Steel Fibre Reinforced Concrete and Pavements:A Review

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Abstract:-*Fibres had been used as a reinforcing material since ancient times. They help in providing sufficient strength to composites. Steel fibres have proved their significance in modern civil engineering. Although these can't replace steel completely as a tension providing material but they are able to perform quite well as reinforcing material plus they have some additional properties that steel don't. For example, steel fibre wires can be laid along any alignment inside a structural component. Now a days achieving more strength along with greater economy in projects is considered as smart work. Those days are gone when it was assuming that with having large dimensions, structures possess great strength. Now higher strengths can be achieved along with having less thicknesses and depths of structures or pavements. Adding steel fibres is one of the methods of achieving good strengths in structures which are subjected to high impact loads. They can be provided with curvy paths which help in providing more stiffness to the concrete and helps in holding it together even when it is cracked. The best application of steel fibres is put in the pavements. Steel fibres are of great use in pavements and in this paper the characteristic properties of steel fibre reinforced concrete in pavements are discussed.*
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Keywords*: Fibres, Steel Fibres, Steel Fibres Reinforced Concrete, Pavements*

1. Introduction

Concrete is most crucial construction material widely used all over the world. It canbe casted in any shape and form. It took overother construction materials which were used earlier such as brick and stone masonry. The durability and strength of concrete can be altered by incorporating changes in the constituents of concrete such as cement, water and aggregates and by adding some various other ingredients. Therefore, concrete comes out to be very well suitable for a wide range of applications.

Below given are some of the drawbacks in concrete-

- Low in tensile strength
- Decrease in capacity after cracking
- Low ductility
- Fatigue life is limited
- Impact strength is also low

The weakness of plain concrete is due to the micro cracks present at the inter face of mortar and aggregate.This weakness could be dealt by inclusion of fibres in the mixture. To increase the toughness and the abilty of concrete to resist the crack growth, different types of fibres can be introduced.Loads at the internal micro cracks can be transferred by fibresnd in this case the concrete is termed as fibre-reinforced concrete (FRC).

In 1910 Porter first introduced the idea that concrete could be strengthened by the inclusion of fibres.Romualdi and Batson in 1963 published a paper related to principles of fracture mechanics. They found out that the closely spaced fibres act as crack arresters and also concluded that with increase in fibre spacing the strength decreases. Since then, several researchers all over the world have shown tremendous interest in the field of fibre reinforced concrete by incorporating different types of fibres in concrete and several interesting experiments have been carried out since then.

2. Steel Fibre Reinforced Concrete

When we usesteel fibre reinforcement the strength of the structure and the crack control property is increased considerably. The crack controlling property of the fibre has three major effects on the behaviour of the concrete composite.

- The onset of flexural cracking is delayed due to introduction of steel fibres in concrete, the increase in tensile strain at first crack being as much as 100%. The ultimate tensile strain is about 20 to 50 times largerthan that of plain concrete.
- The well-defined post-cracking behaviour to the composite is added due tosteel fibres.
- The consequent increase inductility and the above property impartsgreater energy-absorbing property to the composite prior to failure. With only adding 2.5% fibre content, the energy-absorption capacity of reinforced matrix can be increased by more than 10 times as compared to un-reinforced matrix.

By controlling cracking, deflection and increasingthe flexural strength marginally,

the fibres improve the serviceability conditions substantially. The crack-controlling role of the fibres enables, for a given crack width, the permissible stress in the steel reinforcement to be raised to a much higher value. Higher-strength steel ban may thus be used which will also meet the serviceability requirements. Improvement of shear resistence and control of shear cracking in concrete beams and slabs are also possible.

Application of SFRC

Due to the tremendous and amazing structural properties of steel fibre reinforced concrete makes it anperfect material for overlays of roads, pavements of air fields, bridge decks, industrial and other floorings, particularly those structures which are subjected to wear and tear and chemical attack.

3. Literature Review

Rui Liu et al., (2016) As compared to plain concrete the fatigue resistance of the SFRC pavements is much better. It was discovered after a study that the plain cement is much more prone to small cracks due to repeated loading and the steel fibre reinforced concrete can delay minor cracks and even limits further expansion.

W.A. Elsaigh, et al.,(2005) conducted an experimentwhere they compared performance of a SFRC section with its counterpart plain concrete section and evaluation of the use of SFRC for road pavements by taking into account the influence of the SFRC properties on design and performance was done. The authors observed thata 25% thickness reduction in slabs is possible by just adding 30 kg/m^3 of hooked end steel fibres. The results indicated that by the use of steel fibres in the concrete, the thickness of concrete pavements can be reducedmarginally.The performance of the thinner steel fibre reinforced concrete ground slabs on a pavement is same as that of thicker plain concrete slabs. The effects of curling and warping, which are major issues in plain concrete, does not seem to affect the performance of the thinner slab with steel fibres in it.
Recycled concrete aggregates can replace natural aggregates in the SFRC pavements. This can also reduce air emissions occurring during extraction of aggregates from mines. This was stated in the studythat showed that the type of steel fibre used and its dosage have great influence on the environmental (emissions and energy consumption) and economic indicators of concrete pavement. It was concluded that it is more environment friendly and sustainable to recycle wastes than to extract more natural resources.

M.N.S Hadi (2009) By introducingthe steel fibres into the concrete of the column increases its load carrying capacity and strain. Also, afteraddition of enlarged end steel fibres into the cover of the column can considerably increase the ductility. Although only minor improvements were noticedthat for 1.5% and 2% steel fibres increased the load at which cover spalling took place. It was also noted that the columns containing FHSC (fibrous high strength concrete) in the outer concrete and high strength concrete in the core exhibited higher levels of ductility than the columns containing FHSC throughout the entire cross-section. The study also found that by increasing the amount of steel fibres in concrete, workability decreasesand there is greater chance of variations in strength of the concrete and cavities in it.

ShivamanthAngadi (2015) Steel fibres are being used since very long time in construction of pavements and also in floor works. The steel fibres are especially used where heavy load with lot of wear and tear is common. The transmission of forces between fibres and matrix takes place through bond between their faces and this creates the bonds in the SFRC.The majorbonding components includesmechanical anchorage, physical and chemical adhesion, friction, interlocking within fibres and others. According to the studies on SFRC about its tensile behaviour, the tensile strength of concrete increases. It also improves post tensioning behaviour of the concrete,which dependsupon the number of fibresthat cross through the crack. When steel fibres are used it enhances the shear strength of concrete as steel fibres arealmost equally distributed at closed spacing, increasestensile strength.Use of steel fibres increases shear friction strength.They worked out that in case of cement concrete pavements, fibre reinforced concrete has much more advantage over normal concrete. Polymeric fibresfor example polyester or polypropylene can also be used due to their less cost as compared to other fibres as well as their resistance to corrosionbut steel fibreswork quite well for a long period of time. Fibre reinforced concrete is to be placed on base concrete mix having proportion as 1:4:8 cement concrete in spite of placing it over WBM. It isprovided with grooves, in panels of about 4mx4m to avoid contraction andexpansion cracks. After casting of concrete, grooves can also be made using cutters.

Majid Jaral et al., (2018) When 1.6% of steel fibre is used, the compressive strength of steel fibre reinforced steel increases up to 12% as compared to plain concrete. The use of steel scraps as steel fibre in rigid pavement increases the compressive strength as compared to the plain concrete.Congestion of steel reinforcement can be reduced in the beam-column joints by replacing some part of ties in columns with steel fibres. The workability of concrete decreases marginally onaddition of metallic fibres and thus it becomes important to utilize best plasticizers.

Deformation occurring under impact load is controlled much better in SFRC than plain concrete. As found in the above study the use of SFRC in pavements increased the impact strength by 25 times as compared to plain concrete. It was also noted that after the addition of fibres the dimensional stability and integrity of the joints is significantly increased as we increase fibre content the load carrying capacity of the joints also increases.

Constantia Achilleos., etal (2011)- Study was performed as a part of the European research project “EcoLanes”. The objective was to develop recycled steel tyre-cord (RTC) fibre as acosteffective alternative to steel fibres produced industrially which are normally used in SFRC construction and also for the development of dry and wetconsistency mixes of SFRC. The wet and dry SFRC mixes require verylow energy and it also uses recycled materials. The wet consistency SFRC uses commonly used plastic concrete while the dry consistency concrete uses roller-compacted concrete (RCC). The use of steel fibre reinforced roller-compacted concrete (SFR-RCC) and recycled materials such as cement replacements and recycled aggregates, steel tyre-cord fibres, while making pavements can result in construction of long-lasting rigid pavements. It reduces the construction cost and time by at least 10% and reduces energy consumption in road construction by 40%. It was concluded that the fibre incorporation enhanced the post-peak flexural behaviour of RCC. The flexibility of RCC is not affected by use of recycled concrete aggregates. This indicates that the RCC pavements can be recycled after completing their life cycle for the construction of new RCC pavements.

SFRC find their largest use in airport pavements due to implication of high damaging loads.The steel fibres provide quite large improvement in the impact resistance of concrete making it an appropriate material that can be used in structures which have to face impact loads.

M. A. Kamel (2016) compared the life cycle of SFRC pavements with the life cycle of a plain concrete road. SFRC pavements were reported to last much longer. The pavement life of the steel fibre reinforced section increased to 6.5 times than the unenforced section.
The incorporation of steel fibres results in a considerable increase in compressive strength.
The inclusion of steel fibres increases the flexural strength which is vital in design of concrete pavements. Flexural strength improved up to 60% as found in the study. In the same study it was found that indirect tensile and bond strengths increased considerably with the increase of steel fibre dosage.
SFRC pavement slabs had a slow failure as compared to plain concrete slabs. Referring to the study the gain of strength for the SFRC is higher than that for plain concrete since the primary crack load was enhanced with the utilisation of steel fibres.
The reinforcement of concrete pavements with steel fibres may be a good economical alternative in terms of reduction of the construction cost

Kavade et al., (2017). During the experiment, the uni-axial compression test on fibre reinforced concrete specimens were conducted.
As concerned to the mechanical properties of the concrete, the compressive strength of the concrete increased from 6% to 17% and the split tensile strength increased from 14% to 49%.

The flexural strength increased from 25% to 55% andthe increase in the modulus of elasticity was from 13% to 27%. As we know toughness is a measure of the ability of the material to absorb energy.

During the experiment, five different varieties of fibres were added in the mix. The fibres included steel-sheet -cut fibres and steel inglot fibres. These also included four fibre volume fractions i.e. 4%, 6%, 8% and 10%. The steel fibre content dosage ranged between 0.0 % to 2.0%.

The steel fibres were incorporated with the polyolefin fibre in different proportions. The impact on strength and toughness was studied. Toughness, the measure of the ability of the material to absorb energy, increased by 19.27% with addition of 2.0 % by volume of hooked-end steel fibres.

When the steel fibres and the polyolefin fibres, the hybrid is formed. The increase in the toughness and strength was about 31.42% as compared to the plain concrete.

Deepa Sinha et al., (2014) In the study it was found that with the addition of steel fibres, the lump value, compressive strength & flexural strength of the concrete mix are affected.

The compressive strength of concrete mix increases with addition of 1% of steel fibres and thereafter the compressive strength decreases with addition of steel fibres. However, the compressive strength of 2% concrete mix is more than normal mix concrete. The flexural strength increases with increase of steel fibres being maximum at 2%. The slab thickness decreases with steel fibre inclusion and then starts increasing again with the optimum level being at 1% of steel fibre. The increase in percentage of steel fibres

increase the temperature stress carrying ability. The following table compares the various properties of the plain concrete pavement and SFRC pavement.

The study showed that optimum dosage of steel fibres in the plain concrete is 1%.

This dosage of steel fibres can make the road withstand the traffic passing over and reduces the thickness i.e. 3.5 cm less than the normal concrete which is 37 cm and the cost is reduced by 9.6%.

4. Conclusion

We know that the plain concrete is usually low in strain capacity and also have very low tensile strength. Such important structural characteristics can be improved by addition of the steel fibres and in addition to that the thickness of pavement layer can also be reduced, which may help in achieving economy.Improvement in the concrete after addition of the steel fibres depends upon the amount of steel fibres added to per cubic metre of concrete and improvement is also influenced by characteristics of steel fibres, such as their shape, sizes and slenderness. From all the influences of fibre reinforcement on concrete the one which is most significant among them is that it controls tensile cracking and also delays it. This helps in bringing down the total cost of pavement construction due to reduction in thickness requirement of pavement. In addition to that maintenance cost is also reduced and life of pavement is also increased.

Steel fibres are very useful in structures which are subjected to very high impact loads as it helps in significant increase in the impact resistance of concrete. Structures which bear high impact loads are dams, spillways, industry floors and pavement surfaces. Spring load restrictions are completely removed in SFRC pavements.As in plain concrete roads SFRC pavements don't shows signs of rutting, washboard or shove and helps heavy vehicles to move smoothly and reduces fuel consumption. In one of the above studies it was also noted that steel fibres can also be used in combination with other fibres such as polyolefin fibres. Such combinations also show excellent improvements in all the strength parameters of mix. After going through all above features about the steel fibre reinforcedconcretewe can say that SFRC pavements are beneficial for engineering as well as economical.

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