Experimental Investigation on Effect of Different Shaped Steel Fibres on Compressive Strength of Recycled Coarse Aggregate Concrete of M20 Grade

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Abstract

This paper presents the results of the experimental investigation of compressive strength of steel fibre reinforced concrete (SFRC). Variables considered in the project work of various shapes and fiber volume fractions. Compressive strength is investigated using mix of M20 grade and hooked, flat, crimped fibres with aspect ratio 50. The fibre volume fraction is varied from 1% to 2% by volume of concrete separately. Standard test specimens for compressive strength were cast and water cured for 28 days. At 1% addition of steel fibres 25%, recycled coarse aggregate with water cement ratio 0.55 compressive strength tests gives best results.

Keywords: *Recycled Coarse Aggregate (RCA), ACI Mix-design, Steel Fiber, Workability, Compression*

I. INTRODUCTION

One of the major challenges of the present society is the protection of environment. Some of the important elements in the respect are the reduction in the consumption of energy, natural materials and extensive use of waste materials. Nowadays these are getting considerable attention under sustainable development. The use of recycled aggregates from the construction and demolition wastes is showing prospective application in construction as an alternative to the natural, aggregate. It conserves natural resources and reduces the spaces required for the landfill disposal. India is presently generating construction and demolition (C&D) waste of 23.75 million tons annually and these figures are likely to double in the next 7 years. C&D waste, specifically concrete, has been seen as a resource in developed countries. Works on recycling have emphasized that if old concrete has to be used in second generation concrete, the product should adhere to the required compressive strength. Literature reveals that compressive strength primarily depends upon adhered mortar, water absorption, size of aggregates, strength of parent concrete, age of curing and ratio of replacement, interfacial zone, moisture state, impurities present and controlled environmental condition.Concrete makes many desirable properties and moulds itself to a variety of innovative designs. However some deficiencies of the convention cement concrete such as brittleness, poor tensile strength, poor impact strength etc. resulting cracks and hence becoming unsuitable for certain applications. Major research in this field identified crack-free concrete structural possible via secondary reinforcement techniques. Deficiencies encountered with conventional concrete can be overcome by the addition of the fibres to cement concrete, which improves the crack resistance, fracture toughness, resistance to impact and shocks etc. The micro cracks and interfacial discontinuities are the causes of unstable crack propagation and low tensile strength of conventional concrete. The addition of fibres to concrete would alter the crack propagation and makes it more controlled and slow, which leads to reduction crack propagation and improved tensile strength.

II. OBJECTIVES OF THE STUDY

The construction industry and concrete manufactures have realized that they will need to use available aggregate rather search for the perfect aggregate to make us use full concrete. Simultaneously, significant increase in concrete recycling result in hundreds of tons of recycled aggregate that could be used in production of concrete for specific purposes. From the past literature it is noticed that no work has been conducted on RAC with addition of steel fibres by 1% and 2% by the volume of specimen with various ratios. Hence here an experimental work has been planned with the following objectives:

Objectives:

1) To carryout different tests on natural aggregates and recycled aggregates.

2) To compare the compressive strength of control concrete of M20 grade and steel fibres concrete produced by replacing cement by steel fibres in different percentage (1%, 2% by volume of concrete).

3) To find out the percentage use feasible for construction.

III. FIBER REINFORCED CONCRETE (FRC)

Plain concrete possesses a very low tensile strength, limited ductility and little resistance to cracking internal micro cracks are inherently present in the concrete & its poor tensile strength is due to the propagation of such micro cracks, eventually leading to brittle fracture of the concrete. In the past, attempts have been made to impart improvement in tensile properties of concrete members by way of using conventional reinforced steel bars & also by applying restraining techniques. Although both of these methods provide tensile strength to the concrete members, they however, do not increase the inherent tensile strength of concrete itself. In plain concrete & similar brittle materials, structural cracks (micro cracks) develop even before loading, particularly due to drying shrinkage or other causes of volume change. The width of these initial cracks seldom exceeds a few microns, but their other two dimensions may be of higher magnitude. It has been recognized that the addition of small, closely spaced uniformly dispersed fibres to concrete would act as crack arrester & would substantially improve its static & dynamic properties. This type of concrete is fibre reinforced concrete. Fibre reinforced concrete can be defined as a composite material consisting mixture of cement, mortar, concrete & discontinuous, discrete, uniformly dispersed suitable fibres. Continuous meshes, woven fabrics and long wires or rods are not considered to be discrete fibres.

IV. FACTORS AFFECTING PROPERTIES OF FRC:

Fibre matrix: High modulus of fibre (steel, glass, carbon) imparts strength & stiffness to the composite unlikely to improve the strength but help in absorption of energy i.e.

impart greater resistance to impact & offer toughness. This can be improving by increasing the area of contact, frictional properties etc.

Volume of fibre: Increases in volume increases tensile strength and toughness of the composite but higher increases is likely to cause segregation and hardness.

Aspect ratio: Aspect ratio up to 75 increases the ultimate strength but beyond 75 relative strength & toughness reduces.

Orientation: Fibre aligns parallel to the applied load offer more tensile strength and toughness then randomly distributed or perpendicular fibre.

Workability & compaction of concrete: Workability of concrete is reduced due to addition of fibres even after prolonged vibration it depends on the aspect ratio & also the uniformity in distribution of fibres. Workability can be improved by increasing water cement ratio or by using plasticizer.

Size of coarse aggregate: The inter particle friction between fibre& aggregates controls the orientation & distribution of fibres. Consequently there is improvement in the properties of concrete which can be affected by using friction reducing admixtures or admixtures which improve cohesiveness.

Mixing: It needs careful consideration to avoid falling of fibres, segregation & in general the difficulty of mixing the materials uniformly.

V. ADVANTAGES OF FRC:

1) FRC distributes localized stresses.
2) Reduction in maintenance and repair cost.
3) Provides tough and durable surfaces.
4) Reduces surface permeability, dusting and wear.
5) They act as crack arrestor.
6) Increases tensile strength and toughness.
7) Resistance to impact.
8) Resistance to freezing and thawing.

VI. LITERATURE REVIEW:

1. Experimental investigation on steel fibre reinforced concrete using metakaolin.

The experimental work which is been carried out to evaluate mechanical properties of steel fibre reinforced concrete using metakaolin. Effect of steel fibres and metakaolin on mechanical properties of concrete is also studied. Fibre content is varied from 0.25 to 1% at an interval of 0.25% by volume of concrete. The metakaolin is used at 15% by weight of cement. Various mechanical properties considered for investigation are compressive, split tensile and flexural strength. For these total 15 cubes, 15 cylinders and 15 beams are casted. All the specimens are cured for the period of 28 days. The workability is measured using slump cone test. The test results of steel fibre reinforced concrete using metakaolin are compared with control concrete.

2. Strength properties of glass fibre concrete.

The present day world is witnessing the construction of very challenging and difficult civil engineering structures. Quite often, concrete being the most important and widely used material is called upon to possess very high strength and sufficient workability properties. Efforts are being made in the field of concrete technology to develop such concretes with special characteristics. Researchers all over the world are attempting to develop high performance concretes by using fibre and other admixtures in concrete up to certain proportions. In the view of the global sustainable developments, it is imperative that fibre like glass, carbon, polypropylene and aramid fibre provide improvements in tensile strength, fatigue characteristics, durability, shrinkage characteristics, impact, cavitation, erosion resistance and serviceability of concrete. Fibre impart energy absorption, toughness and impact resistance properties to fibre reinforced concrete material and these characteristics in turn improve the fracture and fatigue properties of fibre reinforced concrete research in glass fibre reinforced concrete resulted in the development of an alkali resistance fibre high dispersion that improved long term durability. This system was named alkali resistance glass fibre reinforced concrete. In the present experimental investigation the alkali resistance glass fibre has been used to study the effect on compressive, split tensile and flexural strength on M20, M30, M40 and M50 grades of concrete.

VII. MATERIALS:

Cement:

In this experimental 43 grade ordinary Portland cement with brand name ACC confirming to IS 8112-1989 standards was used for cast specimens. The cement used was fresh and without any lumps. The properties of cement are within the permissible limits as per IS 8112-1989.

Fine Aggregate:

The size of the fine aggregates or sand is below 4.75mm. Natural sand is the fine aggregate, chiefly used on concrete mix. Sand may be obtained from river, lake or pit, but when used in the concrete mix it should be properly washed and tested to ascertain that total percentage of clay silt, silts and others such organic matter does not exceed specified limit. The sand used throughout the experimental work was obtained from the river Tungabhadra near Harihar, Davangere district, Karnataka. The fine aggregates falls under zone I as per IS 383:1970.

Table 1: Physical properties of cement

Sl No	Properties	Experimental value
1	Fineness	3%
2	Specific gravity	3.15
3	Normal consistency	30%
4	Initial setting time	40 minutes
5	Final setting time	435minutes

Table 2: Physical properties of Fine Aggregate

Properties	Experimental value
Fineness modulus	2.73 (ZONE I)
Specific gravity	2.47

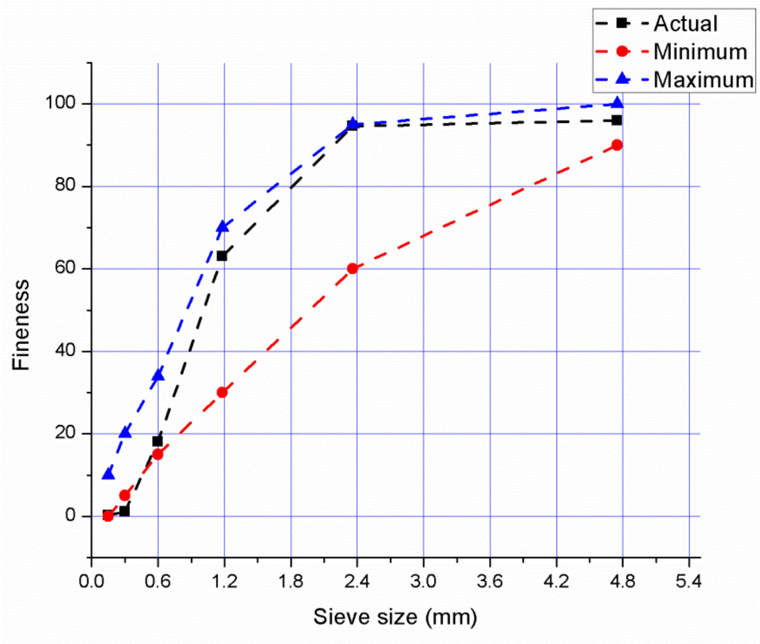


Fig 1: Grading curve for fine aggregate

Coarse Aggregate (Natural and Recycle Coarse Aggregate)

The materials whose particles are of such size are retained on IS sieve no.480 (4.75mm) is termed as coarse aggregates. The size of the coarse aggregate used depends upon the nature of work. The maximum size may be 20mm for mass concrete cement concrete construction; aggregates having a nominal size of 20mm are generally considerable to be satisfactory.

Water:

Portable tap water was used for the preparation of specimens and for the curing of specimens. Portable water as available in GMIT campus was used for the preparation of specimens.

Conplast SP-430:

To obtain better workability (slump 100mm) Conplast SP430, super plasticizing admixture used in the work. It is supplied which disperses in water instantly. It reduces water to higher levels thus increasing the strength. The specific gravity of this admixture is 1.18. For the present experimental work the dosage is varied from 0.6% to 1.0 % by cement weight in order to achieve the slump value.

Steel Fibres:

Steel fibres used as reinforced material for concrete were used in the present work. The steel fibres were purchased from Stewols India pt. Ltd, Nagpur. The technical specification of steel fibres is shown in table. Which is obtained from the manufacture and also the fibres are shown in figure.

Table 3: Physical Properties of Coarse Aggregate

Properties	Natural coarse aggregate (NCA)	Recycled coarse aggregate (RCA)
Water absorption	0.59%	5.08%
Specific gravity	2.69	2.49
Impact value	34.88%.	43.13%.
Abrasion value	26.73%	33.98%

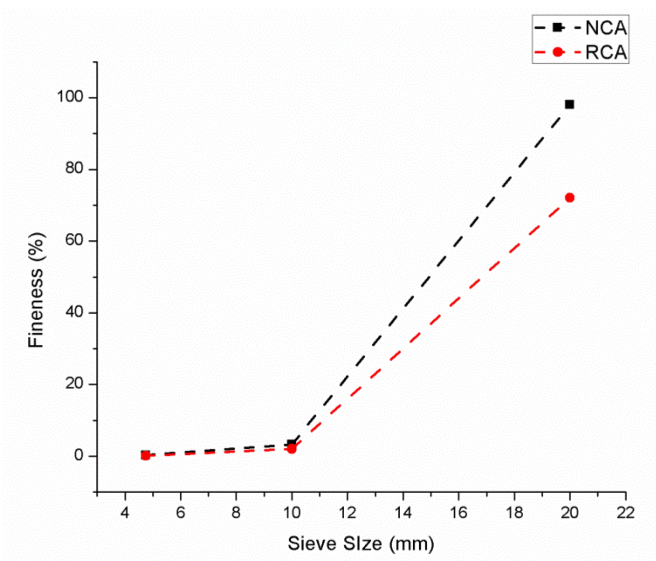
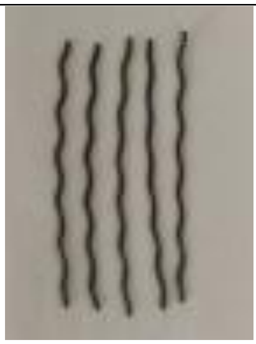


Fig 2: Grading curve for Coarse aggregate

Table 4: Specifications of the steel fibres

Type of fibre	Length (mm)	Diameter (mm)	Aspect Ratio	Images	Fibre properties	Appearance
Round Crimped	50.00	1.00	50		Tensile strength1277 MPa	Bright and clean wire
Flat Crimped	50.00	1.00	50		Tensile strength771 MPa	
Hooked End	50.00	1.00	50		Tensile strength1105 MPa	

VIII. CONCRETE MIX DESIGN:

Table 5: Mix proportions per cubic meter of concrete

Mix	Cement Kg	FA (kg)	NCA (kg)	RCA (kg)	Water (Litres)	SP (Litres)	Mixing ratio
RAC-0	363.64	815.07	900.00	---------	200.00	0.00	1:2.24:2.47
RAC-25	357.14	847.71	652.50	217.50	197.50	2.50	1:2.37:2.43
RAC-50	333.33	874.75	417.00	417.00	197.33	2.67	1:2.62:2.50
RAC-75	333.33	886.74	202.50	607.50	197.00	3.00	1:2.66:2.43
RAC-100	333.33	897.44	--------	774.00	196.66	3.33	1:2.69:2.32

IX. TEST FOR SPECIMENS:

Compression Strength Test:

Fig 3: Compression Testing Machine (CTM)

The test setup for conducting cube compressive strength tests is shown in figure 4.7. This test is conducted by using 3000KN compression machine (CTM). The cube was placed in the CTM and the load is noted as ultimate load. Than the cube compressive strength is computed by using standard formula. The values obtained are presented in the next chapter.

X. RESULTS AND DISCUSSIONS:

The main objective of this experimental investigation is to find out the performance of RAC with and without steel fibres on compressive strength. To estimate the strengths, models are derived in this chapter and detailed discussion related to each parameter is discussed in the following sections.

Table 6: Compressive Strength of Reference Mix of RAC

SL. NO.	MIX	Average Ultimate Load (KN)	Average Ultimate Compressive Strength (N/mm^2)
1	RAC-0(Ref Mix)	633.33	28.14
2	RAC- 25	668.33	29.70
3	RAC -50	645.33	28.66
4	RAC -75	570.00	25.33
5	RAC-100	503.33	22.37

Table 7: Compressive Strength of 1% Flat steel fibre

SL. NO.	MIX	Average Ultimate Load (KN)	Average Ultimate Compressive Strength (N/mm^2)
1	RAC-0	648.33	28.81
2	RAC- 25	733.33	32.59
3	RAC -50	706.66	31.40
4	RAC -75	623.33	27.70
5	RAC-100	596.66	26.51

Table 8: Compressive strength of 2% Flat steel fibre

SL. NO.	MIX	Average Ultimate Load (KN)	Average Ultimate Compressive Strength (N/mm^2)
1	RAC-0	565.00	25.11
2	RAC- 25	598.33	26.59
3	RAC -50	591.66	26.29
4	RAC -75	576.66	25.62
5	RAC-100	433.33	19.25

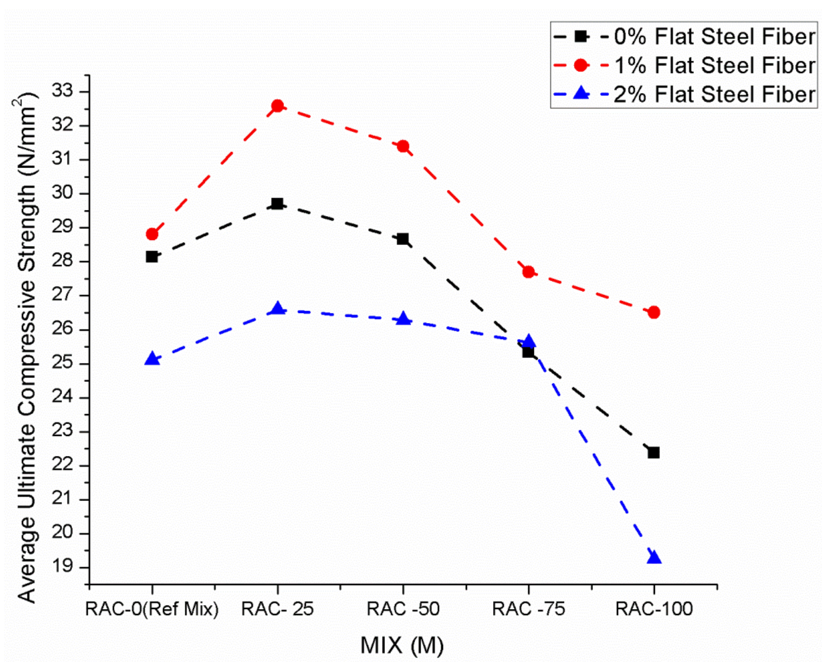


Fig 4: Compressive Strength v/s RAC for Flat Steel Fibre

Table 9: Compressive strength of 1% Crimped steel fibre

SL. NO.	MIX	Average Ultimate Load (KN)	Average Ultimate Compressive Strength (N/mm^2)
1	RAC-0	613.33	27.25
2	RAC- 25	671.66	29.85
3	RAC -50	512.66	23.18
4	RAC -75	520.00	23.11
5	RAC-100	515.00	22.88

Table 10: Compressive strength of 2% Crimped steel fibre

SL. NO.	MIX	Average Ultimate Load (KN)	Average Ultimate Compressive Strength (N/mm^2)
1	RAC-0	588.33	26.14
2	RAC- 25	663.33	29.48
3	RAC -50	580.00	25.77
4	RAC -75	565.00	25.11
5	RAC-100	495.00	22.00

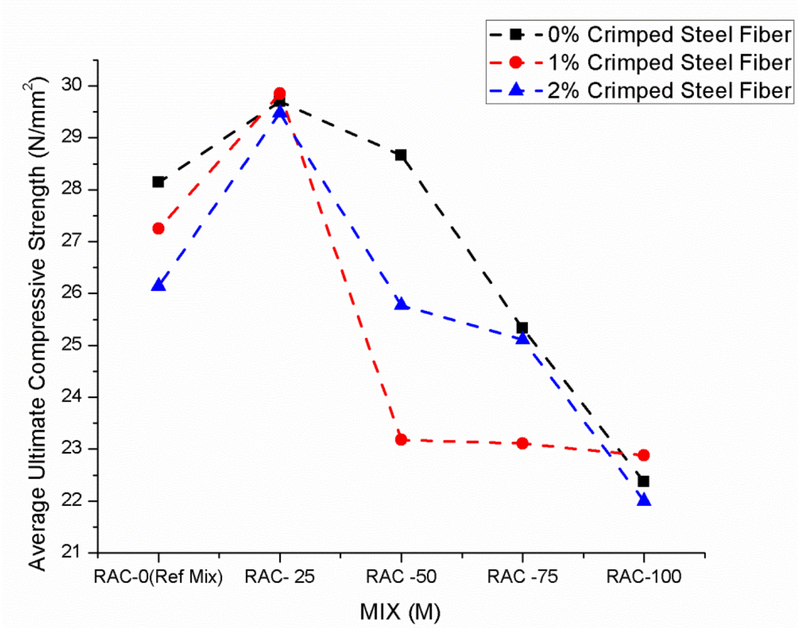


Fig 5: Compressive Strength v/s RAC for Crimped Steel Fibre

Table 11: Compressive strength of 1% Hooked End steel fibre

SL. NO.	MIX	Average Ultimate Load (KN)	Average Ultimate Compressive Strength (N/mm^2)
1	RAC-0	638.3	30.29
2	RAC- 25	680.00	32.44
3	RAC -50	581.66	29.18
4	RAC -75	553.33	28.96
5	RAC-100	540.00	28.44

Table 12: Compressive strength of 2% Hooked End steel fibre

SL. NO.	MIX	Average Ultimate Load (KN)	Average Ultimate Compressive Strength (N/mm2)
1	RAC-0	681.66	28.37
2	RAC- 25	730.00	30.22
3	RAC -50	656.66	25.85
4	RAC -75	651.66	24.59
5	RAC-100	640.00	24.00

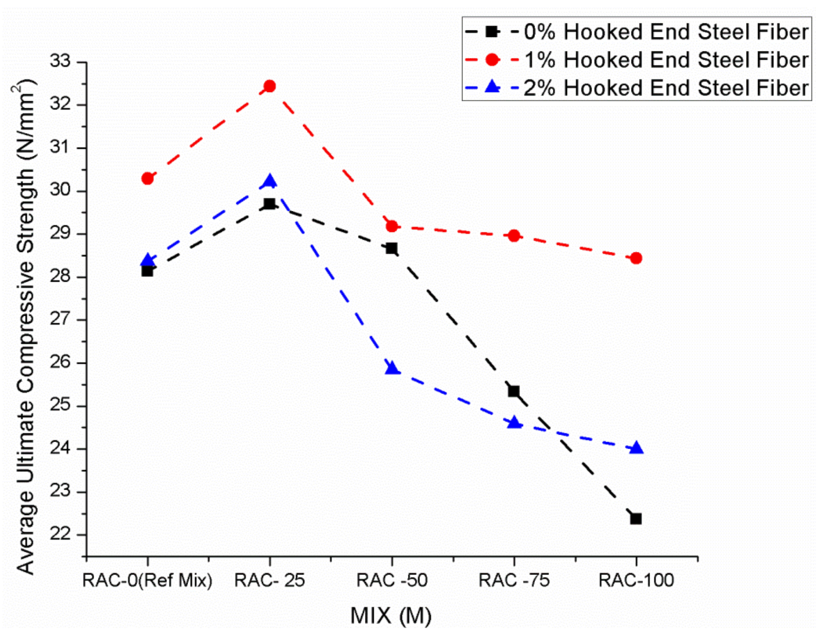


Fig 6: Compressive Strength v/s RAC for Flat hooked Steel Fibre

CONCLUSIONS

The following conclusions are drawn from the present experimental work.

1. The compressive strengths are decreases as the RA content increase in the conventional concrete mix

2. Addition of steel fibres is effective for recycle aggregate concrete.

3. Among three shapes of fibres (Flat, Crimped, Hooked end) the hooked end fibre shown higher compressive strength.

4. Crimped steel fibre volume with 1% volume fraction can be used effectively, without change in design mix up to 25% replacement of recycled aggregate with natural aggregate.

Fig 6: Collection of Recycled Coarse Aggregates (RCA)

Fig 7: Slump Cone Test

Fig 8: Addition of Steel Fibers

Fig 9: Concrete mix

Fig 10: Prepared specimens

Fig 11: Curing of concrete cubes

Fig 12: Testing of a Cube specimen

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