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For Sustainable Development Use of Steel Fiber Concrete in Seismic and Earthquake Engineering

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Abstract—*Earthquakes are inexorable disaster which reluctantly gives numbers of injury and death. According to report of "STATISTA: THE STATISTIC PORTAL" shows the global death troll due to earthquake from 2000 to 2015, around 9,624 people died worldwide in 2015 as result of earthquake. Various researches have been carried out for providing smart material to provide safeguard to structure. One of material that widely used is "Steel Fiber Reinforce Concrete". In earthquake resistance design the impact of ductility is imperative technical contemplation. Basically the tensile cracking strain of cement is low i.e. it is brittle in nature, but in steel fiber concrete it is high. A composite structure when consist of steel fiber reinforce it will crack long before fiber can be fracture. It imparts ductility to structure. Many researcher since decades have been working on it. Various studies have shown the vital properties of Steel fibre Reinforce Concrete. It improves property like tensile strength, toughness, post cracking behavior, impact resistance, and flexural strength. In this paper we discuss the technical matrix behavior that how it work on strength increase. Various researchers' work and application of Steel Fibre Reinforce Concrete in many type of structure will discuss in this paper. So that it may use as great earthquake resistance design material to provide lesser loss from earthquake. Keywords: steel fiber, mechanism, applications, seismic response*

1. INTRODUCTION

Calamities are those event which causes great sudden damage or distress. One of the great misfortunes is Earthquake. They provide lots of demise and injuries. One of recent great earthquake that India discerns is **"Nepal Earthquake"** of April 2015 overall killed nearly 9,000 people and injured nearly 22,000. It have magnitude of 7.8 or 8.1 and maximum Mercalli Intensity of IX (Violet). It is not only earthquake that kill, building do the same. So in today's era of sustainable development we need to focus out great on smart material that provide great strength and also provide safeguard from earthquake.

One of greatly use material is **Steel Fibre**. They have been used progressively in new technologies of civil engineering construction.

2. WHAT IS STEEL FIBRE?

Basically steel fibers are random discrete small fiber. They are of length 1.0", 1.5" and 2.0" (25 mm, 38mm, and 50 mm). They commonly use to improve concrete toughness and shear resistance in structure. They also prevent micro crack to get widen and hence improve structure to not to get brittle failure. Their diameter is in range from 0.6mm to 1.0 mm.

Figure 2.1 STEEL FIBRES

Table 2.1

Fiber Size Diameter – 0.4"(1.0 mm)	Aspect Ratio
1.0" Length	25
1.25" Length	30
1.5" Length	38
2.0" Length	50

3. STEEL FIBERS IN EARTHQUAKE RESISTANT DESIGN STRUCTURE

Steel fibre reinforce concrete are those composite material made of hydraulic cement ,coarse aggregate ,water, fine aggregate and also dispersion of discontinuous small fibers. Reinforcement in concrete is essential as they provide tensile strength. Use of steel material provides ductility to structure

which is essential most important facet in earthquake resistant design structure. To provide proper safeguard from earthquake, do make our building up to that safety consideration that they may properly resist to ground motion produce in earthquake. We can't make earthquake proof structure as they tend to lot of capital investment, but we can provide safeguard through earthquake resistance building. So that structure with proper impact of ductile behavior during earthquake, structure should not show brittle behavior which is dangerous for building and people.

Our best aim in earthquake resistance design structure is to provide proper ductility in structure. Steel reinforcement basically do the same norm but using steel that provide sort of ductility involves large capital and labour cost, basically

- Steel is expensive and increase capital cost of structure.
- Steel can soften and melt with expose to high temperature.
- Concrete aggregate react aggressively with steel and provide spalling. Also combating this can be costly.
- Rusting provides reduce in strength.

Steel reinforcement confinement if properly not provided may produce adverse effect in structure. To provide proper ductility and proper post cracking behavior one switch to steel fiber (discontinuous) .Also fiber prevent micro crack from widening and hence make composite ductile and tough.

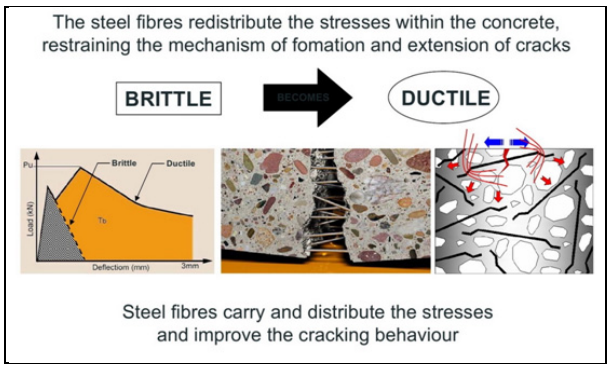

Figure 3.1 Steel Fiber Showing Brittle to Ductile Change

4. HISTORIES BEHIND STEEL FIBRE

In through the development of technologies and new advancement made in civil construction era the use of steel fiber is not new one. Basically fibres are used in construction since through 3500 years back. In this time basically straw were used to reinforce sun-baked bricks in Mesopotamia. Earlier horsehair was used in mortar and straw in mud brick.

Again in 1900, asbestos were used in concrete. It was consider as great materials as because consisting of tensile strength better than that of steel. It contains great of thermal and acoustic insulation. It is also a material of chemically resistant also an electric insulator. In between 1950and 1980 in UK, three main types of asbestos were used-Blue (crocidolite), brown (amosite) and white (chrysotile). In 1920, the first death through asbestos was recorded in US. So in 1985 basically brown and blue one got prohibited and then since 1999 it was banned.

So as because of hazardous effect of asbestos the new replacement came into mind. So by time of 1960 steel, glass (GFRC) and synthetic fibers such as polypropylene fibers used in concrete. also continuous research has been thoroughly pursuing in world of fibers.

Figure 4.1 Horsehair used in concrete

Figure 4.2 Asbestos used in ancient concrete

So fibers are basically not a new trend, they are progressively been studying to provide great sake in civil and architectural trend. Many of research work are been conducted so as to provide their advancement trend in earthquake and seismic engineering.

5. EFFECT OF STEEL FIBER ON EARTHQUAKE RESISTANCE DESIGN STRUCTURE

Many researcher provided work in field of seismic response of steel fiber when it used in construction.

G. Kotsovas, C. Zeris, M Kotsovas [3] in their research work found that it is possible to improve seismic response, satisfying strength, performance and ductility through use of steel fiber. They basically perform experiment in twelve two span continuous RC columns, eight with and four without

steel fibres were tested to failure under constant axial force and monotonic or cyclic lateral displacement .They found structure without fiber shows down brittle failure whereas structure with fibers shows ductile behaviour.

In research work by *Reny D.Lequesne, Gustavo J. Parra-Montesinos and James K Wight* they basically perform seismic response of fiber reinforces concrete coupled wall. In their work the behaviour of coupled T shaped structural wall was studied through test of two large scale four storey specimens under reversed cyclic lateral displacement. In their test they found that FRC structure has better deformation capacity and also it shows less damage after testing.

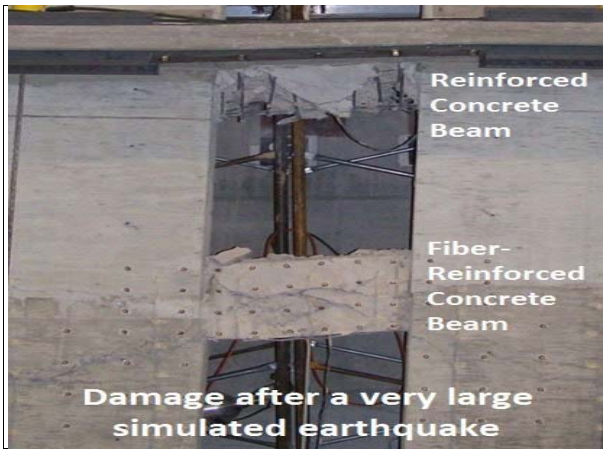

Figure 5.1 Crack pattern in with and without steel fiber concrete

In study showed by *L. Nguyen-Minh, M. Rovnak, T. Tran-Quac* [4] they perform study regarding punching shear resistance of steel fiber reinforced concrete flat slab. They took basically twelve small scale flat slab in which nine are of steel fiber reinforce concrete and three of steel reinforce concrete. Their study shows down increase in punching shear capacity in case of steel fiber. They notice out basically a strong reduction of average crack width up to approximately 70.8% of SFRC as compared to steel reinforce concrete.

6. MECHANISM OF STEEL FIBRE

In plain concrete failure pattern follow up the trend of single crack ,but in mechanism regarding to that of composite structure form of steel fiber work , it going to resist additional crack opening .

Basically in mechanism of steel fiber it follows two distinct mechanisms. The mechanism of steel fiber provides the structure to possess a ductile behaviour nature.

Macro Arrest Mechanism

In brittle matrix when tensile strength exceeded, micro crack goes to develop. The steel fibers basically arrest the micro crack and stop to develop further crack (macro crack).

Crack Bridging Mechanism

Now the second mechanism goes to bridging the crack develop in brittle matrix, ones macro crack has taken.

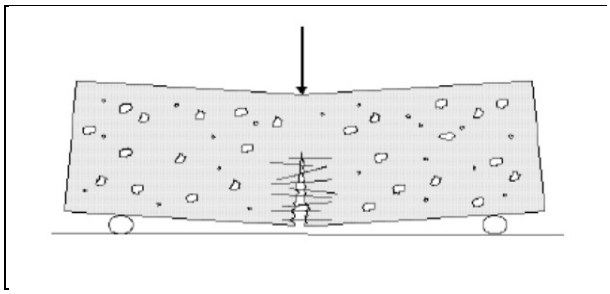

Figure 6.1 Bridging action in steel fiber

7. APPLICATIONS OF STEEL FIBER IN IMPROVING SEISMIC RESPONSE

7.1 Industrial Flooring

Basically concrete structure goes to volumetric change during its lifetime, as because of temperature change it follow expansion and contraction. Also shrinkage occurs in concrete before and after curing. So in flooring volumetric change generate stress which gives rise to crack formation. So to overcome not only need primary reinforcement rather than steel fibers in addition provide crack control and improve seismic response.

Figure 7.1 Industrial Flooring

7.1.1 Advantage of SFRC in Industrial Flooring

- Provide high performance resistance element
- Through better control of shrinkage during curing it increases joint spacing.
- It saves time and money, as it avoids cutting and placing mesh and separators.
- Optimized thickness of concrete can be achieved.
- Provide durable flooring.

7.2 Tunnel Shotcrete

Shotcrete is process in which concrete is projected into surface with high velocity. If Shotcrete improper missed and placed it create void between Shotcrete and water proofing membrane. The request to generate fast acting ground support and also that Shotcrete which is durable, give rise to allow the addition of steel and synthetic fiber reinforce concrete so to get uniform high quality product. Shotcrete fibers are shorter and thinner than other. Fiber reinforce Shotcrete are widely used in tunneling, mining, slope stabilization and also for seismic repair and strengthening.

7.2.1 Advantage of SFRC in Tunnel Shotcrete

- Material saving
- Easy user friendly handling
- Faster application
- Less rebound
- Less void
- Superb ductility
- Excellent durability
- Safer work environment

Figure 7.2 Tunnel Shotcrete

7.3 Precast Concrete Application

Basically precast materials are those factories made piece which are manufactured with concrete. The precast concrete is joined together further to form larger structure.

Various type of precast structure is used in structure and architectural application.

- Precast architectural system such as cladding, free standing wall which use for landscaping, soundproofing and security wall.
- Manhole
- Water and sewage pipe
- Precast tunnel lining
- Structural system such as foundation, beam, floor and wall.

In precast structure steel fiber can provide great benefit. They provide adequate bearing capacity for handling and also full ductility to final state.

7.3.1 Advantage of SFRC in Precast Application

- Elimination of primary steel
- During remoulding, handling and transportation they reduce damage.
- They prevent shrinkage crack and hence reduce rework cost and also reduce spalling.
- They provide reduction in early age cracking.
- Lower labour cost as because of simplified placement and finishing.

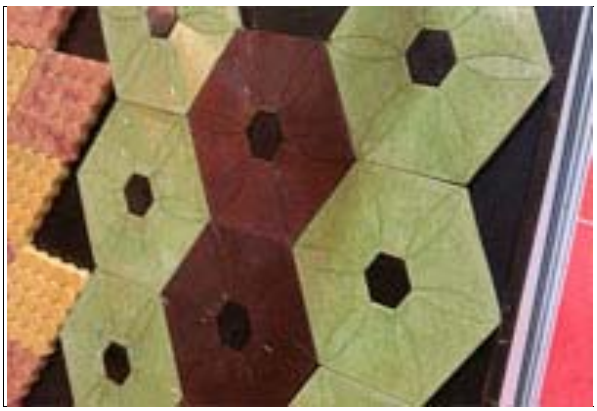

Figure 7.3 Precast Reinforcement

7.4 Internal Roads, Pavement and Driveways

The random distribution of fiber basically provides proper stress redistribution .The fiber composite material basically changes out brittle material to ductile one. So this mechanism of stress redistribution is very vitally used in medium duty application (slab on grade) such as

- Internal road of residential and commercial project
- Composite metal deck
- Pavement and driveway.

7.4.1 Advantage of SFRC in Road work

- Safety in material and labour.
- Reduce slab thickness, hence safe in concrete and placement cost.

- Saving on joint forming cost and its maintenance.
- Increase speed of construction.
- Less cracking.
- High impact resistance.
- Greater fatique endurance.
- Reduce maintenance cost.
- Longer life

Figure 7.4 Internal road

7.5 Refactories

As we know steel industry move away from use of brick, so use of stainless steel fibers in our increasing.

7.5.1 Application in Refactories High Temperatures

- It improves refractory performance.
- Provide lower installation cost.
- Better operating efficiency.
- Lower refractory cost.
- Increased operating plant availability.

Figure 7.5 Refractory

7.6 Friction Lining

Basically lining when applied to friction clutches and break provides high coefficient of friction. They should be such that they are capable to resist heat and wear which develop basically between moving surface for efficient braking.

7.6.1 Advantage in Friction Lining

- Improve performance

Figure 7.6 Friction Lining

8. CONCLUSIONS

In sustainable development we need to switch to modern and sustain approach in earthquake engineering. Fibers are not new; they need to add in steel reinforcement in addition in various applications such as industrial flooring, tunneling, and road structure etc. to provide great strength and durability in structure. Fibre also reduces cost of structure and also they provide great post tensile cracking behaviour. Their post tensile cracking behavior provide ductile behavior into it, which corresponding result structure brittle into ductile. By using steel fiber seismic response of structure also goes to increase. Fibers provide overall increase in strength. Structure can withstand long by using steel fibers. Hence they need to proper add to structure by concerning correct aspect ratio and volume fraction.

9. ACKNOWLEDGEMENTS

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