Experimental Studies of the Application of Turn Steel Scraps as Fibres in Concrete – A Rehabilitative Approach

Vasudev R.[1], Dr. B. G. Vishnuram[2]

[1]Associate Professor, Department of Civil Engineering, Toc H Institute of Science & Technology, Arakkunnam, Ernakulam, Kerala, India

[1] vasu.vasudev@gmail.com

[2] Principal and Professor in Civil Engineering, P. S. R. Engineering College, Sivakasi, Tamil Nadu, India

Abstract— Concrete, even though inevitable in the field of construction, is characterised by its brittle failure. It nears to complete loss of load carrying capacity, once the failure has been initiated. This characteristic, which imparts a negative remark on the application of this material, is improved by the inclusion of a small amount of randomly distributed fibres which can remediate the weaknesses of concrete. Steel fibre reinforced Concrete (SFRC) has the improved properties of tensile strength, flexural strength, shock resistance, fatigue resistance, ductility and crack arrest. It has thus been practised in various professional fields of construction. The concrete construction is not sustainable for a variety of reasons, the foremost being that it consumes huge quantities of virgin materials. Second, being the principal binder in concrete, the Portland cement, during its production causes major contribution to greenhouse gas emissions that causes global warming and drastic climatic changes. Third, many of the concrete structures are less durable, thereby adversely affecting the resource productivity. Therefore the researchers are presently towards rehabilitative approaches on creating sustainable concrete by adopting fly ash blended concrete, which is again modified by adding steel fibres. This addresses all sustainability issues and its adoption will enable the construction industry to become more eco-friendly. Thus, this paper aims to have a comparative study between ordinary reinforced concrete and steel fibre reinforced high strength concrete under tensile and compressive loading. The fibres added in this study are the wastes from lathe shops. The behaviour of concrete samples is investigated by adding varying percentage of turn steel scraps as fibres, viz., 0.25%, 0.5%, 0.75% and 1%. The behaviour of steel fibre reinforced high strength concrete is also evaluated based on flexural capacity, load carrying capacity, cracking behaviour and deflection characteristics. The basic concrete mixes adopted were M40 and M60. The results obtained were promising, which can be adopted in the construction industry.

Keyword- Steel Fibre Reinforced Concrete, Turn steel scraps, Rehabilitative approach

I. INTRODUCTION

Concrete is a vital construction material having high compressive strength and comparatively low tensile strength. Based on fracture toughness values, steel is at least 100 times more resistant to crack growth than concrete. Concrete in service thus cracks easily, and this cracking creates easy access routes for deleterious agents resulting in early saturation, freeze-thaw damage, scaling, discoloration and steel corrosion.

The concerns with the inferior fracture toughness of concrete are alleviated to a large extent by reinforcing it with fibres of various materials. The resulting material with a random distribution of short, discontinuous fibres is termed fibre reinforced concrete (FRC) and is slowly becoming a well accepted construction material. Significant progress has been made in the last thirty years towards understanding the short and long term performances of fibre reinforced concrete, and this has resulted in a number of novel and innovative applications.

The present paper emphasizes on the study of strength parameters of HSC with steel fibre reinforcement in varying percentage up to 1%. The strength parameters considered were compressive strength, split tensile strength and flexural strength. Steel Fibre Reinforced Concrete (SFRC) has an untapped potential application in building frames due to its high seismic energy absorption capability and relatively simple construction technique. To utilize such potential, the utilities of SFRC need to be investigated in detail and the building codes need to be revised to promote its application as a common construction material. The purpose of this paper is to shower lights over the knowledge of the application of SFRC in HSC. By adding fibres made of steel to reinforced concrete, the matrix shall not possess cracks which enable the structure to be more durable. The concrete construction is not sustainable because of many reasons. There is no other heterogeneous material which consumes huge quantities of virgin materials. Portland cement is the principal binder used in concrete. During its production, a high emission of greenhouse gas occurs, which causes global warming and drastic climatic changes. Many of the concrete structures are less durable and hence, it adversely affects the resource productivity. Therefore the researchers are now towards rehabilitative approach on creating sustainable concrete by adopting fly ash blended concrete which is again modified by adding steel fibres. Even the manufacture of steel also highlights these issues. So, rather than using conventional steel fibres, a rehabilitative approach has been adopted by using scrap turn steel which is obtained from lathe industry. It is a classic example of reusing the wastes for enhancing the properties, especially the flexural properties of concrete. This addresses all sustainability issues and thereby enables the construction industry to become more sustainable.

This work aims to enhance the knowledge of the application of SFRC through experimental investigation and analysis by performing tests on cubes, cylinders and beams, made up of concrete of M40 and M60 grades which are modified using turn scrap steel fibres.

II. LITERATURE REVIEW

Concrete is a most widely used construction material in the world. Because of its ability to get cast in any form and shape, it has almost replaced old construction materials such as brick and stone masonry. The strength and durability of concrete can be changed by making appropriate changes in its ingredients like cementitious material, aggregate and water and by adding some special ingredients. Hence, concrete is very well suited for a wide range of applications. However, deficiencies of concrete includes low tensile strength, low post cracking capacity, brittleness and low ductility, limited fatigue life, not capable of accommodating large deformations, low impact strength.

The presence of micro cracks at the mortar-aggregate interface is responsible for the inherent weakness of plain concrete. This weakness can be removed by inclusion of fibres in the mix. Different types of fibres have been introduced into the concrete mixture to increase its toughness, or ability to resist crack growth. Thus, the fibre reinforced concrete is a composite material essentially consisting of conventional concrete or mortar reinforced by fine fibres.

The fibres can be imagined as an aggregate with an extreme deviation in shape from the rounded smooth aggregate. The fibres interlock and forms lumps by surrounding aggregate particles which considerably reduce the workability, while the mix becomes more cohesive and less prone to segregation. The fibres are dispersed and distributed randomly in the concrete during mixing, and thus improve concrete properties in all directions. Fibres help to improve the compressive strength, tensile strength, flexural strength, post peak ductility performance, pre-crack tensile strength, fatigue strength, impact strength and eliminate temperature and shrinkage cracks. Essentially, fibres act as crack arresters restricting the development of cracks and thus, transforming an inherently brittle matrix, i.e., cement concrete with its low tensile and impact resistances, into a strong composite with superior crack resistance, improved ductility and distinct post cracking behaviour prior to failure[5].

A. *High Strength Concrete*

High Strength Concrete (HSC) is defined solely on the basis of its compressive strength measured at a given age. Concrete can be made to have strengths of up to 100 MPa at 28 days by using good quality and well graded aggregates and also by adding supplementary cementitious materials such as fly ash, granulated blast furnace slag, silica fume, rice husk ash and metakaolin. The fundamental parameter for attaining high strength, is low porosity which is achieved by using cement content more than 500 kg/m^3 of concrete, low water/cement ratios (<0.35) , and by adequate compaction and curing[4]. To achieve a normal workable mix, a super plasticizing admixture is inevitable in high strength concrete.

In the 1970s, any concrete mixtures that had 40 MPa or more compressive strength at 28 days were designated as high strength concrete. Later, 60-100 MPa concrete mixtures were commercially developed and used in the construction of high rise buildings and long span bridges in many parts of the world. Since the modulus of elasticity does not increase at the same rate as strength, utilization of higher working stresses in high strength concrete leads to higher strains or deformations than in normal strength concrete. Moreover, it is observed that the brittleness of concrete increases with strength[4]. The advantages of high strength concrete include reduction in member sizes, reduction in self weight thereby reducing the foundation cost, reduction in area of form work, takes up more load even though the member size is less, lower creep and shrinkage, superior durability and thereby reducing the maintenance cost.

B. *Reinforced Concrete & Fibre Reinforced Concrete*

Tensile strength of concrete is typically 8% to 15% of its compressive strength[2].This weakness has been dealt with over many decades by using a system of reinforcing bars (rebars) to create reinforced concrete so that concrete primarily resists compressive stresses and rebars resist tensile and shear stresses. Fibre reinforced concrete is a concrete mix that contains short discrete fibres that are uniformly distributed and randomly oriented. Fibre material can be steel, cellulose, carbon, polypropylene, glass, nylon, and polyester[6]. The amount of fibres added to a concrete mix is measured as a percentage of the total volume of the composite (concrete and fibres) termed V_f. V_f typically ranges from 0.1 to 3%. Aspect ratio (l/d) is calculated by dividing fibre length (l) by its diameter (d)[14]. Fibres with a non-circular cross section generally use an equivalent diameter for the calculation of aspect ratio. The randomly distributed discontinuous fibres bridges across the cracks and improves the load carrying capacity in the post-cracking stage[12].

C. Steel Fibre Reinforced Concrete

Steel Fibre Reinforced Concrete (SFRC) consists of all normal ingredients used for conventional concrete and discrete steel fibres. Incorporating the steel fibres does not mean the direct replacement of longitudinal reinforcement in structural members. Major contribution of steel fibre is that during tension, the SFRC fails only after the steel fibre breaks or is pulled out of the cement matrix. The mechanics of fibre reinforcement is being researched and developed as it strengthens concrete or mortar which can be treated as a composite material relating the properties of fibre used, the improved concrete properties and the properties of the interface between fibre and matrix.

Fig. 1. Steel fibres
(Source: www.metallurgicalocatelli.it)

The major fibre reinforcement properties are the fibre strength, stiffness and its ability to bind itself with the concrete. The bond is dependent on the aspect ratio of fibre. The steel fibres have high strength and Young's modulus [6]. It is protected from corrosion by the alkaline environment of the cementitious matrix and the bond strength can be enhanced by mechanical anchorage and surface roughness. ASTM establishes minimum tensile strength and bending requirements for steel fibres as well as tolerances for length, diameter (or equivalent diameter), and aspect ratio. The minimum yield strength required by ASTM is 345 MPa.

D. Sustainability

Meeting the housing and infrastructural need of the society, by emphasizing the sustainability is an important challenge faced by the concrete industry in the present situation. Major sustainability issues like climatic changes, ecology and resource productivity are to be considered very seriously as it effects the human beings in one way or the other. The steel industry has major issues like energy utilization during its production and service, transportation, use of raw materials and water, emission of harmful substances etc. The cement industry also confronts such issues as one tonne of Portland cement during its manufacture releases approximately one tonne of carbon dioxide to the atmosphere. This is the major contributor to the green house effect and the global warming of the planet. So, the use of cement has to be reduced to achieve the goal of protecting the nature and thereby make it as green as possible.

III. PRELIMINARY STUDY

The sustainable development is thus the need of the hour and this paper deals with the study of making concrete more sustainable. Sustainability shall be achieved by reducing the use of products which causes the depletion of nature. For achieving the same, one should make concrete durable and adopt higher grades than normal mixes. The durability of the structures reduces by crack propagation and it can be addressed by the addition of steel fibres. The Indian Standard Code of Practice for Reinforced Concrete had restricted the use of cement in concrete to 450 kg/m^3. For achieving higher grade of concrete, the use of supplementary cementitious materials is encouraged. The cement content shall thus be reduced and thereby sustainability is achieved. By using higher grades of concrete, the structural cross section is reduced and thereby, the utility space in buildings are increased which attracts more income. In this study, the supplementary cementitious material used is fly ash. Fly ash is not a "filler" material. In fact, in concrete fly ash becomes part of the matrix. It reacts with compounds in Portland cement during the hydration process to form new products that are beneficial. When cement reacts with water, two main hydration products form: calcium silicate hydrate (CSH – a higher strength material) and calcium hydroxide (CH – a lower strength material). When fly ash is added, the amorphous (or reactive) silica will convert the CH to CSH, added an important "S", which results in more strength. Other beneficial properties, such as a denser matrix, reduce the ingress of aggressive agents like chlorides or sulfates, among others.

The steel fibres used in this study are the turn steel scraps from mechanical lathe industry. No proper studies had been conducted on this fibre so far. The turn steel scrap obtained from the workshop is in the form of coiled fibre which was cleaned and cut to the length ranging from 30 – 40 mm. The equivalent diameter of the fibre varied from 0.9 – 1.1 mm and the aspect ratio 33 to 37. A rough estimate of the tensile strength of the fibre was obtained as 361 N/mm^2. It was obtained by loading the fibre until failure. The fibre volume content of 0.25 to 1 % was tried throughout the project.

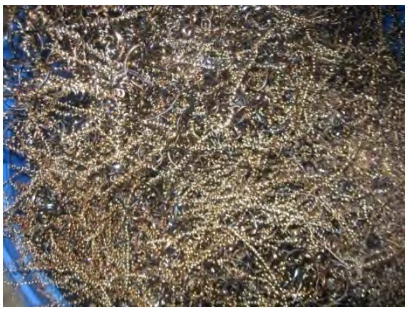

Fig. 2. Turn steel scraps

This experimental work can be considered as recycling of waste thereby improving the properties of concrete. The materials such as fly ash and the turn steel scraps which are recycled in different forms have a new facet of rehabilitation into the concrete industry. The fibres generally seen in literatures are costly, but turn steel fibres are absolutely a scrap and it has efficiency in improving the properties of the concrete. In fact, the entire work offers a cost effective and sustainable approach to the field of construction. Cost effective by productively using the scrap and sustainable in a wide sense by the environmental friendliness it offers by incorporating fly ash and hence reducing cement content in higher grades of concrete.

A. Mix Design

The proportioning of concrete mixes consists of determination of the quantities of respective ingredients necessary to produce concrete having adequate, but not excessive, workability and strength for the particular loading and durability for the exposure to which it will be subjected. The mix design is done in confirmation to IS 10262-2009. The main emphasis shall be on workability with specific consideration on strength aspects also. Therefore, the specific relationships that are used in proportioning concrete mixes should be considered only as a basis for trial, subject to modifications in the light of experience as well as for the particular materials used at the site in each case.

As with any other type of concrete, the mix proportions for SFRC depend upon the requirements for a particular job, in terms of strength, workability, and so on. Several procedures for proportioning SFRC mixes are available, which emphasize the workability of the resulting mix. However, there are some considerations that are particular to SFRC. Commonly, to reduce the quantity of cement, up to 35% of the cement may be replaced with fly ash. In addition, to improve the workability of higher fibre volume mixes, water reducing admixtures and, in particular, super-plasticizers are often used, in conjunction with air entrainment. Concrete mix design can be defined as a tentative procedure for determining the proportions of ingredients in concrete to achieve, desired characteristic compressive strength. Mix proportion done for M40 and M60 concrete as per IS 10262-2009 are given below.

TABLE I
Mix Proportion of M40

Water	**Cementitious (Cement + Flyash)**	**Fine Aggregate**	**Coarse Aggregate (12:20)**
165.3 kg/m^3	311 + 124 kg/m^3	603 kg/m^3	420 : 779 kg/m^3
0.38	1	1.39	0.966 : 1.79

Admixture – 0.6% (Conplast *SP430)*

TABLE II
Mix Proportion of M60

Water	**Cementitious (Cement + Flyash)**	**Fine Aggregate**	**Coarse Aggregate (12:20)**
145.6 kg/m^3	450 + 110 kg/m^3	520 kg/m^3	403 : 748 kg/m^3
0.26	1	0.93	0.72 : 1.33

Admixture – 0.3% (Glenium)

B. Casting & Beam Design

Nominal concrete cubes (150 mm x 150 mm x 150 mm), concrete cylinders (300 mm long and 150 mm diameter) and beams (100 mm x 200 mm and 1 m span) were cast. Mixtures of crimped and irregular steel fibres obtained from lathe shops were cleaned and sorted (30 mm – 40 mm in length) and mixed with the aggregate while casting the specimen. The beams were cast with fibre contents 0%, 0.25%, 0.5% & 0.75%, because on preliminary studies it was observed that the 1% fibres does not contribute for a positive result. The reinforcement was provided in the form of two bars of 8 mm diameter at the top, three bars of 8mm diameter at the bottom and vertical stirrups of 8 mm diameter at 150 mm spacing. It was made sure that the fibres were uniformly distributed throughout the mix.

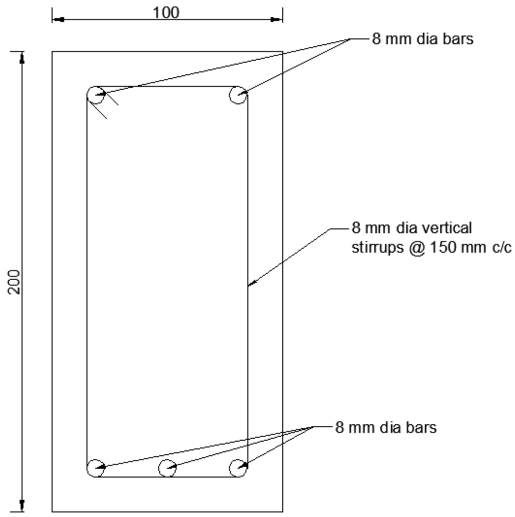

Fig. 3. Cross section of beam

The test specimens was stored in a place, free from vibration, in moist air of at least 90 percent relative humidity and at a temperature of 27° ± 2°C for 24 hours ± ½ hour from the time of addition of water to the dry ingredients. After this period, the specimens were marked and removed from the moulds and immediately submerged in clean, fresh water and kept there until taken out just prior to test. The water in which the specimens are submerged was renewed every seven days and maintained at the same temperature of 27° ± 2°C. The specimens were not allowed to become dry at any time until they have been tested.

IV. TESTING OF SPECIMENS

The mix design was finalised after getting the positive results. The same design was tried throughout the entire project. The materials used were kept consistent throughout the project.

A. Compressive Strength

The cubes were cast in the cubical mould of size 15 mm adopting the designed mix ratio. Cubes of M40 and M60 concrete mix were cast with fibre contents 0%, 0.25%, 0.5%, 0.75% and 1%. The compressive strength test was conducted with cubes after the required period of curing. The Table III and IV show the results of compressive strength for M40 and M60 grade concrete.

TABLE III

Compressive Strength of M40 Grade Concrete Cubes

Fibre content (%)	**7th Day**		**28th Day**	
	Mean Load (kN)	**Compressive strength (N/mm^2)**	**Mean Load (kN)**	**Compressive strength (N/mm^2)**
0%	750.2	33.33	1072	47.64
0.25%	776.13	34.49	1086.7	48.3
0.5%	790.4	35	1148	51
0.75%	763.17	33.9	960	43.07
1%	716.87	31.8	816..3	36.3

TABLE IV

Compressive Strength of M60 Grade Concrete Cubes

Fibre content (%)	7th Day		28th Day	
	Mean Load (kN)	Compressive strength (N/mm^2)	Mean Load (kN)	Compressive strength (N/mm^2)
0%	966.27	42.95	1481	65.86
0.25%	980.13	43.56	1483	65.92
0.5%	1118	49.7	1541.3	68.5
0.75%	1064.7	47.32	1344	59.76
1%	989	43.96	1308.7	58.6

The test results were favourable for those with fibres. Generally, the concrete with fibres does not favour the compressive strength results. But due to good workmanship and by the use of mineral admixtures the results were impressive.

B. Splitting Tensile Strength

The cylinders were cast in the cylindrical mould of size 150 mm diameter and 300 mm height, adopting the designed mix ratio. Cylinders of M40 and M60 concrete mix were cast with fibre contents 0%, 0.25%, 0.5%, 0.75% and 1%. The splitting tensile strength test was conducted on these cylinders after the required period of curing. The results of splitting tensile strength test were as given in Table V and VI below.

TABLE V

Splitting Tensile Strength of M40 Grade Concrete Cylinders

Fibre content (%)	7th Day		28th Day	
	Mean Load (kN)	Split Tensile strength (N/mm^2)	Mean Load (kN)	Split Tensile strength (N/mm^2)
0%	99.67	1.41	214.7	3.04
0.25%	162.58	2.3	241	3.41
0.5%	190.83	2.7	264	3.73
0.75%	137.83	1.95	223.7	3.16
1%	134.3	1.9	260.7	3.69

These results were very significant as it enhances the tensile properties of concrete and is noticeably at par with the results of the conventional fibres readily available in the market.

TABLE VI

Splitting Tensile Strength of M60 Grade Concrete Cylinders

Fibre content (%)	7th Day		28th Day	
	Mean Load (kN)	Split Tensile strength (N/mm^2)	Mean Load (kN)	Split Tensile strength (N/mm^2)
0%	210	2.97	241	3.41
0.25%	220.5	3.12	276	3.9
0.5%	261.5	3.7	319	4.51
0.75%	200.75	2.84	227	3.21
1%	168.2	2.38	209	2.95

C. First Crack Load and Ultimate Load

The beams were cast in the mould of size 100 mm x 200 mm x 1000 mm adopting the designed mix ratio. The beams were designed as under reinforced. A number of beams were cast with fibre contents 0%, 0.25%, 0.5% & 0.75%. Uniform dispersion of fibres was ensured throughout the concrete mass. The reinforcement was provided as discussed earlier. The beams were tested after required period of curing. The Fig. 4 shown below is the test set up for the beam specimen. The results obtained are tabulated from Table VII to XII and the variations are plotted graphically from Fig. 5 to 10.

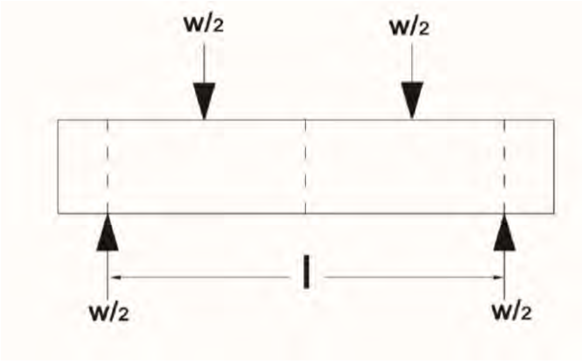

Fig. 4. Loading pattern on beam sample

1) M40 Beams – 3rd Day Strength:

TABLE VII

3rd Day Strength of M40 Beams

Type of sample	Beam	
Mix proportion	1 : 1.39 : (0.97 : 1.79)	
Water cement	0.38	
Fibre content (%)	First Crack Load	Ultimate Load
0	45	63
0.25	49	66
0.5	53	75
0.75	44	59

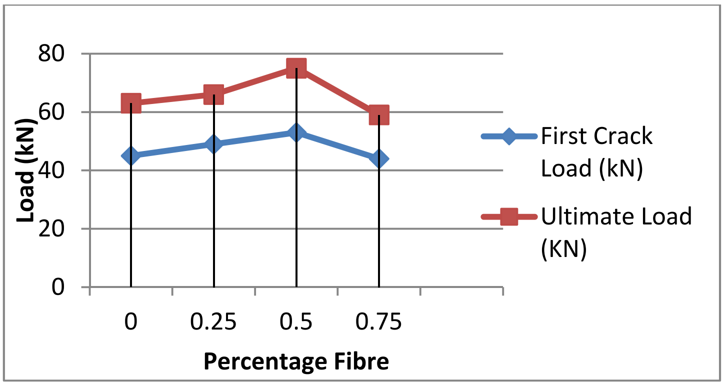

Fig. 5. Variation of first crack load & ultimate load, M40 -3rd day

2) M40 Beams – 7th Day Strength:

TABLE VIII

7th Day Strength of M40 Beams

Type of sample	Beam	
Mix proportion	1 : 1.39 : (0.97 : 1.79)	
Water cement ratio	0.38	
Fibre content (%)	First Crack Load	Ultimate Load
0	49	69
0.25	52	73
0.5	55	84
0.75	47	68

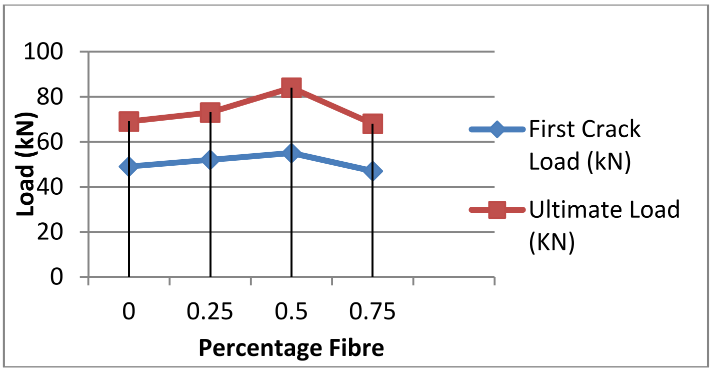

Fig. 6. Variation of first crack load & ultimate load, M40 – 7th day

3) M40 Beams – 28th Day Strength:

TABLE IX

28th Day Strength of M40 Beams

Type of sample	Beam	
Mix proportion	1 : 1.39 : (0.97 : 1.79)	
Water cement	0.38	
Age of specimen	28 days	
Fibre content (%)	First Crack Load	Ultimate Load
0	54	90
0.25	58	93
0.5	63	98
0.75	53	87

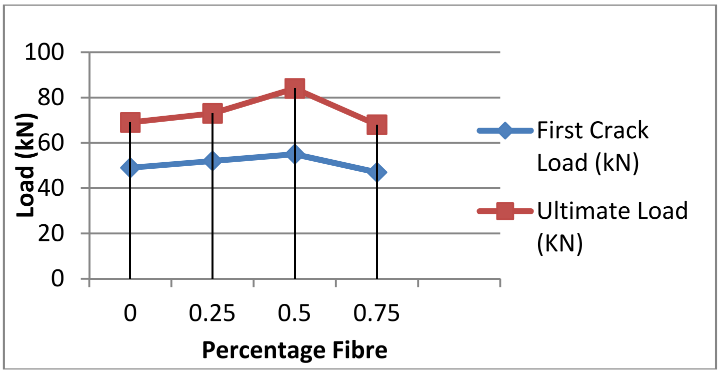

Fig. 7. Variation of first crack load & ultimate load, M40 – 28th day

4) M60 Beams – 3rd Day Strength:

TABLE X

3rd day strength of M60 Beams

Type of sample	Beam	
Mix proportion	1 : 0.93 : (0.72 :1.33)	
Water cement	0.26	
Age of specimen	3 days	
Fibre content (%)	First Crack Load	Ultimate Load
0	45	70
0.25	48	73
0.5	52	79
0.75	46	71

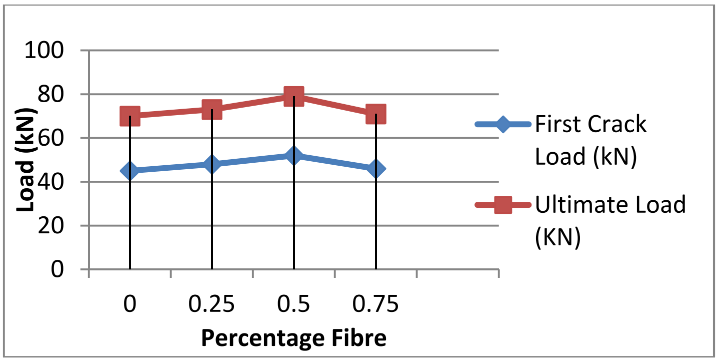

Fig. 8. Variation of first crack load & ultimate load, M60 – 3rd day

5) M60 Beams – 7th Day Strength:

TABLE XI

7th day strength of M60 Beams

Type of sample	Beam	
Mix proportion	1 : 0.93 : (0.72 :1.33)	
Water cement ratio	0.26	
Age of specimen	7 days	
Fibre content (%)	First Crack Load (kN)	Ultimate Load (kN)
0	51	79
0.25	54	85
0.5	59	91
0.75	50	77

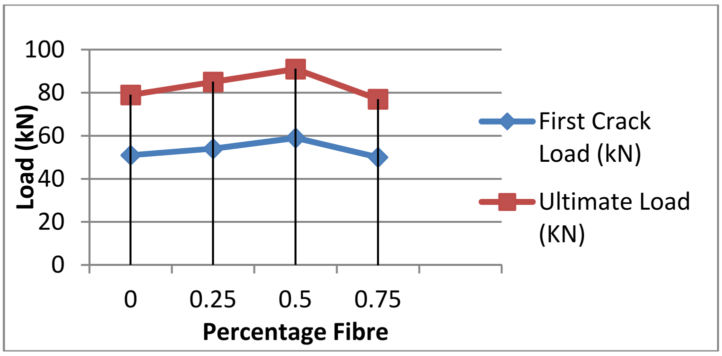

Fig. 9. Variation of first crack load & ultimate load, M60 – 7th day

6) M60 Beams – 28th Day Strength:

TABLE XII

28th day strength of M60 Beams

Type of sample	Beam	
Mix proportion	1 : 0.93 : (0.72 :1.33)	
Water cement ratio	0.26	
Age of specimen	28 days	
Fibre content (%)	First Crack Load (kN)	Ultimate Load (kN)
0	62	100
0.25	65	110
0.5	70	117
0.75	60	98

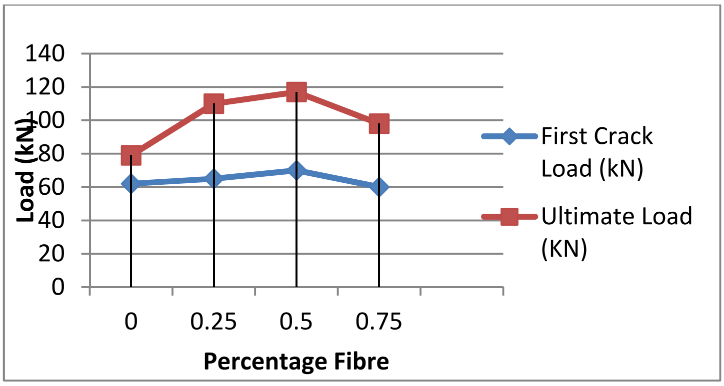

Fig. 10. Variation of first crack load & ultimate load, M60 – 28th day

D. Crack Pattern in Beams

First crack load, ultimate load and crack patterns were analysed after subjecting the beam to two point loading. The tested samples are shown below from Fig. 11 to16.

Fig. 11. Failure mode of M40 Beams- 3rd day

Fig. 12. Failure mode of M40 Beams- 7th day

Fig. 13. Failure mode of M40 Beams- 28th day

Fig. 14. Failure mode of M60 Beams- 3rd day

Fig. 15. Failure mode of M60 Beams- 7th day

Fig. 16. Failure mode of M60 Beams- 28th day

E. Post Cracking and Ductile Behaviour of RC Beams

Post cracking and ductile behaviour of beams were studied by carefully analysing the crack patterns and deflection during loading. Ductility index of beams casted with 0% and 0.5% were found and compared. The ductility of the member can be quantified by the ductility index. The ductility index which is expressed by the following equation is used to examine the ductility of the members.

$\mu = \frac{\Delta f}{\Delta cr}$ where μ is the deflection ductility index of the member

Δf is the deflection at failure of the member

Δcr is the deflection of the member at first crack load

The ductility index of the samples under consideration is consolidated in Table XIII

TABLE XIII

Ductility Index of Beam Specimen

Grade	Fibre content (%)	Deflection at first crack load (mm)		Deflection at failure load (mm)		Ductility index	
		7th	28th day	7th	28th day	7th	28th day
M40	0%	0.7	0.65	1.2	1.8	1.76	2.73
	0.5%	0.95	0.85	2.1	2.5	2.2	2.94
M60	0%	0.6	0.55	1.1	1.5	1.8	2.76
	0.5%	0.9	0.95	2.5	3.4	2.8	3.6

The variations of the deflection with load for various samples are illustrated in Fig 17 to 22 below.

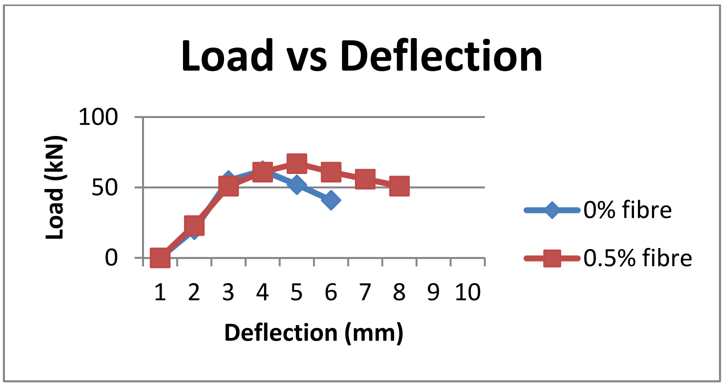

Fig. 17. Post cracking behaviour in M40 beams – 3rd day

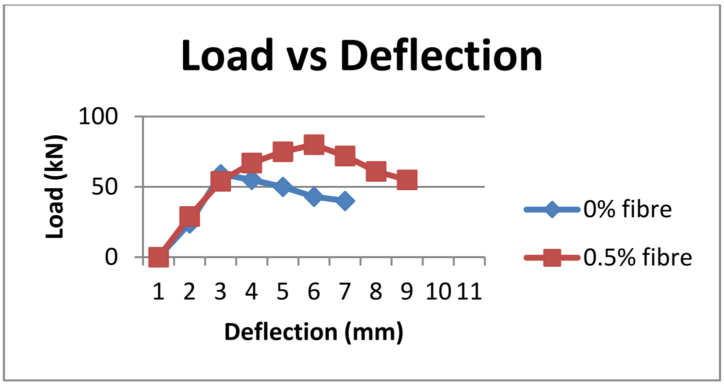

Fig. 18. Post cracking behaviour in M40 beams – 7th day

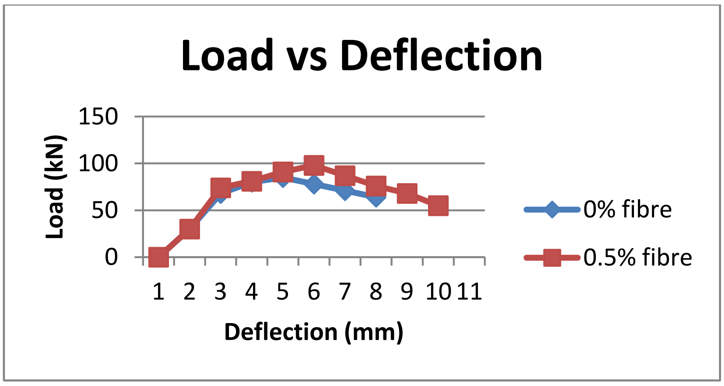

Fig. 19. Post cracking behaviour in M40 beams – 28th day

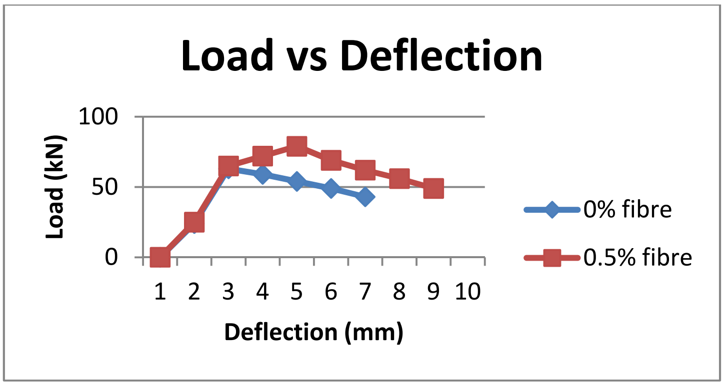

Fig. 20. Post cracking behaviour in M60 beams – 3rd day

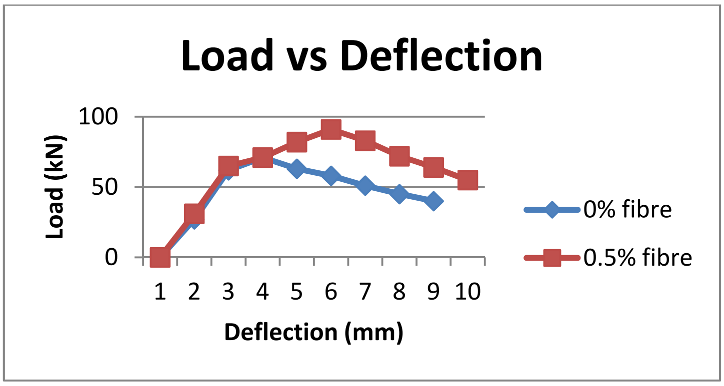

Fig. 21. Post cracking behaviour in M60 beams – 7th day

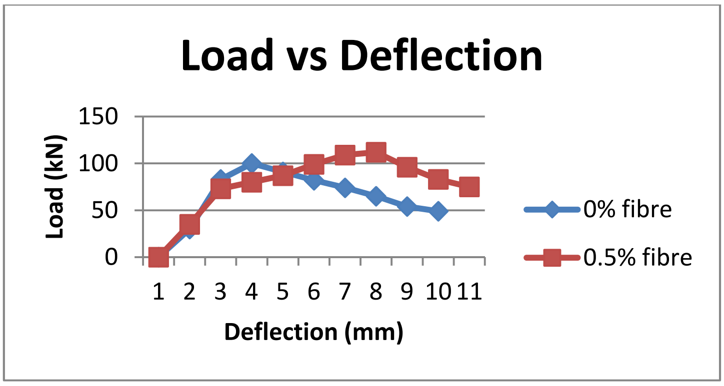

Fig. 22. Post cracking behaviour in M60 beams – 28th day

Based on the experimental results, the following observations were made:-

- It is observed that compressive strength, tensile strength and flexural strength of concrete with 0.5% steel fibres are higher as compared to that produced from 0%, 0.25%, 0.75% and 1% fibres.
- The compressive strength is increased by 7% for M40 grade concrete and 15% for M60 grade concrete, not necessarily by the addition of fibres but due to the improved workmanship and by the addition of mineral admixtures.
- The splitting tensile strength was found to be increased by 23 % for M40 concrete and 32 % for M60 grade concrete by the addition of steel fibres.
- The first crack load is increased by 17 % for M40 grade concrete and 13% for M60 grade concrete by the addition of steel fibres.
- The ultimate load on tested specimen appeared to be increased by 22% for M40 grade concrete and 17% for M60 grade concrete by the addition of steel fibres.

V. Discussions

The concrete industry is to be made sustainable to make this wonderful construction material live for next generations. The exploitation of many natural materials is to be controlled which can be possible only by rehabilitating and reusing many of the waste materials like turn steel fibres from lathes, fly ash etc. The disposal of fly ash was a major issue which later became the most essential material in the cement industry for its blending. Later on it was used as supplementary cementitious materials in the concrete industry. From the above results, it is evident that the addition of steel fibres enhances some of the properties of concrete. Steel fibre has an effect ranging between little to significant on the mechanical properties. Tensile strength and flexural strength at first crack and ultimate load is significantly improved by the addition of steel fibres while there is only a slight improvement in the compressive strength. The fibre volume content of 0.5% was found to be the optimum dosage which rendered the maximum increase in strength and further increase in fibre content tends to be ineffective. The probable reason is that the increase in fibre causes the ball effect as a result of movement of fibres towards each other during mixing thereby reducing the workability of the concrete. Consequently, the compressive strength decreases for larger fibre volumes. It is pertinent to mention that the optimum fibre volume depends on the concrete mix as well as type of fibres.

Adding fibres to a plain matrix has little or no effect on its pre-cracking behaviour but does substantially enhance its post cracking response, which leads to greatly improved toughness and impact behaviour. Besides, ductility in fibre-reinforced cementitious composites is enhanced because the fibres bridge cracked surfaces and delay the onset of the extension of cracks. Further, the increase in compressive strength of high strength concrete enhances the toughness behaviour of the concrete. The addition of steel fibres in these concrete increases the ductility of the concrete as well as toughness. The presence of steel fibre in the concrete improves the crack arresting property of concrete and increases the closure stress at constant crack width. This would increase the energy absorption capacity of the fibre composite.

VI. Conclusion

HSC, that consistently meets requirements for workability and strength development places more stringent requirements on material selection than that for lower strength concrete. Therefore, the production of HSC may or may not require the special materials, but it definitely requires materials of highest quality and their optimum proportions. In the production of HSC, use of strong, sound and clean aggregates is essential. Apart from those, the addition of fibres that are scraps and not used other than for recycling in the steel industry is used for the enhancement of the properties of the HSC. The high strength concrete also tolls for higher amount of cement content which is restricted by the addition of Supplementary Cementitious Materials (SCM) like fly ash. By all these enhancements, even the compressive strength also increased to the range of 7 to 15 %. The addition of steel fibres which is commercially available in market increases the budget of the project. But, by rehabilitating the scraps extracted from the steel lathe shops, improved the tensile properties of concrete in the order of 20 to 35 % in both the grades of concrete. This is very much encouraging as the use of such scraps is affordable by the common man. The higher strength concretes was used for the commercial applications only as it cost high. But, due to its advantageous properties of using fewer materials which is the reserve in nature and revenue returns in the form of utilizable spaces within the buildings, it is adopted by the common man too. The post cracking behaviour of turn steel fibre reinforced concrete is well comparable with the results of concrete enhanced by conventional commercially available steel fibres. The first crack load has an increase from 10 to 17 % and the ultimate crack load to about 15 to 25%. The scraps which was discarded unattended has shown its way of rehabilitation by enhancing the properties of concrete at absolute zero additional cost thus proving a new step of sustainable development.

REFERENCES

[1] Adeyanju and K. Manohar, "Effects of Steel Fibres and Iron Filings on Thermal and Mechanical Properties of Concrete for Energy Storage Application", Journal of Minerals & Materials Characterization & Engineering, Vol. 10, No.15, pp.1429-1448, 2011

[2] ACI Committee 544, (1984) "Guide For Specifying, Mixing, Placing, and Finishing Steel Fibre Reinforced Concrete", American Concrete Institute

[3] ACI Committee 544, (1995), "State of the Art Report on Fibre Reinforced Concrete", ACI Structural Journal, Vol 92, pp 627-628

[4] A M Neville , J J Brooks, Concrete Technology

[5] A M Shende, (2011), "International Journal of Advanced Engineering Sciences and Technologies", Vol no. 6, Issue no. 1, 116 – 120

[6] ASTM A820 / A820M – 11, "Standard Specification for Steel Fibres for Fibre reinforced concrete".

[7] V. Soulioti, N. M. Barkoula, A. Paipetis, T. E. Matikas. "Effects of Fibre Geometry and Volume Fraction on the Flexural Behavior of Steel-Fibre Reinforced Concrete", International Journal of Applied Mechanics, Vol. 47, Issue Supplement s1, pages 535–541, June 2011

[8] Elsaigh W A, (2001) "Comparative Evaluation of Plain and Steel Fibre reinforced concrete ground slabs", PhD dissertation, University of Pretoria

[9] Ganeshan N. Indira P V, "Structural Behavior of Steel Fibre Reinforced Concrete Wall Panels in Two Way in Plane Actions", Indian Concrete Journal, Vol. 84, No:10, pp 21 – 28, October 2010.

[10] Had Bayasi and Henning Kaiser (2001); "Steel Fibres as Crack Arrestors in Concrete", Indian Concrete Journal, Vol. 75, pp 215-219.

[11] Henager C H, (1977), "Steel Fibrous Ductile Concrete Joint for Seismic resistant Structures", SP 53-14, ACI, pp.371-386

[12] Mac Gregor J, (1997), "Reinforced Concrete Mechanics and Design", 3rd edition, New Jersey, Prentice Hall

[13] Mohammad Abdur Rashida, Mohammad Abul Mansurb, (2009) "Considerations in Producing High Strength Concrete", Journal of Civil Engineering, Vol. 37, pp 53-63

[14] "State-of-the-Art Report on Fibre Reinforced Concrete" Reported by ACI Committee 544. ACI Committee 544.1R, (1996) Fibre Reinforced Concrete, American Concrete Institute, Michigan, USA.

[15] Vasudev R., Dr. B. G. Vishnuram, "Studies on Steel Fibre Reinforced Concrete – A Sustainable Approach", International Journal of Scientific & Engineering Research, Vol. 4, Issue 5, pp 1941 – 1944, May 2013.

[16] IS 10262:1982,2009; Guidelines for Concrete Mix design Proportioning.

[17] IS 456:2000; Plain and Reinforced concrete code of Practice

[18] IS 383:1970; Specification for coarse and fine aggregates from natural sources for concrete

[19] IS 10086:1982; Specifications for moulds for use in test of cement and concrete

[20] IS 516:1959; Methods of test for strength of concrete

[21] IS 5816:1999: Method of Test Splitting Tensile strength of Concrete