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A STUDY ON PROPERTIES OF STEEL FIBRE REINFORCED ROLLER COMPACTED CONCRETE

V. D. R. Kumar[1]; S. KrishnaRao[2]; B. Panduranga Rao[3]
[1]M.Tech Student, [2] Associate Professor, [3]Professor,
Civil Engineering V. R. Siddhartha Engineering College, Vijayawada, Andhra Pradesh, India
drk_vemulapalli@yahoo.com, snkrishnarao@gmail.com

ABSTRACT

Roller compacted concrete for paving is a construction technique that uses zero slump concrete. This type of concrete is transported, placed, distributed and finally compacted using heavy road construction equipments. Generally concrete pavements are widely used for heavy traffic roads and to reduce maintenance. Roller compacted concrete is placed in layers thin enough to allow complete compaction. The optimum layer thickness ranges from 20 to 30 cm. To ensure adequate bonding between the new & old layer are at cold joint, segregation must be prevented and a high plasticity bedding mix must be used at the start of the placement. A compressive strength of above 7 Mpa to 30 Mpa have been obtained. For effective consolidation, roller compacted concrete must be dry enough to support the mass of the vibrating equipment, but wet enough to allow the cement paste to be evenly distributed throughout the mass during mixing & consolidation process. The present study deals with the usage of super plasticizer in Roller compacted concrete pavements. Trial mixes are prepared in varying proportion of super plasticizer i.e 2.5, 5.0, 7.5ml per 1kg of cement and the specimens are tested for compressive strength, split tensile strength and flexural strength for 3days, 7days and 28days. Further steel fibres are used in order to improve the tensile strength. Steel fibres are added in different percentages i.e 0.25, 0.50 and 0.75% by volume of concrete. Specimens are tested for compressive, split tensile and flexural strengths for 3days, 7days and 28days. These results are compared with that of normal mix.

KEYWORDS: Roller compacted concrete, steel fibres, compressive strength, flexural strength, split tensile strength.

I. INTRODUCTION

Roller-compacted concrete for pavements (RCCP) suffers from a number of problems. In particular, the use of tie bars or slip bars is difficult, because of the heavy compaction by vibratory roller. As a result, it is known that RCCP is prone to cracking due to thermal stress or drying shrinkage and this prevents the placing of pavement slabs with long joint spacing. On the other hand, steel-fiber reinforced concrete (SFRC) has been used for tunnel linings and bridge deck strengthening, where it offers superior flexural strength and crack resistance, and the strengthening effect of SFRC has been looked over again from a view point of compound materials. If roller-compacted concrete (RCC) could be given the properties of SFRC, it would offer advantages as a heavy traffic pavement because of its rapid construction and shorter lead time. There is good reason, therefore, to accumulate basic data on the properties of such a new type of pavement.

Ficheroulle indicated that one could lay pavement with steel-fiber-roller-compacted concrete (SFRCC) containing 30mm corn type steel fibers as easily as with conventional RCC. From the results of observations, it was clarified that the surface texture of the pavement could secured by paving with a thin layer of asphalt without joints and that traffic noise was reduced. This method proved suitable for heavy traffic. However, details of mix proportion and the mechanical and physical properties of the SFRCC were not described in the report.

In this study, steel fiber is tested from the viewpoint of reinforcement effect. The first step in the study was to decide on the mix proportion. The relation between water content and modified VC value as a consistency reading was obtained, and a unit water content and sand percentage for a given consistency were decided. Then relations between fiber content and both modified VC value and flexural strength was obtained and appropriate fiber contents were decided from the viewpoints of workability and strength. The degree of unit water content reduction and the resulting change in flexural strength when a super plasticizer was added were examined, and an appropriate dosage selected.

Secondly, the mechanical properties of the concrete were investigated, and differences in flexural strength and toughness depending on fiber percentage variation were clarified. Then, assuming that SFRCC would be overlaid on the abraded asphalt pavement surface, the bond strength between the concrete and asphalt was tested. Finally the physical properties of the SFRC were investigated. A number of useful results were obtained from these investigations.

II. EXPERIMENTAL OUTLINE

Materials and Mix Proportions

Normal Portland cement (density: 3.15g/cm3), river sand (density: 2.62g/cm3), crashed stone (density: 2.72g/cm3), a super plasticizer (cornplast were used. All agents were used in the form of undiluted solution or solution, and they were combined with the water.

Table 1 Shape and size of steel fibers

Sym	Gravi	Length	Diameter	Percentage	Aspect ratio
P1	7.85	30	0.5	0.25%	60
P2		30	0.5	0.50%	60
P3		30	0.5	0.75%	60

Table 2 Mix proportions of concrete

No.	Vb (Sec)	W/C Ratio	Sand Percentage	Steel Fiber Content*	Super Plasticizer Content (ml)	Unit Weight(Kg/Cumt)					
						Water	Cement	Sand	Coarse Aggregate	Steel Fibers (Kgs)	Super Plasticizer (ml)
1.	35	0.413	40	0	0	126.23	305	841.2	1261.27	0	0
2.	32	0.413	40	0	2.5	126.23	305	841.2	1261.27	0	762.5
3.	32	0.413	40	0	5.0	126.23	305	841.2	1261.27	0	1525.0
4.	30	0.413	40	0	7.5	126.23	305	841.2	1261.27	0	2287.5
5.	30	0.413	40	0.25	7.5	126.23	305	841.2	1261.27	19.625	2287.5
6.	30	0.413	40	0.50	7.5	126.23	305	841.2	1261.27	39.25	2287.5
7.	30	0.413	40	0.75	7.5	126.23	305	841.2	1261.27	58.875	2287.5

***(% to Volume of concrete)**

Generally, for good reinforcing effect, fiber length is greater than the maximum size of aggregate and the diameter to length ratio (aspect ratio) is more than 50. However, the aspect ratio should be less than 100 because longer fibers tend to form fiber balls. In this study, one fiber lengths with varying percentage were used. The fiber percentage, sizes, and aspect ratios are shown in Table 1.

Table 2 shows the mix proportions of the concrete used in the experiment. Mix proportions 2 to 4 and 5 to 7 were used to examine the characteristics of SFRCC mix proportions. Table 3, 4 and 5 shows the Compressive, Split tensile and Flexural strengths respectively for 3days, 7days and 28days to the varying dosage of super plasticizer to weight of cement. Table 6, 7 and 8 shows the Compressive, Split tensile and Flexural strengths respectively for 3days, 7days and 28days to varying percentage of steel fibers to volume of concrete.

Table 3 Compressive Strength for dosage of super plasticizer

Dosage of Super plasticizer (ml/kg of cement)	Compressive Strength(CS), N/mm²					
	3 days		7 days		28 days	
	Weight kg	CS N/mm²	Weight in kg	CS N/mm²	Weight in kg	CS N/mm²
2.5	8.68	15.11	8.94	28.44	8.81	34.66
5.0	8.78	24.44	8.93	30.22	9.00	40.44
7.5	8.92	28.44	8.93	32.85	9.06	42.22

Table 4 Split Tensile Strength for dosage of super plasticizer

Dosage of Super plasticizer (ml/kg of cement)	Split tensile strength(STS), N/mm²					
	3 days		7 days		28 days	
	Weight kg	STS N/mm²	Weight kg	STS N/mm²	Weight kg	STS N/mm²
2.5	13.57	1.55	13.69	2.12	13.67	2.82
5.0	13.62	1.69	13.85	2.40	13.80	3.39
7.5	13.90	1.69	13.90	2.54	13.80	3.25

Table 5 Flexural Strength for dosage of super plasticizer

Dosage of Super plasticizer (ml/kg of cement)	Flexural Strength(FS), N/mm²					
	3 days		7 days		28 days	
	Weight kg	FS N/mm²	Weight kg	FS N/mm²	Weight kg	FS N/mm²
2.5	13.04	4.12	12.13	4.80	12.82	5.90
5.0	12.84	4.80	12.55	5.40	13.02	6.50
7.5	12.85	5.20	12.33	5.60	13.08	6.70

Table 6 Compressive Strength for Percentage of steel fibers to volume of concrete

Percentage of steel fibers to volume of concrete	Compressive Strength(CS), N/mm²					
	3 days		7 days		28 days	
	Weight kg	CS N/mm²	Weight in kg	CS N/mm²	Weight in kg	CS N/mm²
0.25	8.73	29.33	8.91	30.11	8.81	42.22
0.50	8.77	30.22	8.91	36.00	9.06	42.66
0.75	8.82	31.11	8.78	36.88	8.94	43.55

Table 7 Split Tensile Strength for Percentage of steel fibers to volume of concrete

Percentage of steel fibers to volume of concrete	Split tensile strength(STS), N/mm²					
	3 days		7 days		28 days	
	Weight kg	STS N/mm²	Weight kg	STS N/mm²	Weight kg	STS N/mm²
0.25	13.87	2.68	13.69	3.32	13.76	3.89
0.50	14.12	3.18	14.00	3.52	13.88	4.38
0.75	13.90	3.25	13.91	3.67	13.89	4.95

Table 8 Flexural Strength for Percentage of steel fibers to volume of concrete

Percentage of steel fibers to volume of concrete	Flexural Strength(FS), N/mm²					
	3 days		7 days		28 days	
	Weight kg	FS N/mm²	Weight kg	FS N/mm²	Weight kg	FS N/mm²
0.25	12.84	4.00	12.03	4.50	12.92	6.00
0.50	13.03	4.40	12.45	4.80	13.22	6.90
0.75	13.05	4.90	12.43	5.00	13.38	7.40

III. Manufacture of Concrete

To produce SFRCC, the crashed stone, sand, cement, and water (containing the agents) were placed in a pan-type mixer of 0.05m3 capacity and mixed for 60 seconds. Super plasticizer was mixed along with the water at a dosage of 7.5ml/kg of cement. The fiber was then manually added little by little and mixed for 210 seconds. The total mixing time was therefore four and a half minutes. For conventional RCC, the concrete was mixed for 90 seconds. After mixing, test sample was taken from the concrete and consistency was measured using a Swedish-type VB consistency-meter. Compaction degree was measured after 60 seconds of vibration. The specimens were casted for compressive strength, split tensile strength and flexural strength. The size of test specimen for compressive strength is 150X150X150mm, for split tensile strength is cylinder of diameter 150mm and length 300mm and for flexural strength the size of specimen is 500X100X100mm. The concrete is placed in layers and compacted using the tamper of weight 10kgs. The samples are cured and tested.

<u>Test Method for Mechanical Properties</u>

A) Compressive Strength Test Method

Specimens of SFRCC of size 150X150X150mm were casted and were cured in a water bath at 21°C for 3days, 7days and 28 days. The compressive strength of concrete was measured. Three or four specimens were tested for a given test condition.

B) Split Tensile Strength Test Method

Specimens of SFRCC of size 150mm diameter and 300mm length were casted and were cured in a water bath at 21°C for 3days, 7days and 28 days. The Split tensile strength of concrete was measured. Three or four specimens were tested for a given test condition.

c) Flexural Strength Test Method

Specimens of SFRCC of size 100X100X500mm were casted and were cured in a water bath at 21°C for 3days, 7days and 28 days. The Flexural strength of concrete was measured. Three or four specimens were tested for a given test condition.

IV. Examination of Mix Proportion

Characteristics

There have been no previous reports on mix proportions for SFRCC as applied to pavements, but it is thought that the design process basically begins with a decision on unit water content and sand percentage from a viewpoint of good workability, required strength, durability, crack resistance, and other factors.

The purpose of this chapter is to examine differences in mix proportion when steel fibers are used, based on the mix design of conventional roller compacted concrete. To this end, the consistency of the concrete was measured using a Swedish-type Vee bee apparatus in terms of a vibrating compaction value (VC value), and then appropriate unit water content, sand percentage and fiber content were determined. The water reducing effect of adding a super plasticizer was also examined.

<u>Graphs showing the variation of Strengths to varying dosage of Super Plasticizer:</u>

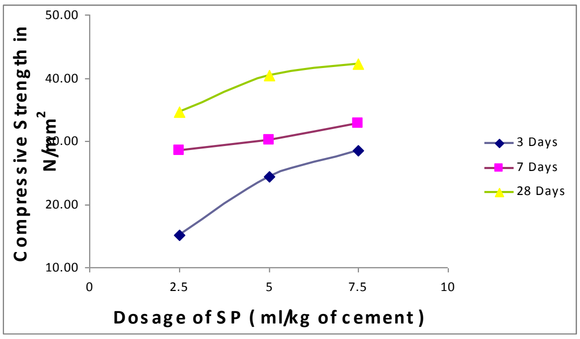


Fig. 1 Graph showing variation of Compressive Strength

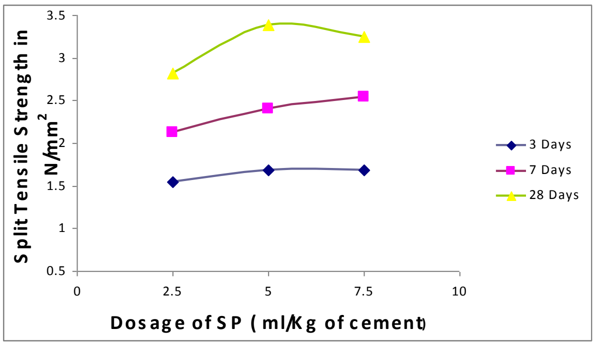


Fig. 2 Graph showing variation of Split tensile strength

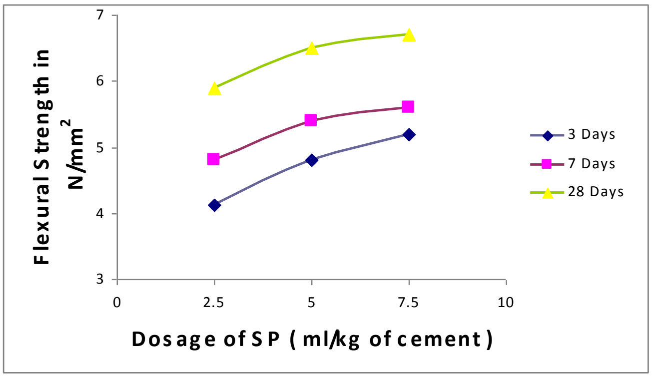
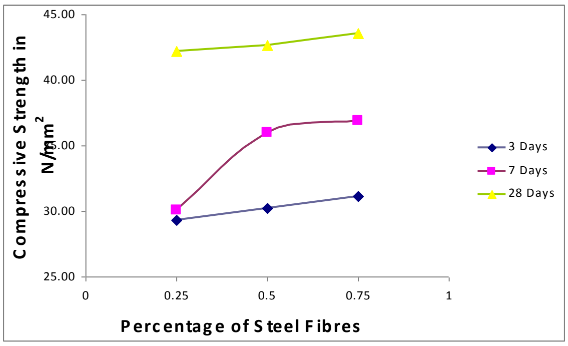


Fig. 3 Graph showing variation of Flexural strength

Pictures showing the steel fibers samples

Graphs showing the variation of Strengths to varying percentage of steel fibres to volume of concrete:



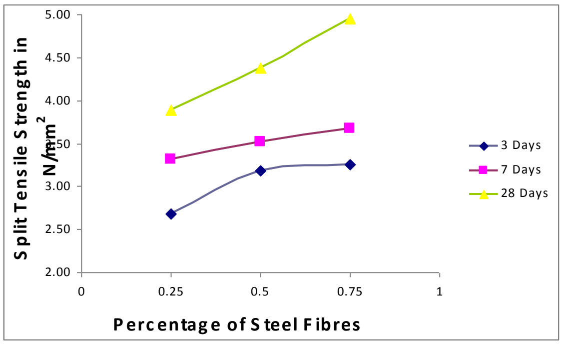


Fig. 4 Graph showing variation of Compressive Strength **Fig. 5** Graph showing variation of Split tensile strength

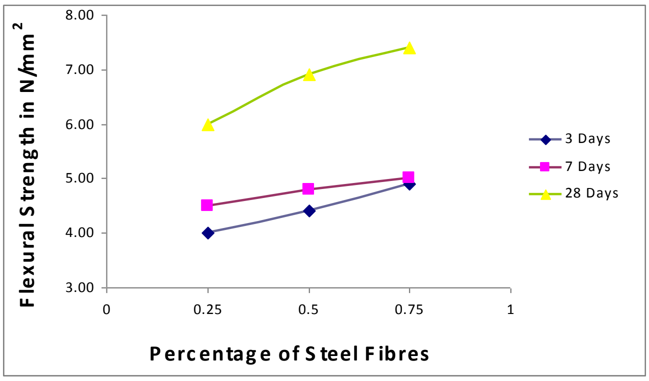


Fig. 6 Graph showing variation of Flexural strength

Picture showing the test method for the compressive, split tensile and flexural strengths and failure beam sample.

V. EXAMINATION OF MECHANICAL CHARACTERISTICS

In this section, the flexural strength, compressive strength and split tensile strength of SFRCC are examined for a given mixture and varying super plasticizer dosage and varying percentage of steel fibers.

Flexural strength, compressive strength and split tensile strength was examined for a given mixture (mix proportions 2 to 7 as shown in Table 2). The load-deflection curve was measured and characteristics of SFRCC deformation for dosage of super plasticizer and percentage of fiber were clarified.

Compressive, split tensile and flexural strengths of given Mix Proportion:

Figure 1, 2 and 3 shows the variation of compressive strength, split tensile strength and flexural strength for varying dosage of super plasticizer i.e. 2.5, 5.0 and 7.5ml per kg of cement. The same mix proportions were used in each case and the VC value was compared with that of the conventional roller compacted concrete. The VC value was reduced by increasing the dosage of super plasticizer. The strengths obtained in each case were compared and it is observed that the flexural strength is increasing by increasing the dosage of super plasticizer.

Further the dosage of super plasticizer is fixed based on the obtained flexural strength values as 7.5ml per kg of cement. The same mix proportion is used in each case by varying the percentage of steel fiber content to the volume of concrete. Figure 4, 5 and 6 shows the varying compressive strength, split tensile strength and flexural strength to the varying percentage of steel fiber to the volume of concrete. Usually steel fibers are used to increase the split tensile strength of concrete. The obtained values are compared with that of conventional RCC.

VI. CONCLUSIONS

This study clarifies that the mix design procedure for SFRCC to be used as pavement material is the same as for conventional pavement concrete in that the choice of appropriate sand percentage and fiber content is very important. The properties of hardened SFRCC, such as flexural strength, are remarkably better than those of conventional RCC. The conclusions reached with respect to mix proportion and the properties of fresh and hardened SFRCC are given below.

(1) The modified VC value of SFRCC is greater than that of conventional RCC, and the change in VC value for each 1 kg/m^3 change in water content is about 3 to 4 seconds, regardless of the presence of fibers. For a given unit water content, there exists a sand percentage at which the modified VC value reaches a minimum. This sand percentage is about 40% regardless of fiber content.

(2) Flexural strength of the samples casted by using super plasticizer is compared with the conventional concrete. It is observed that the flexural strength of the concrete is increasing by increasing the dosage of super plasticizer. By the obtained results it is observed that the flexural strength is increased by 10% to that of conventional concrete.

(3) It is observed that the split tensile strength of the concrete increases by increasing the percentage of steel fibers and it is noted that the strength increases by 35%

(4) Flexural strength of the samples casted by using steel fibers along with super plasticizer is compared

with the conventional concrete and it is observed that the flexural strength of the concrete is increasing by increasing the percentage of steel fibers. By the obtained results it is observed that the flexural strength increases by 20% to that of conventional concrete.

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Authors

V. D. R. Kumar, Post Graduate student, Department of Civil Engineering, V. R. Siddhartha Engineering College, Vijayawada, Andhra Pradesh, 520007. Email ID:drk_vemulapalli@yahoo.com

S. Krishna Rao, Associate Professor, Department of Civil Engineering, V. R. Siddhartha Engineering College, Vijayawada, Andhra Pradesh, 520007. Email ID:snkrishnarao@gmail.com

B. Panduranga Rao, Professor, Department of Civil Engineering, V. R. Siddhartha Engineering College, Vijayawada, Andhra Pradesh, 520007.