Mechanical Properties of Lathe Scrap Steel Fibers in Pavement Concrete Mix Design

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Abstract: Fiber Reinforced Concrete (FRC) clearly improves the load carrying capacity and energy absorption compared to normal concrete. Various types of industrial fibers such as steel, carbon, glass, polypropylene, nylon and others have been used to reinforce the thick concrete in which lathe scrap waste is not explored as compared to other wastes. In this work, lathe scrap steel fibers has been mixed in different proportion in M25 concrete mix design and mechanical properties of the produced material has been evaluated by measuring slump, compressive strength and flexural strength of the moulds manufactured. Sieve analysis has been carried out both for coarse and fine aggregates used in the mixture. Materials are prepared by mixing and casting 0.0%, 0.1%, 0.25%, 0.5%, 0.75%, 1%, 1.5% and 2% ratio of scraped steel fiber produced from lathe waste in M25 concrete mix design by weight of cement. Cube specimens of size 150 mm3 are prepared to test compressive strength of the moulds after 7, 14 and 28 days of curing. Similarly prism specimens are prepared of size 500*100*100 to test flexural strength of the materials. Workability has been check by taking slump test which falls in 50-60 mm. Experimental results shows increase in compressive strength after 28 days of curing from 33.32 kN/mm2 to 38.53 kN/mm2 when 0.25% and 2% of lathe scrap fiber is used respectively. Similarly increase in flexural strength is noted after 28 days of curing which is 1.88 Mpa (MegaPascal) for material having .25% of scrap fiber and 2.28 Mpa for 2% of lathe scrap fiber.**

***Index Terms* – Scrap Steel fiber, Lathe waste, Compressive test, Flexural Test, Slump Test.**

I. INTRODUCTION

Concrete is one of the main constituent used for construction and is a heterogeneous material consisting of cement, water, sands and aggregates. A variety of types of concrete exist and one of it is Self Compacting Concrete (SCC).

One of the most important functions of steel fibers in concrete is the transfer of stress across the cracks, giving the RC beam a diagonal tightening after the crack. Fibers are found to control cracking, prevent crack width, increase shear strength and hardness and reduce the deviation of concrete beams. In addition, the use of steel fiber changes the pattern of failure to a ductile flexural failure instead of brittle shear [9].

Steel fiber reinforced concrete (SFRC) is a composite material whose components include the traditional constituents of Portland cement concrete (hydraulic cement, fine and coarse aggregates, admixtures) and a dispersion of randomly oriented short discrete steel fibres. Just as with all FRC materials, compared to plain concrete the most noticeable differences are improved ductility and post-cracking performance [12].

Since plain concrete shows poor response under tensile stresses and exhibits early primary cracking, it is considered a brittle material [3]. The addition of steel fibres transforms concrete into a 'pseudo-ductile' material through the ability of fibres to bridge and control cracking. The mechanical properties of steel fiber reinforced concrete (SFRC) are influenced by a number of parameters related to the fibres and concrete matrix, including:

(a) Aspect ratio of the fiber;
(b) Fiber content and type;
(c) Bond between the fiber and the concrete matrix;
(d) Orientation factor.

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.

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 hereto 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.

Lathe waste for making concrete mixtures

Lathe industries generate daily approximately20 kg lathe waste and heavily contaminate the ground water and soil by dumping in the barren lands. Effective management of waste steel scrap material derived from lathe to be used as steel fiber is among the finest solutions for civil construction like pavements and other structures; this recycles the lathe scrap with concrete [19].

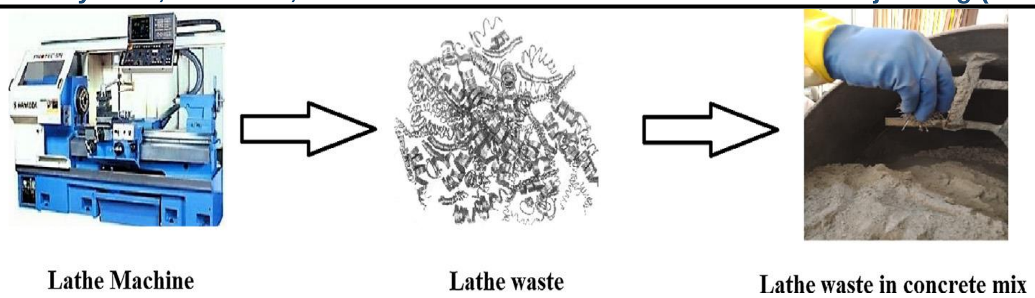

Figure 1: Use of Lathe waste in concrete mixtures [9]

The lathe waste can be used to create concrete so that its strength can be increased. This research will focus on preparing concrete mixture from waste material of lathe machine.

Hooked end lathe waste fibers with aspect ratio varying from 50 to 100 was used as processed manually. The thickness varies from 0.30 mm to 0.60 mm, width 1.50 mm to 2.00 mm and length from 20 mm to 50 mm.

II. Literature Survey

Sengul, O. (2016) [17] obtained the following conclusions: Geometric properties such as diameters of the waste steel fibers recovered from scrap tires may change significantly. There may also be materials such as rubber in the fibers. The fibers that have consistent properties and free from rubber etc. can be preferred for the production of steel fiber reinforced concretes.

Domski, J. et al. (2017) [8] investigated and compared the properties of ESFs and WSFs. Tested ESFs proved to be much more diverse than the commonly assumed fibers. The aspect ratio and other geometrical properties are not associated with changes in the mechanical characteristics of ESFs. More properties of ESFs should be tested and analyzed at the same time (preferably using multivariate statistics) to get clear correlations. The achieved results should be compared with the pullout characteristics of ESF. Before harnessing WSF on an industrial scale in concrete industry, a possible chemical contamination of the WSF should be tested to be sure whether it is safe to use as concrete reinforcement.

Neethu, E. J., & Akhil Raj, S. R. (2017) [16] found the Saenz stress strain model to be applicable for all the SCC, RSCC and SFRSCC mixes. The proposed stress block parameters for the mixes such as effective average concrete stress ratio (α1), the effective stress block depth factor (β1) and the neutral axis depth to effective depth ratio (Xu/d) were found to be lesser than the values for normal concrete specified by IS 456 and that these parameters could be used to determine the flexural strength of members made using the above composites.

El-Sayed, T. A. (2019) [9] investigated the effects of recycled lathe fibers on structural behavior of reinforced concrete beams under static loading conditions. From the above discussions, the following conclusions can be drawn. Using steel & lathe fibers exhibit high ultimate failure load with respect to control specimen. Steel & lathe fibers had high effect in increasing load capacity, deflection, and less cracks propagate. There an acceptable agreement between experimental and numerical results obtained in form of ultimate failure load, deflection and load displacement curves.

Ahmed M. Soliman et al. [14] (2014) explored the mechanical properties of DCSFRC mixtures made with different types and dosages of steel fibres. Laboratory results on small specimens were further confirmed through full-scale production and testing of DCSFRC precast pipes. The engineering properties of DCSFRC mixtures were improved as the fibre dosage was increased. Consequently, DCSFRC precast pipes incorporating higher fibre content exhibited higher ultimate and post-cracking strengths. The reinforcing index, RIv can be utilized for comparing the splitting tensile and flexural strengths of different DCSFRC mixtures, while it showed no defined correlation with the compressive strength and modulus of elasticity.

III. Problem Formulation

After studying the literature, it is clear that most of research has been done on use of steel fibre in concrete. But less work has been done on use of waste steel material produced from Lathe machine. The use of steel scrap fiber reinforced concrete (SSFRC) could be considered as a potential alternative to the use of traditional shear reinforcement. SSFRC is the generic term used to define a composite material whose components include the traditional constituents of concrete and a dispersion of randomly waste steel fibres produced from lathe machine. Concrete is very weak and brittle in tension, the use of steel scrap fiber reinforced concrete (SSFRC) can transform this behaviour. The addition of steel fibres improves the diagonal tension capacity of concrete and thus can result in significant enhancements in shear capacity. There is very little study found which evaluates the performance of scraped steel fibres in Indian standard concrete mixes.

IV. MATERIALS USED IN RESEARCH

CEMENT

For this research work, Ordinary Portland cement of Grade 53 is used. The used cement was gray and free from lumps.

Aggregates

These are inert materials that are combined or mixed with some binding material in some fixed amount to produce the concrete. The aggregates are responsible for providing hardness, strength, and durability to the created constructions or pillars, pipes etc.

Types of Aggregates

Fine Aggregates

In fine aggregates, the grain size is between 4.75 mm and 0.15 mm. In other words, this sieve step with the mesh size of 4.75 mm and is preserved in a0.15 mesh size sieve. Sand is the most naturally available natural natural aggregate.

Coarse Aggregates

The coarse aggregates are those that are conserved in the sieve of the mesh size of 4.75 mm. Its upper size is usually around 75 mm. The river bed waterfalls are the best coarse aggregates in the preparation of common concrete.

The properties of lathe waste fibers are given in below table:

Table 1: Properties of lathe waste fibers

Average Length (mm)	1-50
Average width (mm)	1.50–2.00
Average thickness (mm)	0.30–0.60
Aspect Ratio	50–100
Young’s modulus (GPa)	200
Tensile strength (MPa)	970–1190
Density (kg/m^3)	7850
Specific Gravity	7.85

WATER

It is the main material for making the concrete as it participates actively in the chemical reaction of producing concrete. The water that needs to be used for making concrete must be free from impurities like alkalis, oil, acids etc. and clean. Also, the pH level must be between 6 and 8. For this research work, locally available water is used that is suitable for drinking as well. In this work, we used Lathe scrap produced from the lathe machine. The below figures shows the pictures of scrap materials.

Figure 2: Lathe waste produced from Lathe machine

V. Results and Discussion

This section shows the value of results taken after carrying out compressive strength, flexural strength and slump tests for the specimens prepared form M25 mix design in which eight different ratio types of 0.0%, 0.1%, 0.25%, 0.5%, 0.75%, 1%, 1.5% and 2% of lathe steel fiber scrap weight is used with respect to cement weight in the mixture. The experiments were conducted in JPR Balaji Pavers Pvt. Ltd. (Ludhiana)

Compressive Strength Test

Standard metallic cube molds (500mm * 100mm * 100 mm) were casted for compressive strength. A table vibrator was used for compaction of the hand filled concrete cubes. The specimens were demoulded after 24 horns and subsequently immersed in water for different age of testing. For each age three specimens were tested for the determination of average compressive strength. In this test compressive strength has been carried out on the M-25 grade of concrete by adding lathe scrap steel fiber in the concrete by using ratio eight different ratios of steel fibres as 0.0%, 0.1%, 0.25%, 0.5%, 0.75%, 1%, 1.5% and 2% of that of the cement. Readings has been taken after 7 days, 14 days & 28 days of casting.

Table 2: Compressive strength test of concrete by varying lathe scrap steel fiber material

Mix design	Sample No.	Compressive strength test (kN/mm2)			Average 28 day compressive strength
		7 Days	14 days	28 days	
M-25-LS.0	S1	19.32	24.54	28.97	28.905
	S2	19.46	24.9	28.84	
M-25-LS.01	S1	20.67	25.98	30.48	30.22
	S2	20.43	26.36	29.96	
M-25-LS.025	S1	21.52	26.95	33.32	33.365
	S2	21.47	26.65	33.41	
M-25-LS.05	S1	23.62	29.06	33.67	33.725
	S2	23.86	28.97	33.78	
M-25-LS.075	S1	24.86	30.12	34.06	33.955
	S2	24.55	29.96	33.85	
M-25-LS.1	S1	25.54	31.14	35.01	35.135
	S2	26.03	31.29	35.26	
M-25-LS.1.5	S1	28.08	33.68	37.93	37.355
	S2	27.59	33.3	36.78	
M-25-LS.2	S1	29.29	34.51	38.53	38.38
	S2	29.06	34.17	38.23	

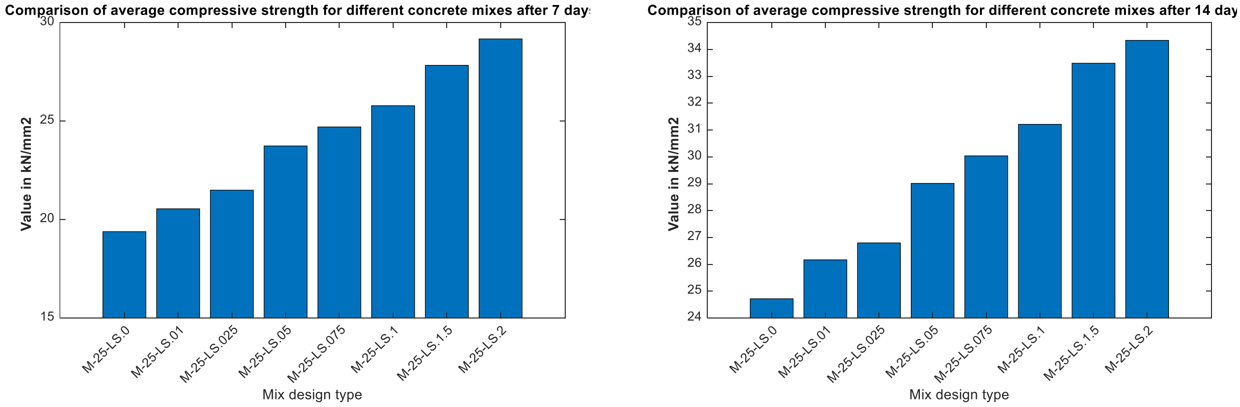

Figure 3: (a) Comparison of average compressive strength for concrete mix (a) after 7 days (b) after 14 days

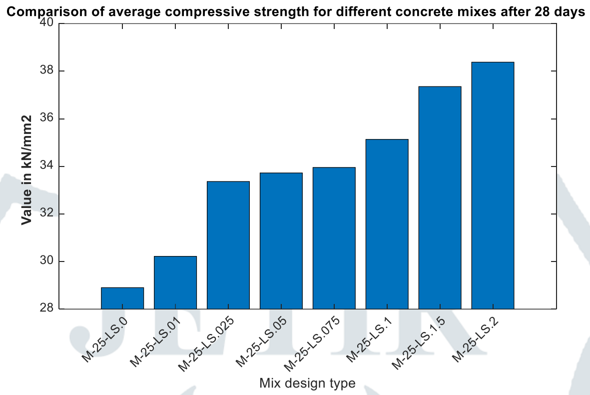

Figure 4: Comparison of average compressive strength for concrete mix after 28 days

Result of average values of compressive test were taken for concrete mix after 7, 14, and 28 days. It can be seen that the compressive strength of the concrete mix is increasing with the increasing ratio of lathe scrap. The highest compressive strength is found for the 2% ratio in which the lathe scrap used were 2% of the complete mixture.

Flexural Strength Test

Flexural tensile strength is conducted to determine the strength of concrete by varying the % of lathe steel fiber mix with respect to cement to know the strength of concrete mix of M-30 lathe waste materials. Standard metallic beam moulds (100 mm * 100 mm * 500 mm) were casted for the preparation of concrete specimens for flexural strength. A table vibrator was used for compaction of the hand filled concrete beams. The specimens were de-moulded after 24 hours and subsequently immersed in water for different age of testing. For each age three specimens were used for the determination of average flexural strength.

Table 3: Flexural tensile strength test of concrete by varying %age of lathe scrap steel fiber material

Mix design	Sample No.	Flexural tensile strength test (Mpa)			Average 28 day Flexural strength
		7 Days	14 days	28 days	
M-25-LS.0	S1	1.285	1.41	1.9	1.895
	S2	1.278	1.401	1.89	
M-25-LS.01	S1	1.281	1.405	1.908	1.905
	S2	1.284	1.416	1.902	
M-25-LS.025	S1	1.36	1.436	1.886	1.899
	S2	1.315	1.435	1.912	
M-25-LS.05	S1	1.327	1.448	1.933	1.939
	S2	1.331	1.453	1.945	
M-25-LS.075	S1	1.358	1.424	1.983	1.978
	S2	1.346	1.448	1.974	
M-25-LS.1	S1	1.382	1.563	2.013	2.02
	S2	1.393	1.557	2.027	
M-25-LS.1.5	S1	1.512	1.635	2.128	2.131
	S2	1.457	1.627	2.134	
M-25-LS.2	S1	1.635	1.861	2.273	2.279
	S2	1.573	1.824	2.286	

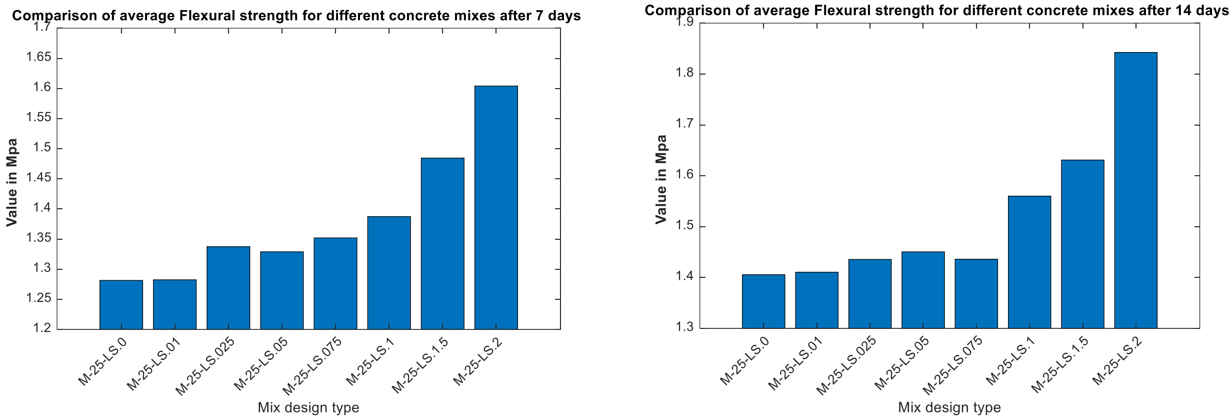

Figure 5: Comparison of average flexural tensile strength for concrete mix (a) after 7 days (b) after 14 days

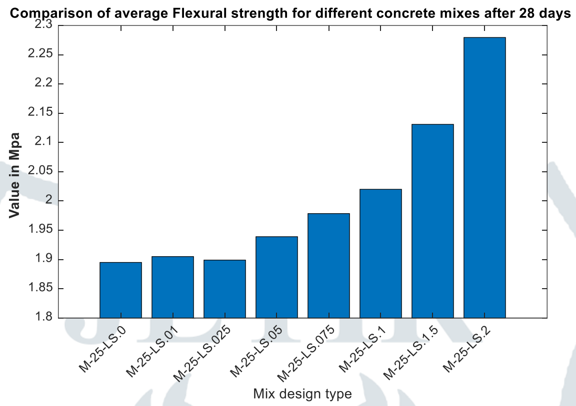

Figure 6: Comparison of average flexural tensile strength for concrete mix after 28 days

Result of average values of flexural test were taken for concrete mix after 7, 14 and 28 days respectively. It can be seen that the compressive strength of the concrete mix is increasing with the increasing ratio of lathe scrap amount. The highest flexural strength is found for the 2% ratio in which the lathe scrap used were 2% of the complete mixture. Although, the highest strength results were observed for ratio 1.5% and 2.0% as compared to other mixtures.

Slump test

Slump test is generally carried out before pouring the concrete into road, beams, slabs etc. It has low value (0-25mm) when concrete mix is dry generally in making roads and moderate 50-100 mm when there is some reinforcement usually in case of beams, slabs etc. The value of slump test has been carried out for 8 samples in which eight mixes are used with lathe scrap steel fiber.

Table 4: Slump test for different types of concrete mix design

Mix design	Slump value (in mm)
M-25-LS.0	74
M-25-LS.01	73
M-25-LS.025	69
M-25-LS.05	67
M-25-LS.075	66
M-25-LS.1	60
M-25-LS.1.5	55
M-25-LS.2	49

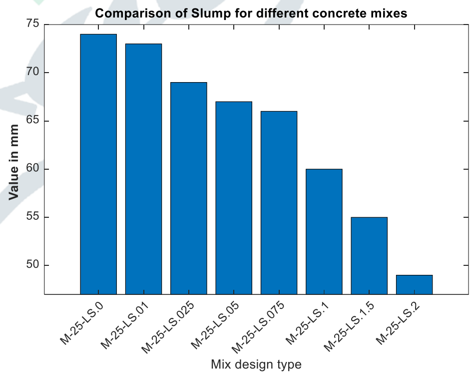

Figure 7: Slump test for 8 different types of concrete mix design

From figure 7 of Slump test results, it can be observed that the slump of mixture having 2% of lathe scrap is lowest as compared to the other mixtures having less amount of lathe scrap. So, this can be observed that the good slump value is obtained for the mixture having 2% of lathe scrap.

VI. Conclusion

The purpose of this study is to use lathe scrap steel fibres in M25 mix design by taking different proportion with respect to cement and to check the workability of the materials produced. The research idea is based on using the lathe waste fibers in the concrete mixture to increase its strength. Here, M25 type of mixture is used for the concrete mix. Different ratios of scrap lathe waste is mixed in the concrete mixture to check it's properties like, compressive strength, flexural strength, and slump vale. These tests were performed to check the workability of the produced concrete using the lathe waste. The percentage of recycled lathe fibers was (0.0%, 0.1%, 0.25%, 0.5%, 0.75%, 1%, 1.5% and 2%) by weight of cement. From the results of study, it can be concluded that by taking higher ratio of the scrap fibers, the strength of the mixture is increased and slump is reduced. The results of compressive strength, flexural strength, and slump test of mixture having 2% of lathe scrap are very good as compared to the other mixtures having less amount of lathe scrap. So, this can be observed that the good slump value is obtained for the mixture having 2% of lathe scrap. This signifies the efficiency of proposed design of creating concrete mixture by using the lathe scrap waste along with other materials like aggregates, water, and cement etc. This research used the scrap produced form lathe machine to increase the strength of the concrete by taking different proportions of the lathe scrap to the complete mixture. In future, more types of materials like waste plastic, rubber tires etc. can be considered along with lathe scrap to check the workability of the produced concrete.

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