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Reuse of Lathe Waste Steel Scrap in Concrete Pavements

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ABSTRACT
These project works assess on the study of the workability and mechanical strength properties of the concrete reinforced with industrialized waste fibers or the recycled fibers. In each lathe industries wastes are available in form of steel scraps are yield by the lathe machines in process of finishing of different machines parts and dumping of these wastes in the barren soil contaminating the soil and ground water that builds an unhealthy environment. Now a day's these steel scraps as a waste products used by innovative construction industry and also in transportation and highway industry. In addition to get sustainable progress and environmental remuneration, lathe scrap as worn-recycle fibers with concrete are likely to be used. When the steel scrap reinforced in concrete it acquire a term; fiber reinforced concrete and steel fibers in concrete defined as steel fiber reinforced concrete (SFRC).Different experimental studies are done to identify about fresh and hardened concrete properties of steel scrap fiber reinforced concrete (SSFRC) and their mechanical properties are found to be increase due to the addition of steel scrap in concrete i.e. compressive strength, flexural strength, impact strength, fatigue strength and split tensile strength were increased but up to 0.5-2% scrap content . When compared with usual concrete to SSFRC, flexural strength increases by 40% and considerable increases in tensile and compressive strength. These steel scrap also aid to improve the shrinkage reduction, cracking resistance i.e. preventing crack propagation and modulus of elasticity. The workability of fresh SSFRC are carried out by using slump test but it restricted to less scrap contents. This work focuses on the enhancement of structural strength and improvement in fatigue life of concrete pavements by reuse of scrap steel in concrete. These concrete roads with SSFRC promises an appreciably eminent design life, offer superior serviceability and minimize crack growth and corrosion. The pioneer idea of this work is the reuse of waste lathe scrap as recycled steel fibers, which provides more cost-effective and eco-friendly sustainable SFRC PAVEMENTS.
Keywords: fatigue life, steel scrap, sustainability, fatigue strength

I. INTRODUCTION

The effective utilization of locally available lathe waste material is certainly a great have to in the recent years. It also describes the influence of fibers on SSFRC properties. The actual role of the fibers is to enhance the toughness of the SSFRC under different type of loading. Toughness defined as area under load vs. deflection curve i.e. fibers provide a enormous arrangement of energy inclusion in post peak section of load deflection curve. In concrete pavements fatigue failures take place under the application of repetitive or cyclic flexural load due to moving traffic. Therefore fatigue performance is an important parameter to be considered for design of SFRC pavements.

The main objectives of this paper are-

- To investigate the use of steel scraps as steel fiber in rigid pavement.
- To scrutinize the various physical and mechanical characteristics of the steel fibers in concrete.
- To compare the effectiveness volume fraction of steel fibers.
- Perform laboratory investigations in order to substantiate workability of steel fibers.
- Flexural Fatigue scrutiny of steel fiber reinforced concrete under repeating load.
- To compare the characteristics of strength between ordinary concrete and SFRC.

II. STEEL SCRAP FIBER REINFORCED CONCRETE (SSFRC)

Steel scrap fiber reinforced concrete (SSFRC) defined as composite materials made with OPC, aggregates and reinforced with steel scrap randomly distributed fibers or discrete discontinuous fibers. The function of fibers in SSFRC is to improve

- Post peak ductility
- Durability
- Pre –crack tensile strength
- Fatigue strength
- Impact strength
- And eradicate temperature and shrinkage cracks

For effective use of fibers in concrete

- Fibers should be extensively stiffer i.e. have a higher modulus of elasticity than the matrix.
- It must be have sufficient length.
- Fibers also have high aspect ratio i.e. ratio of their relative length to its diameter.
- It must be a good bonding with concrete matrix.

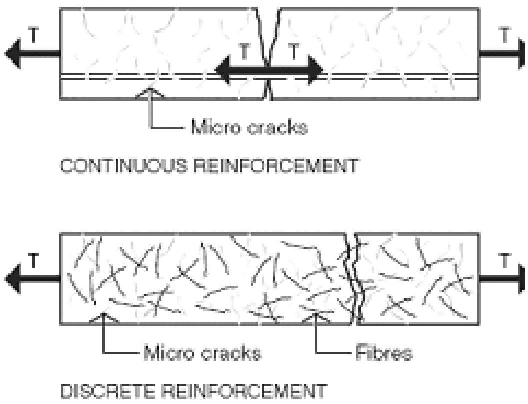
In SFRC, steel fibers balance the forces by transmitting tensile forces to the steel fibers which run along the cracks, as the result flexural toughness and flexural strength increases to great amount. SFRC used broadly in two types of concrete structure i.e. reinforced concrete structure using steel bars and non-reinforced structure. That is for the reason that steel fibers in concrete and steel bars reinforced in concrete members are completely different.

Scrap Steel Fibers obtained from the lathe machines of length 20-30 mm, width 1.5-2 mm and thickness 0.3-0.6 mm are used here to reinforce the concrete matrices. And aspect ratio varies from 50-70 with high modulus of elasticity about 200 GPa. The shape of scrap fibers cross section may be rectangular, twisted and metallic bight appearance.

2.1 Reinforcement Mechanisms

The primary reinforcement mechanism of SSFRC composite is that to linking the post peak macro-crack and behave like crack holder. In fiber reinforcement mechanism, load carrying capacity will increases even cracking occur when moment redistribution take place. Steel fibers give better response at higher dosages of fibers, and increases tensile and flexural strength with strain hardening response beyond crack localization. Before carrying out this mechanism, crack will sustain the load and after once the mechanism complete load capacity will drop.

Evaporation of water and hydration process in concrete breeds shrinkage strains and plastic shrinkage in concrete; this result in contraction stresses causes cracking. Plastic shrinkage cracking remains a severe concern, especially for areas like pavement slabs, overlays, linings and tunneling. Fibers gathering importantly here to employ water in concrete and reduce plastic-settlement, thermal and shrinkage strain, bleeding, segregation and stresses at critical position imposed by external restraints. The result shows that less water evaporates and cause less shrinkage only because of use fiber in concrete composite.



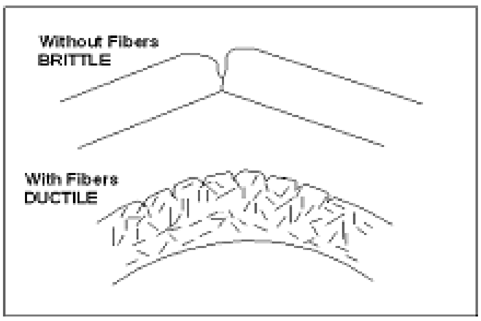


Fig.2.1 Reinforcement Mechanisms

Fiber characteristics controlling SFRC properties

1. Fiber types
2. Fiber Shape
3. Fiber-matrix bond
4. Fiber Length
5. Fiber Orientation
6. Fiber Volume Fraction
7. Aspect ratio (l/d)
8. Fiber reinforcing index (FRI)
9. Modulus of Elasticity of fibers

2.2 Properties of SSFRC

In reinforcement mechanism, steel fibers can also provide an adequate internal restraining mechanism when shrinkage compensate cements are used, it function as a crack control. The transfer of stresses involved from matrix to the fiber or by interlink between the fibers and concrete. As a consequence some important physical properties of SFRC, such as shrinkage, thermal conductivity, electrical properties, freezing and thawing also expose. Therefore after recognize SSFRC properties significances, like conventional concrete are broadly classified as

- Mechanical properties
- Physical and Durability properties

Mechanical properties

The mechanical properties are basically influenced by the fibers characteristics i.e. types of fibers, aspect ratio, quantity of fibers, strength of concrete matrix ;size, shape and designing methods of specimen and aggregates. The mechanical properties are discussed in following section;

1. **Compression:** Typical stress strain curves for SFRC in compression shown in figure curves describes that a substantial increase in the strain at the peak stresses can be found. And the curve slope of the descending portion is less steep for SFRC than specimen without fibers. This stress-strain curves or load deflection curves estimate the toughness from the area under the curve.

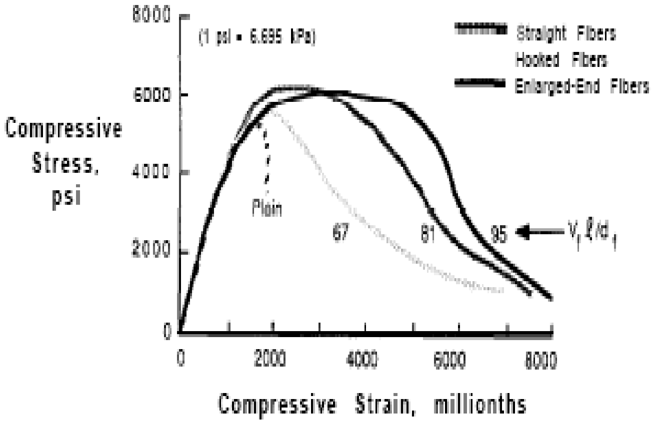


Fig 2.2 Figure 2.7 Stress-strain curves for SSFRC in compression

2. **Flexural strength:** Ultimate flexural strength increases; directly relates to the product of the fiber volume concentration V and aspect ratio (l/d). Less fiber content 0.5% with low aspect ratio is negligible effects on the strength while hooked or enlarged ends have produced flexural strength more than 100% as compared to unreinforced or conventional concrete. High flexural strength in mortar are obtained by consider 0.45 water cement ratio, 6.5 to 10 MPa for 1.5 % by volume of fibers and 13 MPa for 2.5 % by volume of fibers depends on aspect ratio. For SFRC, strength decrease with increase in maximum size of aggregate and proportion of coarser aggregate. For proper workability, aspect ratio will be 100 for uniform straight fibers; aggregates size 8 to 19 mm with fiber content 0.5 to 1.5 % gives typical range of flexural strength 5.5 to 7.5 MPa, depends on water cement ratio and fiber type. Use of super plasticizers increases the strength over the concrete with admixtures if w/c ratio is decreased.
3. **Shear and torsion:** A steel fiber enhances the shear and torsional strength of concrete under static loading, and actual strength achieve by SFRC depends on the alignment of fibers in shear failure zone and shear testing techniques. But there is conflict that of conventional reinforcing bars and reinforced beams to that of reinforced beam made with a SFRC matrix. It is also found out 1% of steel fibers by volume in concrete increase shear strength up to 30%.
4. **Modulus of elasticity and Poisson's ratio:** Practically, When fiber contents by volume in SFRC is less than 2% than modulus of elasticity and Poisson's ratio is taken same as concrete without fibers; Poisson's ratio of SFRC 0.15 should be consider in design.
5. **Direct tension:** Shah et al. 1978 demonstrated the stress-strain curve for steel fiber reinforced mortar. But practically no standard test exists to determine stress-strain curve in direct tension. The obtained curve depends on the size of the specimen, method of testing, stiffness of machine and gage length. The observed curve divide in two sections ascending and descending; ascending section of curve is similar to unreinforced mortar and descending section depends on fiber reinforced parameters, fiber shape, fiber amount and aspect ratio. Descending curve is a post cracking portion of the curve, if one crack forms in the tension specimen, deformation is concentrated at the crack and calculated strain depends on the gage length.
6. **Flexural toughness**: Flexural toughness defines as the area under the load-deflection curve, under static loading i.e. total energy

absorbed earlier before complete separation of specimen. It is one of the most excellent properties of SFRC which makes it different from conventional concrete. Presence of fibers reduce the brittleness of concrete, even cracks occurred SFRC maintain its strength at the point of rupture.

Physical and Durability Properties

Several different materials are used to improve physical properties of materials such as creep, shrinkage, abrasion, skid resistance, thermal properties etc., in addition permeability and freezing thawing damage causes due to cracking makes concrete less durable. These effects of fibers in concrete have been determined using testing methods and some physical properties of SFRC are**;**

1. **Creep:** The presences of low fiber content in concrete from 0.1% to 1% have no significant effect on the creep. SFRC showed small long term deflection than conventional concrete without fiber due to flexural creep performance. ASTM C 1399 perform creep test based on the average residual strength of the beam size 100x100x350mm to a deflection of 0.2mm. It is important in interface bond strength where enclosure behavior of fiber permitted only in pullout mode rather than fracture mode.
2. **Extreme temperature and fire:** Due to low thermal conductivity and high heat capacity concrete is more resistance to extreme temperature and does not fuel combustion when exposed to flames. Steel fibers reinforce in concrete improve the performance under extreme temperature and fire. Conventional concrete resistance the high temperature up to 400˚ F after this temperature concrete degrades as the bond of cement and aggregates. At 800˚ F normal concrete sustain only 50% of its original compressive strength. If temperature increases up to 1700˚ F, there is loss of 90% of structural integrity of concrete; fibers will not prevent failure under such extreme temperature but increases its time of fire exposure to help people . This safe time help fire extinguisher to evacuate structures and allow fire safety. Fire studies involves temperature and duration of fire, rate of feat transfer, moisture content, specimen geometry, concrete age, types of aggregates and other factors.
3. **Shrinkage:** The mainly shrinkage property of concrete depends on the property of materials, temperature and relative humidity of the environment. Concrete shrinks and restrained due to drying environment, tensile stresses are developed and concrete may crack. It is one of the most common causes of cracking of walls, slabs and pavements. And method to resist shrinkage is reinforcing short discrete fibers in concrete.

Steel fibers in shrinkage resistance play important role as;

- They allow multiple cracking in matrix.
- They allow transfer tensile stress across the cracks.
- Permitting healing and sealing of concrete.

4. **Permeability and diffusion:** Conventional concrete are susceptible to degradation and different factors are responsible for this such as corrosion in reinforcement and in aggregates, freezing thawing, alkali-silica reaction, sulphur attack, damage all theses causes permeability and diffusion in concrete. SFRC overcome these problems and has been used successfully in structures where water proofing required such as linings in tunnel, storage tanks for liquids. Permeability of concrete is negligible in an un-cracked condition when water cement ratio just about less than 0.45. Steel fibers in FRC impart improved crack escalation resistance, and also increased surface roughness of individual cracks and become good in branching cracks, due to this reinforcement in concrete reduce permeability of cracked concrete.
5. **Thermal conductivity:** For measure thermal conductivity both transient i.e. unsteady heat flow and steady state heat are used for materials. The steady heat procedures consider for non homogenous materials, such as mortar and concrete, from this linear heat flow and thermal temperature gradient is measured. The fibers blocks of size 75x75x150mm was prepared to test thermal conductivity, contains 0, 0.5, 1.0, 2.0, 4.0 and 8.0%steel fibers. The thermal conductivity of conventional mortar was0.862 W/m˚C and concrete was 1.530 W/m˚C with 0.0, 0.5, 1.0, 1.5 % volume of steel fibers with two different geometric shapes; flat and crimped.
6. **Abrasion/ cavitations/ erosion resistance:** Abrasion resistance relates to pavement and slab wear-tear under wheeled traffic is largely unaffected by steel fibers. Steel fibers also have no effects on abrasion resistance of concrete matrix by debris of flowing water. SFRC has greater resistance to cavitations forces produced by the high

velocity water flow and impact caused by debris in high velocity flowing water.
The erosion caused by low velocities particles and impact caused by high velocities difference between two is noted. Tests were conducted at Waterways Experiment Station with addition of steel fibers in concrete do not improve abrasion or erosion resistance due to adjustments of coarse aggregate in mixture reduces coarse content and increase paste content.

7. **Friction and skid resistance**: Laboratory tests were performed to test the friction and skid resistance property of and concrete SFRC i.e. skid, rolling resistance and static friction. The sample prepare for test have size of aggregate 9.5 mm in SFRC, maximum size aggregate. Tests result showed that for dry concrete surface, has no wear or erosion resistance and deterioration of the surface, while SFRC have abrasion or erosion resistance with 15% high skid and rolling resistance than conventional concrete under dry, wet and frozen condition.
8. **Freezing and thawing:** The durable property of SFRC under freeze and thawing conditions includes following factors i.e cement concrete, aggregates, air content, water cement ratio, fiber types and geometry, fiber content. Balaguru and Ramkrishnan 1986 examine the effects of air content, cement concrete, water cement ratio, fiber types, fiber content and geometry on the freezing and thawing resistance of SFRC. Air contents varied from 1.2 to 10.8 %, cement contents of 362,408,473 kg/m3 and steel fibers hooked ends 44.4 and 59.2 kg/m3were used in experiments. Two specimens are prepared of size 100 x 100x 350 mm were subjected to more than 300 freezing and thawing cycles. Air content is an important factor for freeze and thawing resistance, like plain concrete air entrained in SFRC improves its freezing thawing resistance. The modulus of rupture of beam specimens decrease with freezing and thawing cycling for both plain and concrete. The most of the author conclude that SFRC has excellent resistance to freezing and thawing measured under ASTM C 666/ C 666 M.
9. **Corrosion resistance:** The primary cause corrosion in concrete is similar to SFRC i.e. chloride-induced corrosion and corrosion caus4d by the reduction of pH of the concrete matrix from carbonation. When SFRC are exposed to marine tidal cycles showed no corrosion of low-carbon steel and galvanized steel fibers added in concrete matrix by 2 % weight of cement. From different types of steel fibers, melt extract fibers remained free from corrosion at very much greater levels of chloride ions.
10.

III. MATERIALS

3.1Cement: Ordinary Portland cement (OPC- 53 grade) is used in this experimental work and tested as per IS 12269-1987. Conforming weight of each cement bag was 50 kg.

Table no. 3.1Properties of cement

S.NO.	Properties	Values
1.	Standard consistency (%)	33
2.	Initial setting time(min.)	30
3.	Final setting time (min.)	600
4.	Specific gravity	3.15
5.	Compressive strength at 28 days N/mm²	53
6.	Fineness (%)	2.25

3.2Aggregates

Fine aggregates: Fine sand used from zone II consider for the experiment. The properties of fine aggregates are

Table no. 3.2Properties of Fine aggregates

S.NO.	Properties	Values
1.	Water absorption (%)	0.05
2.	Specific gravity	2.65
3.	Fineness modulus	2.46

Coarse aggregates: The properties of the coarse aggregate are

Table no.3.3 Properties of Coarse Aggregate

S.NO.	Properties	Values
1.	Water absorption (%)	1
2.	Specific gravity	2.70
3.	Fineness modulus	7.133
4.	Impact value (%)	7.5
5.	Abrasion value (%)	18.9
6.	Crushing value (%)	20

3.3 Fibers: These steel fibers are in scarped form called steel scrap or elongated chips. These are in form of waste product and used as steel fibers in concrete.

Table no.3.4Properties of Scrap Steel Fiber

S.NO.	Properties	Values
1.	Cross –section	Straight and deformed
2.	Diameter(mm)	0.3-0.75
3.	Length (mm)	25-40
4.	Density kg/m^3	7850
5.	Young modulus(N/mm²)	2 x 10^5
6.	Tensile strength (N/mm²)	500-3000
7.	Specific gravity	7.85
8.	Aspect ratio	45-100
9.	Elongation (%)	5-35

IV. FRESH AND HARDEN PROPERTIES OF SSFRC

1. Workability: The workability of fresh SFRC is a measured of its ability to be mixed, handled, transported and importantly place and consolidated. Slump test is a common, convenient and inexpensive test but refer only for small fiber contents, for high volume contents inverted cone or vebe test is referred.

Table no.4.1 Slump for SFRC

S.NO.	Steel fibers (%)	Slump (mm)
1.	0	80
2.	0.5	75
3.	1	70
4.	1.5	70
5.	2	70

2. Compressive Strength: Fibers usually minor effects on compressive strength, slightly increasing or decreasing the result. Cubes moulds are used to prepare 15 cubes testing under universal testing machine.

Table no.4.2 Compressive strength of SFRC

Steel fibers (%)	S.NO	Load at failure (KN)	Strength at 28 days (N/mm²)	Average strength at 28 days (N/mm²)
0%	1	520	23.67	24.41
	2	530	24.11	
	3	560	25.44	
0.5%	1	510	23.22	24.55
	2	540	24.55	
	3	570	25.89	
1%	1	530	24.41	24.95
	2	560	25.44	
	3	550	25	
1.5%	1	550	25	25.00
	2	570	25.89	
	3	530	24.11	
2%	1	540	24.55	23.92
	2	520	23.67	
	3	540	23.55	

3. Splitting Tensile Strength: 15 cylinder specimens of size 150 mm dia. by 300 mm height were prepared for each fiber contents. Result from the tensile test, following tensile strength of SFRC after 28 days .ACI 544, 2R-89 refer splitting tensile test for fiber content concrete.

Table No.4.3 Split tensile strength of SFRC

Steel fiber (%)	S.NO.	Load at failure KN	Strength at 28 days (N/mm²)	Average strength (N/mm²)
0%	1	270	3.64	3.4
	2	220	3.07	
	3	250	3.49	
0.5%	1	280	3.91	3.63
	2	240	3.35	
	3	260	3.64	
1%	1	300	4.20	3.91
	2	280	3.91	
	3	260	3.64	
1.5%	1	300	4.20	4.06
	2	310	4.34	
	3	260	3.64	
2%	1	280	3.91	3.82
	2	280	3.91	
	3	260	3.64	

4. Flexural Strength and Flexural Toughness: The principle of flexural behaviour of SFRC depends on the load deflection curve of the third-point loading test. For plain concrete, the stress ratio for flexural fatigue endurance (at 2 million test cycles)is usually 0.45 to 0.50whereas for SFRC with high dosages of steel fibers it can be from 0.65 t0 0.9. Higher factor 0.7 and above cannot be used, unless results of specific investigations are available. For load reversal the fatigue strength is only slightly less. If micro polymeric fibers are used in small dosages (< 0.3% by volume of concrete) for plastic shrinkage control, the endurance stress ratio 0.45 will remain.

Following flexural strength of SFRC increases with increases in fiber contents of steel.

Table no 4.4 Flexural strength of SFRC

Steel fibers (%)	S.NO	Load at failure (Kg)	Strength at 28 days (N/mm²)	Average strength at 28 days (N/mm²)
0%	1	2170	4.432	4.110
	2	2330	4.752	
	3	1530	3.148	
0.5%	1	1850	3.790	4.164
	2	2090	4.272	
	3	2170	4.432	
1%	1	2330	4.753	4.59
	2	2250	4.593	
	3	2170	4.432	
1.5%	1	2570	5.234	5.79
	2	2490	6.074	
	3	2490	6.074	
2%	1	2650	5.395	5.02
	2	2410	4.913	
	3	2330	4.753	

Endurance limit 0.50

1. Straight line relation for SR from 1 to 0.576

$\text{Log}_{10} N= (0.9800\text{-SR})/0.07618$

Or

$SR=0.980-0.07618 \text{ Log}_{10} N$

At SR=0.576, N= 2.00 $x10^5$

2. From SR=0.576 or less, relation is a curve.

$N= [3.3735/ (SR-0.480)]^{3.333}$

OR

$SR = (3.7375/N^{0.300)} + 0.480$

At N=3.73 $X10^7$, SR=0.50; At N=Infinity, SR=0.48

Endurance limit 0.60

1. Straight line relation for SR from 1 to 0.627

$\text{Log}_{10}N = (0.9900\text{-SR})/0.06189$

OR

$SR= 0.990-0.06189 \text{ Log}_{10}N$

At SR =0.627, N= 5.00 x 10^5

2. From SR=0.627 or less, relation is a curve.

$N= [2.9212/ (SR-0.570)]^{3.333}$

OR

$SR= (2.9212/ N^{0.300}) +0.570$

At N=4.25 X 10^6, SR=0.60; At N= infinity. SR= 0.570

Endurance limit 0.70

1. Straight relation for SR from 1 to 0.714

$\text{Log}_{10}N= (1.00\text{- SR})/0.04761$

OR

$SR = 1.00-0.04761 \text{ Log}_{10}N$

At SR=0.714, N= 1.00 x 10^6

2. From SR=0.714 or less, relation is a curve.

$N= [4.0381/ (SR-0.65)]^{3.333}$

OR

$SR= (430381/ N^{0.300}) +0.65$

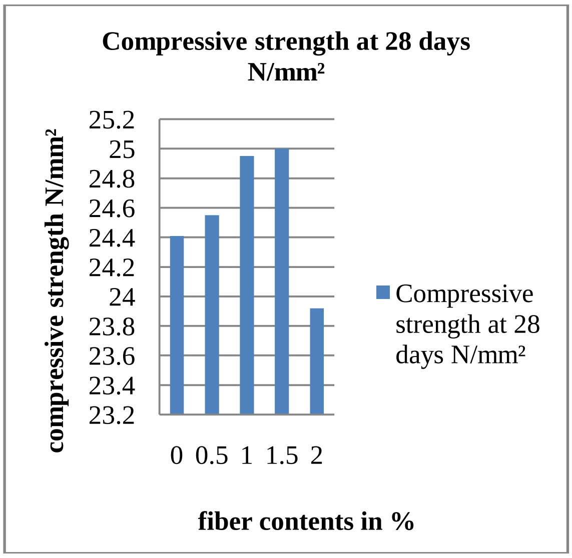
At N=2.28 x 10^7, SR =0.70; At N= Infinity, SR= 0.650

V. RESULTS, GRAPHS AND DISCUSSIONS

Following results are achieved, after 28 days i.e.;

1. Compressive strength of SFRC slightly increases 3% as compared to plain concrete.
2. Tensile strength of scrap steel fiber concrete increases up to 20% considerable increases.
3. Flexural strength of SFRC effectively increases nearly 40 %.

However, results are found that mechanical properties of SSFRC increases up to addition of 1.5% fiber contents and on further increasing fiber contents it will decrease the strength. ACI and JSCE also recommend use of fiber contents up to 2 % more than it needs further investigations. Due to increase in flexural strength of SFRC, fatigue behaviour of SFRC also analysis, stress ratio for SFRC obtained i.e. 0.65 to 0.90 and also IRC: SP-46-2013 recommends this stress ratio for SFRC pavements. With this results SSFRC are suitable for concrete pavements with flexural strength exceeds up to 40% and fatigue ratio 0.65 nominal.



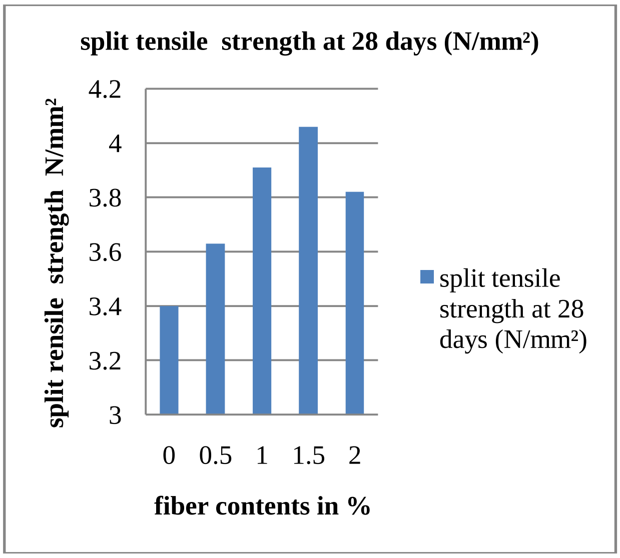


Figure.5.1 Compressive strength of SFRC after 28 days Figure 5.2 Split tensile strength of SFRC after 28 days

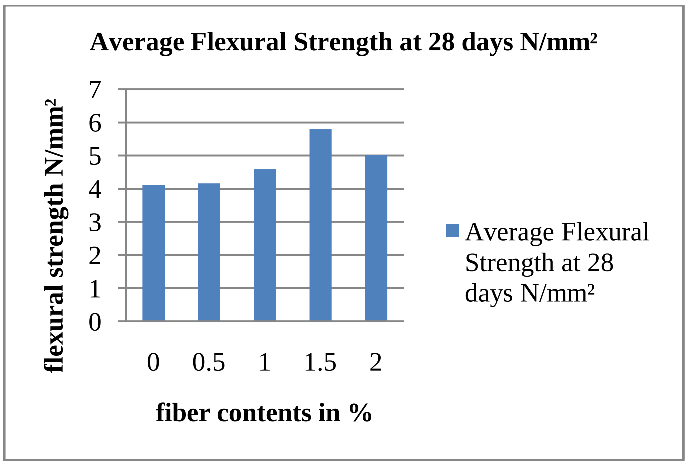


Figure.5.3 Flexural strength of SFRC after 28 days

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