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PERFORMANCE OF SFRC FOR FLEXURAL FATIGUE SUBJECTED TO VARIOUS STRESS RATIO'S AND STRESS RANGES

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Abstract— SFRC now a days very useful for pavement construction. The fatigue strength of the pavement should be sufficient in order to withstand the load acting on it. In this paper performance of SFRC is checked for flexural fatigue subjected to different stress ranges and stress ratios in order to simulate practical loads. Total 70 prisms of size 75×100×500 with different percentage of fibers are casted and tested for different stress ratios. From the results S-N curves are drawn and regression equation has been established to find out life of the pavements. It is observed that flexural strength and fatigue performance increases with increase in percentage of fibers.

Keywords— SFRC, flexural fatigue, SN curve, rigid pavements, fibrous concrete

I. INTRODUCTION

Among all major modes of transportation road is the only mode which could give maximum service to one and all. This mode has the maximum flexibility for travel with reference to direction, time and speed of travel etc…through any mode of road vehicle. Traffic is the most researched load mechanism that is applied to a pavement. Although environmental loading contributes to distress development and a resultant reduction in the performance, traffic is usually the principle cause of reduced serviceability. In almost every part of the world, pavements have shown premature distress, which results in frequent replacement of the existing surface. Often, though the construction cost of the pavements is low, the maintenance costs are very high and time is lost due to frequent resurfacing and replacement.

Due to the current scenario of depleting resources, it has become essential to devise designs based on materials that cost the least for the entire transportation system life and at the same time have minimum environmental impact over a sufficiently large analysis period. There are a few modern material solutions that may meet these criteria, like the use of steel fiber reinforced concrete (SFRC) for pavement constructions, a proper evaluation of the performance and impact of utilization of such materials is lacking. In addition, maintenance budgets are more often than not insufficient, thereby requiring the optimal usage of funds for repair and rehabilitation.

The solution for this is addition of steel fiber. Steel fiber reinforced concrete has extra strength in flexure and impact as compared to plain concrete. Steel fibers distributed in the concrete delay the growth of cracks thus improving the ductility of the matrix. The ability of steel fibers in improving the properties of concrete depends on the bond characteristics, aspect ratio of the fiber. The fatigue performance of SFRC is one of the important parameter to be considered in the design.

II. FIBER REINFORCED CONCRETE

The fiber reinforced concrete may be defined as a composite material made with Portland cement, aggregate and incorporating discrete discontinuous fibers. The plain concrete is a brittle material, with a low tensile strength and a low strain capacity. The role of randomly distributed discontinuous fiber is to bridge across the cracks and to provide some post cracking ductility to the structure .If the fibers are sufficiently strong and properly bonded to material, and then they permit the FRC to carry significant stresses over a relatively large strain in the post cracking stage. The real contribution of the fibers is to increase the toughness of the concrete (defined as some function of the area under the load vs. deflection curve), under any type of loading.

A. ***Steel fibers:*** It is possible to produce steel fibers in many ways. Round fibers are produced by Cutting or chopping wires. Flat fibers may be produced either by shearing sheets or flattening wires. Crimped and deformed steel fibers of various shapes are also produced, in which deformations may extend through the length of the fiber or may be limited to the end portions. Some fibers are collated into bundles using water soluble glue dissolving during the mixing process, in order to ease handling and mixing. Depending on the type of steel and the type of production technique, steel fibers may have tensile strengths of about 280-2800 MPa. Different shapes of steel fibers are shown in figure 1.

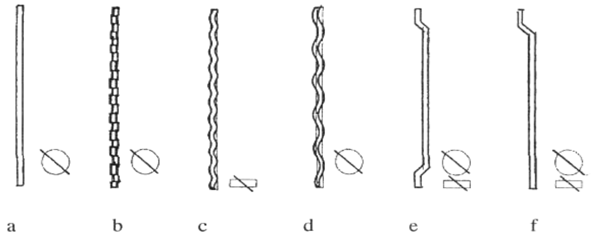

***Figure 1**. Steel fiber types with different geometric properties*

***(a)** straight **(b)** waved **(c)** Crescent **(d)** Class C hooked end **(e)** hooked end **(f)** single hooked end*

B. ***Use of SFRC:*** The application of steel fiber reinforced concrete as composite matrix is potentially advantageous from the point of view of its capacity to bear much higher stresses. Under similar loading conditions pavement thickness can be considerably reduced in SFRC, hence reduction in material and cost. SFRC pavement promises an appreciably higher life expectancy, reduced crack growth offer better serviceability and minimum corrosion. Maintaining the Integrity of the Specifications

III. LITERATURE REVIEW

In 1910, Porter was the first to put idea that the concrete can be strengthened by inclusion of fibers. The early theoretical study, initiated by Romualdi, Batso, and Mandel, in the 1950's and 1960's focused mainly on the characteristics of steel fiber reinforced concrete (SFRC). Only straight steel fibers were used in the beginning. Though remarkable improvements in toughness and ductility were obtained, problems in mixing and workability were encountered.

Patrick conducted experiment on behaviour of steel fiber reinforced polymer and concluded that Steel Fiber Reinforced Polymer (SFRP) specimens performed better than Carbon Fiber Reinforced Polymer (CFRP) specimens in terms of fatigue performance. At equal internal steel stress ranges, SFRP specimens achieved a longer fatigue life. At equal applied load ranges, specimen affected a greater reduction of stress in the internal reinforcing steel than any of the CFRP companion specimen. 2 million cycles of applied load had only marginal effects on performance of specimen.

S.P.Singh et al….(2006) They conducted experiments on fatigue strength of SFRC containing fibers of mixed aspect ratio. They used four-point flexural fatigue loading to obtain fatigue lives of SFRC at various stress levels. With the help of S-N-P_f curves they predicted the flexural fatigue strength of SFRC for desired level of survival probability and for given combination of fibers.

Ravindra V solanki et al….(2011) They worked on SFRC and concluded that fiber reinforcement in a cement bound road base has the potential to improve performance by improving fatigue life of the base and improved resistance to reflective cracking of the asphalt. The studies also establish that the properties of hardened SFRCC, such as flexural strength are remarkably better than those of conventional RCC. The use of SF for effective pavement construction can be suggested positively.

S.P.Singh et al…(2012) They have worked on flexural fatigue strength of SFRC containing blends of lime stone powder and silica fume and concluded that the effect of steel fiber on fatigue performance is remarkable and it is difficult for steel fiber to play a full role in concrete if there are weaknesses in the interface between fiber and matrix.

IV. OBJECTIVE OF THE PAPER

The objective of this paper is to study the flexural fatigue behavior of SFRC for M40 grade concrete for 1% steel fiber by volume fraction of concrete (Shaktiman steel fibers with aspect ratio 54). Type of steel fibers is crimped round steel fibers of diameter 0.5mm and length 30mm. The obtained fatigue data will be used to develop a relationship among stress ratio 'S', number of cycles of failure 'N' for constant loading. The experimental work is carried out for 3 stress ratios(S) and 3 stress ranges (SR).

V. EXPERIMENTAL INVESTIGATION

The experimental program consists, casting of M40 grade concrete for 3 trail mixes to optimize cement content. The tests for compressive strength for the concrete are carried out for 7 and 28 days. The optimized concrete mix was used in addition of steel fibers by 1% volume fraction of concrete to obtain fibrous concrete. The required tests to ascertain the workability were carried out. To maintain the requirements of Indian standards addition of plasticizer was taken up. The tests for static flexural strength and fatigue strength for non-fibrous and fibrous concrete were carried out for 3 stress ratios and 3 stress ranges. In the above tests 3 number of specimens were casted to quantify each parameter. Total experimental work consists of casting and testing of 20 cubes and 70 prisms.

For compressive strength test the cube dimension are 150x150x150mm and the cubes were casted and cured for 7 and 28days. The cubes are classified into two sets, the first set consists of 10 non fibrous (NF) and 10 fibrous (F) cubes.

For static flexural strength the prism dimension used is 75x100x500mm and these prisms were casted and cured for 28 days. The prisms are classified into two sets , the first set consists of 35 non-fibrous (NF) and 35 fibrous (F) prisms. 5 non-fibrous prisms and 5 fibrous prisms were tested for static flexural strength. Flexural fatigue testing of steel fiber reinforced concrete is the main thrust of this investigation. Fatigue tests were conducted at different stress ranges (SR) 1%, 10% and 20%. Constant amplitude, half sine curve is applied at a frequency of 4 Hz. In our experimental study three Stress Ratios (S) i.e 0.75, 0.8 and 0.85 were taken.

The machine used for carrying out the compressive strength test is 200T (U.T.M) Compressive Testing Machine and for fatigue tests, repeated load test setup of capacity 2T, controlled by software developed by Spanktronics, Bangalore.

VI. RESULTS AND DISCUSSION

In this project work the observations are recorded for compressive, flexural, fatigue strength and stress ratio at 50% probability of failure, slump and compaction factor values fresh concrete were noted.

Table:1 *Workability test on fresh concrete*

NF/F	Dosage of superplasticizer	Slump (mm)	Compaction factor
Non-fibrous	0.8%	150	0.87
Fibrous	1.1%	60	0.86

Table :2 *28 days Compressive strength results (NF)*

Sl no	w/c	Load(kN)	Compressive strength (N/mm^2)	Average (N/mm^2)
1	0.41	1177.20	52.32	51.971
2	0.41	1216.44	54.06	
3	0.41	1177.20	52.32	
4	0.41	1196.82	53.19	
5	0.41	1079.10	47.96	

Table: 3 *28 days Compressive strength results (Fibrous)*

Sl no	w/c	Load(kN)	Compressive strength (N/mm^2)	Average (N/mm^2)
1	0.41	1334.16	59.296	52.494
2	0.41	1098.72	48.832	
3	0.41	1128.15	50.14	
4	0.41	1157.58	51.448	
5	0.41	1187.01	52.756	

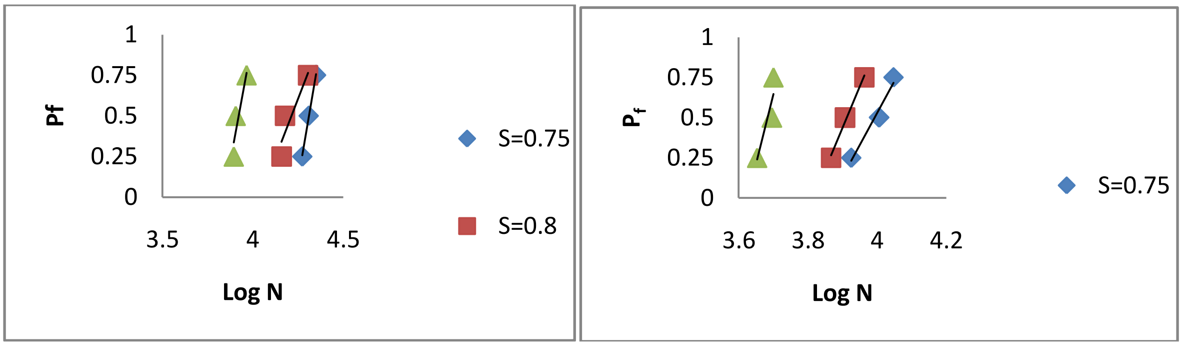

Figure:2 *P_f–Log N diagram for different stress ratio for fibrous(left) and non fibrous(right) specimens*

Table:4 *28 days Static flexural strength (Non fibrous)*

Sl.no	Load(t)	Flexural strength (N/mm^2)	Average (N/mm^2)
1	0.65	3.401	4.269
2	0.74	3.872	
3	0.85	4.447	
4	0.95	4.97	
5	0.89	4.656	

Table: 5 *28 days Static flexural strength (fibrous)*

Sl.no	Load(t)	Flexural strength (N/mm^2)	Average (N/mm^2)
1	0.95	4.97	5.123
2	0.9	4.71	
3	1	5.232	
4	0.95	4.97	
5	1.1	5.755	

VII. CONCLUSIONS

1. The compressive strength of non-fibrous concrete is 51.971 N/mm^2 and that of fibrous concrete is 52.494 N/mm^2.
2. An increase in flexural strength of 20% has been observed for fibrous concrete when compared with non-fibrous concrete.
3. The nature of failure in flexural fatigue test and static flexural test was identical for both non-fibrous and fibrous specimens.
4. The failure was due to pull out of fibers which is observed after looking at failed specimen.
5. The S-N curve for stress level 20% non-fibrous and fibrous exhibits a linear line
6. By the SR-N curves we observed that as the stress range increased number of cycles of failure decreased.
7. For non fibrous and fibrous at stress ratio 0.75 and stress level 10% P_f-N curve exhibit a linear line.
8. Regression equations obtained for Stress ratio at 50% probability of failure are different for non-fiber and fibrous concrete.

   S= -0.783ln(x)+1.8958 for NF at stress level 1%
   S= -0.887ln(x)+2.0088 for NF at stress level 10%
   S= -0.439ln(x)+1.3472 for NF at stress level 20%
   S= -1.445ln(x)+2.9116 for F at stress level 1%
   S= -97ln(x) + 2.1794 for F at stress level 10%
   S= -1.131ln(x)+2.3283 for F at stress level 20%
9. By using these regression equations we can predict the life span of the concrete.

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