FATIGUE BEHAVIOUR OF STEEL FIBRE REINFORCED CONCRETE – A REVIEW

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Abstract - *Now a day there are so many fibres are available in the civil engineering sector. Generally their behaviour is considered satisfactory if they withstand two million cycle of repetitive loading without distress or failure at the required mean stress level. The addition of fibre in the concrete mix improves the monotonic flexural strength, flexural fatigue strength, impact strength, shock resistance, ductility, and flexural toughness in concrete, besides delaying and arresting crack proportion. Fatigue is described by a parameter, which essentially represents the number of cycles the material can withstand under a given pattern of repetitive loading, before falling. This paper presents to study the behaviour of reinforced concrete beam cast at different types of steel fibre in the concrete matrix and subjected to fatigue loading.*

Key Words: *steel fibres, fibre reinforced concrete, flexural fatigue strength, fatigue loading.*

1. INTRODUCTION

The word fatigue is derived from the Latin word fatigue are which means 'to tire 'Suresh, 2006. The fatigue behaviour of SFRC can easily be analyzed using stress-life approach. The fatigue defined as the process of progressive, permanent internal structural changes in material subjected to repeated loading. Different loading arrangement have been used in fatigue testing, including compression tension and bending test the fatigue failure of steel fibre reinforced concrete pavement under repetitive flexural load is discussed. The majority of fatigue life prediction and design of FRC structures. The fatigue behaviour of SFRC can be easily analyzed stress - life approach.

In addition of steel fibres in concrete improve the bending fatigue performance of concrete members. Common application of FRC including paving such as airport highways bridge decks and industrial floors.

1.1 STEEL FIBRES

Steel fibres mixed into the concrete can provide an alternative to the provision of conventional steel bars or welded fabric in some applications. The concept had been in existence for many years (the first patent was applied for in 1874). Among the first major uses was the patching of bomb craters in runways during world war.

1.2 STEEL FIBRE REINFORCED CONCRETE

Steel fibre reinforced concrete (SFRC) is a composite materials for instance, flexural, tensile and shear strength, toughness, impact resistance, crack resistance, and resistance to frost damage can be improved by the use of steel fibres. SFRC has been commonly used in industry for tunnel lining and road paving.

2. LITERATURE REVIEW

In this chapter literatures are presented under the topic of steel fibre reinforced concrete

Medeiros et al. (2015) studied the effect on fatigue behaviour of concrete. In this study two types of fibres using polypropylene and steel fibre. In this study the compressive and fatigue tests were conducted. The fatigue test was conducted in two stages. Four different loading frequencies 4 Hz,1 Hz,1/4 Hz, and 1/16 Hz. In fatigue life lower frequencies were less than the higher frequencies. The compressive and fatigue test were performed through a servo-hydraulic testing machine. The displacement between two steel plates was measured by two LVDTs. From this study the author concluded was the effect on fatigue behaviour of a plain concrete and FRC.

Moon et al. (2015) evaluated the factors influencing mechanical tensile properties of steel-fibre-reinforced concrete exposed to high temperatures. The two types of fibres twisted or hooked were used and the aspect ratio was 80 and 60 & 80. Three fibre volume of fraction was 0.25%, 0.5% and 1%. All cast specimens stored in air ambient temperature for two days prior to demolding. The SFRC specimen was heated in electric furnace capable of heating up to 10000˚ the maximum temperature of room is 3000˚c and 5000◦ c or 7000˚c. Finally the SFRC weakened, lost stiffness and showed reduced rupture energy.

Farghal (2014) studied about the fatigue performance of reinforced concrete (RC)-T-beams strengthened in shear with Carbon Fibre Reinforced polymer (CFRP) composite. Twelve RC-T beams were tested under a two-point loading bending test over a simple span. Six specimens were tested statically and another six specimens were tested under repeated loading. The repeated load was inclemently applied. The maximum applied load was taken as one half of the failure load. And the minimum loads were constant at 14 KN. Finally the author concluded was the different strengthen beams survived a million cycles without any apparent signs of damage, demonstrating thereby the effectiveness of the used strengthening technique on extending the fatigue life of a structural element.

Khan et al. (2014) investigated to obtain use of externally bonded CFRP wraps instead of strips to strengthen RC beams in flexure with and without end anchorages. Six beams were tested with different aspect ratios under the four point bending tests. The beams are divided in to two groups based on span/depth ratios. Group 1 span/depth ratio was 3.4 and group 2 span/depth ratio was 2.5. Finally the author was concluded CFRP increasing the stiffness, ductility and increasing load carrying capacity of the strengthened RC beams with end anchorages.

Michel et al. (2013) conducted the experimental and numerical investigation on the post cracking strength, the energy absorption and fracture energy of steel fibre reinforced concrete (SFRC). Two types of steel fibres were used in this study. First one fibre named was Type A tabix+1, It was 60 mm length, 1 mm diameter and aspect ratio was 60 and another one was tabix+1.3 it was 50 mm length, 1.3 mm diameter and aspect ratio was 39. Finally the author concluded the numerical recalculation of the experimental beam and plate tests and thus a comparison of fracture energies of SFRC elements with different size and geometry.

Sen et al. (2013) evaluated the tensile, flexural behaviour was characterized and compared with the carbon textile (CFRP) and glass textile (GFRP) reinforced polymer composite. The natural fibre reinforced polymer was a strong, light composite material made of natural fibres. Totally fourteen beams were tested under bending test. The jute textile material was huge potential as a structural strengthening material. Static loading tests were conducted on both fatigue test specimen and without fatigue test specimen. Finally the jute textile FRP was a strengthening material.

Lin et al. (2013) performed to obtain the fatigue behavior of composite steel and concrete beams subjected to negative bending moment. Repeated load was used in this study and to finding the initial crack and stabilized crack. Two steel-concrete composite beams were performed substructures respectively. Three overturned simply supported steel-concrete composite beams were tested under concentrated load at mid-span and to measuring the deflection using LVDT, and also strain gauges were used to measure the strain in steel web, upper and lower steel flanges. Finally the fatigue tests will reduce the girder stiffness in the in elastic stage and ultimate load carrying capacity.

Makita et al. (2013) studied the tensile fatigue tests on R-UHPFRC elements. Ultra–high performance fibre reinforced concrete (UHPERC) was a Cementitious composite material, it consisting of cement, quartz, sand, silica fume and fibre. It has high compressive strength and high tensile strength of concrete. Single quasi-static load was applied on the specimens. The tensile behavior of UHPFRC was explained by analyzing the force global deformation curve obtained and also improve the load bearing capacity of bridges was glowing due to the increase of traffic loads for more efficient transport industrial product. Finally it is concluded that the steel rebars improve actually the fatigue force bearing capacity of UHPFRC by distributing the applied fatigue stress.

Slater et al. (2012) evaluated the shear strength of the steel fibre reinforced concrete (SFRC) beams. The SFRC beams were divided in to six different groups based on their span-depth ratio. Different ranging of steel fibres was used in this study. The shear strength was obtained performing both linear and non-linear regression analysis of each data base. Finally the shear behaviour of SFRC was wider applications in the concrete industry. Many researchers had developed analytical and numerical tools for predicting the shear strength of SFRC beams.

Gajalakshmi et al. (2012) investigated the cumulative damage of in-filled steel columns subjected to quasi-static loading. The two types of in-fills named as plain cement concrete and steel fibre reinforced concrete. Cyclic loading was applied on both the specimens. Finally the test results was conducted increase the ductility, energy absorption capacity and decrease in damage index of steel fibre reinforced concrete columns compared with plain cement concrete column.

Soustos et al. (2012) evaluated the ductility of concrete made with available steel fibre was investigated and to determined the Flexural-deflection relationships. To calculate the Flexural strength, flexural toughness, equivalent flexural strength ratio. The residual tensile strength in the post-crack softening region has usually been ignored in the design of concrete. Finally the influence of shape, length, and dosage of steel fibres on the flexural performance and other mechanical properties of fibre reinforced concrete had been investigated. The FRC was widely used for industrial pavements.

Xie et al. (2012) studied to obtain the fatigue damage behavior of reinforced concrete (RC) beams strengthened with prestressed fibre reinforced polymer (FRP) in this study totally ten specimens were fabricated from OPC and tested under three- point loading. The fatigue response of beams were externally strengthened with pre-stressed FRP laminates and load carrying capacity of beams with pre-stressed FRP is obviously larger than that of those with Non-prestressed FRP and also the ductility of the beams with Non-prestressed FRP is better than the pre-stressed FRP.

Yan et al. (2012) studied to obtain the fatigue performance of glass fibre reinforced concrete in flexure. The volume fraction of fibre contents can be varied from 0, 0.6, 0.8 & 1% by volume of concrete. The fibre was gradually sprinkled into drum by fatigue-life of glass fibre reinforced concrete was at a given stress level. All the specimens were tested under four-point flexural fatigue loading by universal testing machine (UTM). Finally they concluded coefficients of the fatigue equation can be used for obtaining the flexural fatigue strength of GFRC is better than plain concrete.
Girish et al. (2012) conducted the flexural fatigue analysis of steel fiber reinforced concrete. subjected to repeat loading pattern. Totally three specimens were casted and tested under two point flexural fatigue load. The fatigue behavior of SFRC can easily analyzed using stress life approach. From this study the author concluded that the crimped steel fiber in the concrete matrix resulted improvement on the compressive and flexural strength. Stress Ratio Fatigue Life graph was plotted at various stress levels.

Rousan et al. (2011) investigated the fatigue performance of reinforced concrete beams strengthened with CFRP sheets. In this study totally nine reinforced concrete beams externally and strengthened with different number and configuration of CFRP sheets. Mechanical fatigue load was applied on all the specimens. The test results showed that the ultimate load and stiffness was reduction for the CFRP strengthened beams.

Chalioris et al. (2011) studied the shear performance of concrete beams using steel fibres. Totally seven concrete beams were casted and tested. Two beams were tested monotonically increasing four point loading and remaining specimens were tested under cyclic deformations. It was found that the fibrous specimens increasing shear strength, ultimate deflections and energy dissipation capacities compared with conventional specimen.

Samer et al. (2010) investigate the viability of extending beams length using steel fibre reinforced concrete. The experimental was conducted with sixteen large scale welded beams and four control beams under three points loading. Totally thirty six prismatic concrete elements were designed the volume of fraction of steel fibre was 2% and 3%. Two different welded beams were tested. One welding joint at mid span of the beam and two welding joint At third point of the beam. Cyclic loading was applied on all the specimens. Load-deflection curve, failure and cracking behaviour and ultimate flexural capacity of the beams were monitored. Finally the test results suggested that increase in strength and ductility of the welded beam and the behaviour of moment-curvature capacity of the welded beams with curved joints were better than those with the zigzag joints.

Sirijaroonchai et al. (2010) studied the behaviour of strain hardening high performance of fibre reinforced cement composites when subjected to uniaxial, biaxial and triaxial compression loading. In this study two types of fibres were used named as hooked end steel fibre and polyethylene fibre with volume fractions of 1%, 1.5% & 2%. The tests were done with Universal Testing Machine. Finally, the authors had concluded that the strength ratio between equal to biaxial and uniaxial compression was significantly greater for hooked and polyethylene fibres compared with conventional specimen.

Lee (2007) investigated to improve on the brittle column behavior of the columns during seismic excitation. The authors conducted tests with eight specimens for shear strength and behavior of reinforced concrete columns using steel fibres. The volume fractions of steel fibres were 0%, 1%, 1.5%, and 2%. The nominal ratio of shear reinforcement was 0.26% & 0.21%. From this study the author concluded that SERC column was more effective improving the strength and ductility capacity than the stiffness and energy capacity.

Carpinteri et al. (2006) performed the fibrous composite beam with an edge crack is submitted to a cyclic bending moment. In this study used as ductile fibre. It was a composite material. The ductile fibre was used improve the several mechanical properties. Increasing an amount of Fiber-reinforced cementitious composites. Finally the authors worked on a theoretical model based on fracture mechanics concepts and proposed to analyze the fatigue behaviour of a brittle-matrix fibrous composite beam subjected to a constant amplitude cyclic bending.

Lau et al. (2006) studied about the high performance steel fibre reinforced concrete with various temperatures. The flexural strength, compressive strength, elastic modulus and porosity of concrete reinforced with 1% steel fibre (SFRC) was investigated. This experimental study used 'Green Island' cement that is equal to ASTM type 1 and coarse aggregates and fine aggregates were used for crushed granite and river sand of zone. Dramix cold drawn stainless steel fibre was used in this study. The steel fibres were improvement of fire resistance and crack. Finally the authors concluded that incorporating steel fibre remains beneficial to concrete which has been exposed to temperatures up to 1200° C confirming that at 1% steel fibre content as no deleterious effect on heated concrete.

Chenkui et al. (2005) conducted the properties of tensile and compressive, flexural strength, flexural toughness and flexural fatigue strength of steel fibre reinforced concrete. More than 400 specimens were used in this study. The results showed tensile, flexural strength, fatigue endurance, impact resistance, capacity inhibiting crack and energy absorption were subsequently improved. For the experimental purpose Crushed stone was divided into two ranges medium stone with sizes were 20 to 40 mm and fine stones were 5 to 20 mm. from this study the authors concluded that the steel fibres also used in reinforced concrete containing larger aggregate of maximum sizes of 40 mm with good fatigue performance of fibre concrete for larger crushed stone under field test and laboratory tests.

Lee et al. (2004) investigated the fatigue behavior of plain and Fibre reinforced concrete. The tension, compression and bending tests were used to different loading arrangements. The loading pattern was applied on cyclic loading. The mechanism of fatigue failure of concrete was to be three distinct stages. The test results showed that the first stage involves the weak regions with in the concrete and Second stage is characterized by slow and progressive growth of the inherent flaws and the Final stage involved with a sufficient number of unstable cracks has formed and also fibres can benefit the fatigue performance of concrete. Common applications for FRC include paving applications such as in airports, highways, bridge decks & industrial floors.

Zhang et al. (2002) studied the theoretical analysis on monotonic and fatigue performance in bending of polyvinyl alcohol (PVA). In this method static and cyclic load was applied and to calculate the deflection at midpoint of the beam. The monotonic loading and fatigue loading was used in larger deformation at peak load. Finally the author suggested that the ECC was used increase the load bearing capacity and deformability of the overlaid composite beams compared to PC overlaid system.

Cachim et al. (2002) studied to obtain the performance of plain concrete and fibre-reinforced concrete under compressive fatigue loading. In this study there are two type of hooked-end steel fibres were to be used. Cylinder was casted and studied. The Concrete should be compacted using vibratory needle. The specimen was to be tested under monotonic loading using MTS testing machine. Finally the author suggested that to calculate the stress levels, deformations, strength, ductility, toughness, durability of concrete for using S-N diagram.

2.1 SUMMARY OF LITERATURE

In this literature study the tensile, compression and flexural tests are conducted. Steel fibres have been added crack patterns are to be reduced and increase the structural strength and ductility. Finally the test results are conducted increase the ductility, energy absorption capacity and decrease in damage index of steel fibre reinforced concrete. If added steel fibre benefit the fatigue performance of concrete

3. CONCLUSION

From above the discussions It is understood that the steel fibres are good composite material in reinforcing concrete structures. The steel fibres (hooked end) can benefit the fatigue performance of concrete. It used in the project has shown considerable improvement in all the properties of concrete when compacted to conventional concrete. The steel fibre is free from water absorption. It improves the bending fatigue strength.

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