete mixes. The steel fibers are mostly used fiber for fiber reinforced concrete out of available fibers in market. According to many researchers, the addition of steel fiber into concrete creates low workable or inadequate workability to the concrete, therefore to solve this problem of superplasticizer without affecting other properties of concrete may introduce.

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REFERENCES:

[01] Banthia N (2012),"FRC: Milestone in international Research and development", proceedings of FIBCON2012, ICI, Nagpur, India, February 13-14, pp 48

[02] Nataraja M.C., Dhang N. and Gupta A.P, (1998), "Steel fiber reinforced concrete under compression", The Indian Concrete Journal, 26(3), pp 353-356.

[03] Nataraja M.C., Dhang, N. and Gupta, A. P (1999), "Stress- strain curve for steel fiber reinforced concrete in compression", Cement and Concrete Composites, 21(5/6), pp 383- 390.

[04] Song P.S. and Hwang S (2004), "Mechanical properties of high-strength steel fiber reinforced concrete "Construction and Building Materials, pp 669-676.

[05] Brown J. & Atkinson T.(2012),"Propex Concrete Systems (International), United Kingdom", proceedings of FIBCON2012, ICI, Nagpur, India, February 13-14

[06] Chen B, Liu J (2000),"Contribution of hybrid fibers on the properties of the control concrete hybrid fibers. Cem. Con. Comp". 22(4): 343-351

[07] Shah Surendra and Rangan(1994), "Effect of Fiber addition on concrete strength", Indian Concrete Journal

[08] Byung Hwan Oh(1992), "Flexural Analysis of Reinforced Concrete Beams Containing Steel Fibers", Journal of Structural Engineering, ASCE, Vol 118, No.10

[09] Barros JAO, Figueiras JA(1992), "Flexural Behavior of SFRC, testing and Modeling", Journal of Materials in Civil Engineering, Vol 11, No.4

[10] Chen S. (2004), "Strength of steel fiber reinforced concrete ground slabs", structures and Buildings" Issue SB2

[11] Dwarakanath HV, Nagaraj TS.(1991)," Comparative Study of Predictions of Flexural Strength of Steel Fiber Concrete", ACI Materials Journal, Vol 88, N0. 73, pp.49-58.

[12] James J, Beaudoin (1990)"Handbook of Fiber Reinforced Concrete; principles, properties, Development and Applications", Noyes Publications, New Jersey, United State of America,.pp.57-63

[13] Patton ME, Whittaker WL.(1983) "Effects of fiber Content and Damaging Load on Steel Fiber Reinforced Concrete Stiffness", ACI Journal, Vol .80, No.1

[14] Rossi P, Acker P, Malier Y.(1987)"Effect of steel fibers at two different stages", The Material and the Structures, Vol.20, pp.34-39.

[15] Sener S, Begimgil M, Belgin C.(2002) "Size Effect on Failure of Concrete Beams with and without Steel Fibers", Journal of Materials in Civil Engineering, Vol.14, No.5

[16] Swamy RN, Saad A(1981)."Deformation and Ultimate Strength in Flexural of Reinforced Concrete Beams Made with Steel Fiber Concrete", ACI Material Journal, Vol.78, No.5

[17] Tan, K.H., K Murugappan, P. Paramasivam, 1993. "Shear Behavior of Steel Fiber Reinforced Concrete Beams" . ACI Struct. J., 90: ACI Struct. J., 90(1), (1993) 103-114.

[18] Vandewalle L(2000), "Cracking behavior of concrete beams reinforced with combination of ordinary reinforcement and steel fibers", ACI Materials and Structures, Vol.33, No.227

[19] Eduardo N. B. Pereira, Joaquim A.O.Barros and Aires Camões.(2008),"Steel Fiber-Reinforced Self-Compacting Concrete: Experimental Research and Numerical Simulation", Journal of Structural Engineering, 134(8), pp.1310-1321

[20] M. T. Kazemi, F. Fazileh, and M. A. Ebrahiminezhad (2007) "Cohesive Crack Model and Fracture Energy of Steel-Fiber-Reinforced-Concrete Notched Cylindrical Specimen", Journal of Material in Civil Engineering, 19(10), pp.884-890

[21] H. V. Dwarakanath and T. S. Nagaraj.(1992), "Deformational Behavior of Reinforced Fiber Reinforced Concrete Beams in Bending", Journal of Structural Engineering, 118(10),pp.2691-2698

[22] Job Thomas and Ananth Ramaswamy (2007), "Mechanical Properties of Steel Fiber-Reinforced Concrete", Journal of Material in Civil Engineering, 19(5), pp.385-392

[23] Hehua Zhu et al.(2006), "Numerical Analysis and Field Test on Performance of Steel Fibre Reinforced Concrete Segment in Subway Tunnel", Proceedings of Sessions of Geo Shanghai, Editors Shanghai, China

[24] L. G. Sorelli, A. Meda, and G. A. Plizzari (2005), "Bending and Uniaxial Tensile Tests on Concrete Reinforced with Hybrid Steel Fibers", Journal of Material in Civil Engineering, 17(5), pp.519-527

[25] Luo X, Sun W, Chan SYN (2001),"Steel fiber reinforced high performance concrete: A study on the mechanical properties and resistance against impact", ACI Materials and Structures, Vol.34, No.237

[26] Eswari S., Raghunath P. N. and Kothandaraman S.(2011), "Regression Modeling For Strength And Toughness Evaluation Of Hybrid Fibre Reinforced Concrete", Journal of Engineering and Applied Science, Vol.6, No 5.