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Fiber Reinforced Concrete

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Abstract: Road transportation is undoubtedly the lifeline of the nation and its development is of a great concern. Due to the long life , lesser maintenance requirements and various other properties cement concrete pavements are being used in different parts of our country. This paper presents a comprehensive review on work done on fiber reinforced concrete using steel, glass, polypropylene, hybrid fibers. Polymer fibers are also being used nowadays as it was a recently added in the field of fiber reinforced concrete pavement design. As we know that a polymer increases various properties of a plain concrete same is in the field of FRC pavements. Various behavioral properties of fiber reinforced concrete in pavements are discussed in this paper.

Keywords: Fiber reinforced concrete, glass fibers, polypropylene fibers.

INTRODUCTION

Concrete pavements, which can also be known as rigid pavements, are made up of Portland cement concrete and may or may not have a base course between the pavement and sub grade. A pavement is a durable surface of a road on which vehicles travel. It serves for two purposes one is to provide a comfortable and durable surface for vehicles and the second is to reduce stresses on the soil beneath it. In India, the traditional system of bituminous pavements is widely use. No doubt concrete has many advantages due to its fresh and hardened properties however Concrete has some deficiencies as low tensile strength, low post cracking capacity, brittleness and low ductility, limited fatigue life, low impact strength. Cement concrete is characterized by brittle failure, the nearly complete loss of loading capacity once failure is initiated. In order to overcome these deficiencies materials which satisfies required facilities should be used. Recently micro fibers, such as those used in traditional composite materials have been introduced into the concrete mixture to increase its toughness, or ability to resist crack growth. FRC is one of the greatest remedial measures for the above concern. In FRC, thousands of small fibers are dispersed and distributed randomly in the concrete during mixing, and due to which improvement in concrete properties can be seen in all directions. The plain concrete structure cracks into two pieces when the structure is subjected to the peak tensile load and cannot withstand further load or deformation. The fiber reinforced concrete structure cracks at the same peak tensile load, but does not separate and can maintain a load to very large deformations. Fibers can cause improvement in the post peak ductility performance of concrete, pre-crack tensile strength, fatigue strength, impact strength and eliminate temperature and shrinkage cracks. Economy and reduced pollution are the two main factors that are of much demanded requirements of pavement material in India and both these are satisfied by FRC. It also has several other advantages like longer life, low maintenance cost, fuel efficiency, good riding quality, increased load carrying capacity and impermeability to water over flexible pavements.

1.1 Fiber reinforced concrete

Fibers reinforced concrete is a concrete containing fibrous material which increases its various engineering properties. Polymeric fibers are gaining popularity because of its properties like zero risk of corrosion and cost effectiveness. The polymeric fibers commonly used are polyester, Recron 3s, and polypropylene. Various fibers like glass, steel, some forms of recycled fibers like plastic, disposed tires, carpet waste and wastes from textile industry can also be used as fiber reinforcements. These fibers act as crack arresters, restricting the development of cracks and thus changing a brittle material

into a strong composite material with various superior properties like crack resistance , ductility, post cracking behavior before failure.

1.2 Glass fibers

Glass fiber is formed when thin strands of silica-based or other formulation glass are extruded into many fibers with small diameters suitable for textile processing. The technique of heating and drawing glass into fine fibers has been known for millennia, and was practiced in Egypt and Venice.[1] Before the recent use of these fibers for textile applications, all glass fiber had been manufactured as staple (that is, clusters of short lengths of fiber).

The modern method for producing glass wool is the invention of Games Slayter working at the Owens-Illinois Glass Company (Toledo, Ohio). He first applied for a patent for a new process to make glass wool in 1933. The first commercial production of glass fiber was in 1936. In 1938 Owens-Illinois Glass Company and Corning Glass Works joined to form the Owens-Corning Fiberglas Corporation. When the two companies joined to produce and promote glass fiber, they introduced continuous filament glass fibers.[2] Owens-Corning is still the major glass-fiber producer in the market today.

Concrete pavement may b less strong and weak against impact but GFRC is a suitable material for strength and impact, durability, adaptability etc. GFRC can adapt to nearly any complex shape, from rocks to fine ornamental details. There is no risk of aging as water can't get in-there and hence no cracks will occur and that's a durable. It reduces the use of other kinds of reinforcement which can be difficult to place as it is reinforced internally. GFRC can have flexural strength as high as 4000psi and it has a very high strength-to-weight ratio.[3]

Fig 2

1.3 Polypropylene fibers

Polypropylene fibers as shown in fig 3 are new generation chemical fibers. About 4 million tones of polypropylene fibers are produced in the world in a year. In 1965 Polypropylene fibers were first suggested for use as an admixture in concrete for construction of blast resistant buildings meant for the US Corps of Engineers. Subsequently, the polypropylene fiber has been improved further and is now used as short discontinuous fibrillated material for production of fiber reinforced concrete or as a continuous mat for production of thin sheet components. Further, the application of these fibers in construction increased largely because addition of fibers in concrete improves the tensile strength, flexural strength, toughness, impact strength and also failure mode of concrete. These fibers are manufactured using conventional melt spinning. Polypropylene fibers are thermo plastics produced from Propylene gas. Propylene gas is obtained from the petroleum by products or cracking of natural gas feed stocks. Propylene polymerizes to form long polymer chain under high temperature and pressure. However, polypropylene fibers with controlled configurations of molecules can be made only using special catalysts. Polypropylene fibers were formerly known as Steal the,. These are micro reinforcement fibers and are 100% virgin homopolymer polypropylene graded monofilament fibers. For effective performance, the recommended dosage rate of polypropylene fibers is 0.9 kg/m3, approximately 0.1% by volume. Monofilament polypropylene fibers can be used in much lower content than steel fibers [4]. Concrete pavements may be weak in tension and against impact, but PFRC is a suitable material which may be used for cement concrete pavement as it possesses extra strength in flexural fatigue and impact etc. The usage of fibers in combination with concrete also results in a mix with improved early resistance to plastic shrinkage cracking and thereby protects the concrete from drying shrinkage cracks. It also helps to reduce bleeding in concrete during placing. Their uniform

distribution in concrete improves homogeneity of the matrix of concrete. [5]The use of polymer fibers with concrete has been recognized by the Bureau of Indian Standards (BIS) and Indian Road Congress and is included in the following Standard documents:

IS: 456:2000 – Amendment No.7, 2007

IRC: 44-2008 – Cement Concrete Mix Designs for Pavements with fibers

IRC: SP: 76:2008 – Guidelines for Ultra Thin White Topping with fibers

Vision: 2021 by Ministry of Surface Transport, New Delhi

Fig 3

Advantages and disadvantages of GFRC:

ADVANTAGES:

1) Light weight: with GFRC concrete can be cast in thinner sections and is therefore as much as 75% lighter than similar pieces cast with traditional concrete.

2) High strength: GFRC can have flexural strength as high as 7000 psi and it has very high strength-to-weight ratio.

3) Reinforcement: it reduces the use of other kinds of reinforcement which are difficult to place into complex shapes as it is drawn internally.

4) Equipments: GFRC is very economical as equipments used are not expensive.

5) Toughness: GFRC doesn't crack easily as it can be cut without chipping.

6) Surface finish: the surface has no bug holes or voids as it is sprayed on the wall.

7) Consolidation: no need of vibrators in case of sprayed GFRC and in case of poured GFRC vibrators or rollers are easy to achieve consolidation.

8) Adaptability: sprayed or poured into a mould it can adapt to nearly any complex shape from rocks to fine ornamental details.

9) Durability: The durability of GFRC is very high as compared to other as it has ability to hinder the water from entering into the concrete(Michael Driver).

10) Sustainable: Because it uses less content of cement than equivalent concrete and also often significant quantities of recycled material GFRC qualifies as sustainable.

11) Cost: GFRC as a material is expensive however the cross sections can be so much thinner, that cost is overcome in most decorative elements.

DISADVANTAGES:

The disadvantage of glass fiber are the decrease in long term strength (stress fracture), low elastic modulus, moisture resistance, alkali resistance.

LITERATURE REVIEW:

Because of the satisfactory and outstanding performance in the industry and construction field FRC is successfully used in variety of engineering purposes. However, most of the engineers and researchers are still researching about the thing that leads to successful performance of these fibers. So, to recognize the usage of fibers in concrete, in these last four decades, most of the researches were done on behavior of fiber reinforced concrete in pavements.

Md Zoheb1 Amaresh S Patil[6] has done the work on steel fiber Reinforced concrete He analyze the rigid pavements in which steel fibers were used for temperature stresses under Static load coming from vehicles using ANSYS software. For both linear temperature gradient and non-linear temperature gradient, temperature stresses were obtained by him. He also determines the effect of slab length & slab thickness on curling stresses. He has done the work using Finite Element Software in order to find the critical temperature stresses at different places in pavement. In his project work the model is generated & engineering analysis is carried out using ANSYS. & from his work he concluded that:

a) There is about 2 to 5% increment in stresses yielded from Positive curling temperature gradient & negative curling temperature gradient in steel fiber reinforced concrete, when compared to conventional concrete.
b) The variation of length of slab does not affect the curling stresses distribution in both the case of positive and negative temperature gradient for SFRC slab. The increase in stresses for SFRC lies in the range of 20-41% when compared with those of conventional concrete.

Rakesh Kumar, Pankaj Goel and Renu Mathur[7] has determined the change that takes place by adding polypropylene fiber discrete and fibrillated fiber on the properties of a paving grade concrete mix of 48 MPa compressive strength after 28-day. Six concrete mixes with fiber dosages 0.05%, 0.10% and 0.15% by volume fraction under controlled conditions were manufactured. Discrete and fibrillated polypropylene fiber was used in his study. The properties such as settlement, compressive strength, drying shrinkage, and abrasion resistance of the concrete were evaluated. The research suggested a significant decrease in settlement and drying shrinkage without significant change in compressive strength for the concrete mixes which are reinforced with fiber. The main conclusions that get emerged from the experimental work are as:

Fibrillated fiber is more effective in decreasing the settlement of concrete than multifilament fiber. However, its effect was less on slump reduction than multifilament fiber at the same fiber quantity. However on 28-day compressive strength of concrete there was no effect by the addition of these multifilament fibers. Fibrillated fiber performs very well than multifilament fiber in controlling drying shrinkage of concrete. Concrete containing fibrillated fiber and multifilament fiber performs similar function in the development of abrasion resistance.

Rajarajeshwari B Vibhuti [8] studied the effect of addition of mono fibers and hybrid fibers on the mechanical properties of concrete for pavements. Steel fibers of 1% and polypropylene fibers 0.036% were added individually to the concrete mixture as mono fibers and then they were added together to form a hybrid fiber reinforced concrete. Mechanical properties such as compressive, split tensile and flexural strength were determined. The results show that hybrid fibers improve the compressive

strength marginally as compared to mono fibers. Whereas hybridization increases split tensile strength and flexural strength noticeably. She suggested that the improved mechanical properties of HFRC would result in reduction of warping stresses, short and long term cracking and reduction of slab thickness.

Mohammed Maaz Salman1 Prof. Amaresh S Patil [9] has done the work on steel fiber reinforced rigid pavements and studied for stresses developed due to Moving loads & temperature differentials. Contrast of curling stresses in SFRC with conventional concrete is carried out. All the models are generated and analysis is carried out using the ANSYS software. Parametric study for the effect of change in slab length & slab thickness of pavements on curling stresses is also done. Curling stresses due to Linear &Non linear temperature distribution in upper & bottom layer of SFRC pavement slabs are also calculated. Analysis results shows, SFRC shows more stresses as than conventional concrete &Non linear temperature distribution develops stresses more than linear temperature distribution.

He observed that Positive curling temperature gradient & negative curling temperature gradient yields 3 to 5 % higher stresses in steel fiber concrete pavements reinforced as compared to conventional concrete pavements. He also reported that there is no effect on curling stresses due to variation of length of SFRC slab up to 8M in both the positive and negative temperature gradient, thus confirming Westergaard's observation that slab curling stresses are independent of slab length. With increase in thickness or temperature (temperature gradient) in SFRC slab, curling stresses in SFRC slab increases. Frictional stresses in steel fiber reinforced concrete pavements calculated using ANSYS are to some extent similar to the stresses obtained for conventional concrete pavements. For 1% to 3% percentages of steel fibers in concrete, Non-linear temperature distribution root 21.17% to 25.15% higher curling stresses in SFRC than the linear temperature distribution. For moving loads in SFRC, maximum loading stress will be at starting position of edge for both the speeds of 45kmph & 80kmph.

Cent Karakurt , Ahmet turap arslan[10]: They observed that steel fibers increase the flexural and energy absorption capacity of concrete however concrete highways made of SFRC can cause corrosion ,in order to overcome this difficulty they made the use of polypropylene and polyester fibers .various mixtures were done with 0%,1%,2% and various tests were performed in laboratory. Mechanical and tensile behavior of the specimens was observed using 150*150*150 and 100*100*100 mm cubic specimens respectively. The CEM I 42.5 R type Portland cement, Aggregates were in dimension with 0-5 mm, 5-12 mm and 12-22 mm. The consistency of concrete is adjusted by using GRACE Dracem 200 super plasticizing agent. The steel fiber concrete (SFC), polypropylene and polyester fibers were used as fibers. The main observation was as;

Rigid pavements generally subjected to compression, bending and abrasion effects under heavy traffic loads but Utilization of fibers in these pavements will increase the performance of the concrete pavements against harmful effects, workability will gets decreased with increase in utilization amounts, polymer fibers show better results than individual one on strength and abrasion behavior of FRC.

Ahmed Shalabyand Scott Murison[11] has presented the work on fiber reinforced polymer concrete to transfer the loads across transverse joints and to prevent faulting, they make use of Glass fiber-Reinforced polymers, as a load transferring device. During their experiment, two types of dowel construction were made and tested among which, one was a round GFRP dowel bar having a 38-mm diameter and the second was a concrete-filled GFRP pipe having a 60-mm outside diameter. Various executing projects and Laboratory tests were carried out. The field test section was made on a regional highway in the city of Winnipeg and involved three types of GFRP dowels in addition to epoxy-coated steel. Falling Weight Deflectometer (FWD) testing was conducted after its service period of a year and showed that GFRP dowels produced 30% higher deflections compared to steel dowel. GFRP dowel is 20-30% larger in diameter than the steel dowel as a result of which larger diameter results in a reduction in bearing stresses which in turn reduces the ability for faulting.

Samprati Mishra[12]: She done the experiment like compressive strength test on glass fibers as glass fibers fall under economical class means it can be used without any expenditure. Glass fibers she used here are of 12mm in length and diameter of each fiber is 14micron.she made 10 mixes by varying percentage and the mixes that she used were M25 and M40 and compressive strength test was done at 7 and 28 days. The main outcomes of the experiment were as;

With the addition of Glass fibers strength gets increased, maximum compressive strength is obtained when the percentage of glass fiber is 0.20% in M40 mix.

Discussion:

From the above literature reviews it has been noted that a tremendous work has been done on steel fiber reinforced concrete pavement such as use of steel fibers in pavement for temperature stresses [6]. The effect of hybrid fibers on mechanical properties of concrete [8].Comparison of curling stresses in SFRC with conventional concrete was carried out [9]. Some researchers has presented the work on use of Glass fiber-Reinforced polymers, GFRP as load transfer devices [11].Use of steel fibers ,polypropylene fibers on various mechanical properties of concrete pavement [10]. But it is noted that no work was reported to understand the effect of glass fiber reinforced concrete in pavements with the addition of waste tire in order to make it light weighted, shock absorber and also economical.

CONCLUSION

1} Steel fiber reinforced concrete with 2% steel fibers yields slightly more stress as compared to 1% & 3% steel fiber reinforced concrete for both Positive curling temperature gradient & negative curling temperature gradient.

2} Increment in stresses for SFRC lies in the range of 20-41% when compared with those of conventional concrete.

3} Frictional stresses in steel fiber reinforced concrete pavements are almost similar to the stresses obtained for conventional concrete pavements.

4} Polypropylene fibers enhance the strength of concrete, without causing the well known problems, normally associated with steel fibers.

5} Problem of low tensile strength of concrete can be overcome by addition of polypropylene fibers to concrete.

6} Polypropylene fibers reduce the water permeability, plastic, shrinkage and settlement and carbonation depth.

7} Steel fibers along with polypropylene and polyester fibers increases mechanical properties of concrete pavements.

8} The increased diameter and reduced stiffness of the GFRP dowels results in lower bearing stresses between the concrete and dowel, which are major causes of dowel looseness and slab faulting.

9} Hybrid fibers improve the compressive strength marginally as compared to mono fibers. Hybridization also improves split tensile strength and flexural noticeably.

10} Fibrillated fiber is more effective in reducing the settlement of concrete than multifilament fiber. However, it has lesser effect on slump reduction than multifilament fiber at the same fiber content.

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