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AN EXPERIMENTAL INVESTIGATION ON SHEAR BEHAVIOUR OF CONCRETE BY VARYING THE COARSE AGGREGATE SIZE AND ADDITION OF STEEL FIBRE

Dr.B.Madhusudhana Reddy[1] and B.Girish[2]

[1] Assistant Professor, Structural Engineering Division, Department of Civil Engineering, Sri Venkateswara University College of Engineering, Tirupati.
[2]PG Student, Department of Civil Engineering, Sri Venkateswara University College of Engineering, Tirupati.

Abstract: It is well known that coarse aggregate plays an important role in concrete. As coarse aggregate occupies over three-fourth of the volume of concrete and research indicates that changes in coarse aggregate can change the strength and fracture properties of concrete greatly. Aggregate interlocking plays an important role in the shear resistance of Reinforced Concrete(RC) beams without shear reinforcement. Maximum size of aggregate is one of the important parameters for effective aggregate interlocking. Shear failures in concrete structures are very hazardous. These failures being brittle in nature can rarely be predicted and often noticed by rupture. In order to study the shear failure of the concrete beams were cast of grades M20 and M25. The coarse aggregate size 20mm,12.5mm and 20&12.5mm and of steel fibres by varying the percentage 0, 0.25, 0.5, 0.75,1 and 1.25 were varied in different combinations. For most of the combinations shear mode of failure was noticed. The shear mode of failure was resisted greatly at 1% of steel fibre and 20&12.5mm coarse aggregate combinations.

KEY WORDS: Mix design, Coarse aggregate, Shear failure, Steel fibre, RC beam, Shear strength, Flexural strength

I. INTRODUCTION

Concrete is composed of aggregates, cement and water with aggregates taking about three-quarter of the concrete volume and the coarse aggregates taking between 50 and 60 percent of the concrete mix depending on the mix proportion. There are several modes of failure in concrete structures. As concrete structures are fragile, shear failure is one of the most important and undesirable mode of failure. Shear strength of concrete depends remarkably on the ability of the coarse aggregate to resist shearing stresses. In general it is believed that aggregate interlock transfers a large part of the total shear force. As concrete is a brittle material, its undesirable characteristics are its low tensile strength and strain capacity. So concrete requires reinforcement in order to be used as a structural members. This reinforcement is provided in the form of continuous steel bars placed in the concrete structure in the appropriate positions to withstand the imposed tensile and shear stresses.

Fibres, on the other hand, are short, discontinuous, and randomly distributed throughout the concrete member to produce a composite construction material known as fibre reinforced concrete (FRC). There are several types of fibres which are primarily made of steel, glass, and polymer or derived from natural materials. Fibres can control cracking more effectively due to their tendency as they are more closely spaced than conventional reinforcing steel bars. Steel fibre (SF) is the most popular type of fibre used as concrete reinforcement. Initially, SFs were developed in view to strengthen the concrete matrix. Later researchers found that fibres do not typically alter the strength properties of matrix. Rather, the major role of the fibres is to improve the crack control and post cracking behavior of the concrete matrix. The typical length of steel fibres ranges from 6 to 64 mm, and its diameter ranges from 0.5 to 1.0 mm. Steel fibres tensile strength, modulus of elasticity, stiffness modulus and mechanical deformations provide an excellent means of internal mechanical interlock. This provides a user friendly product with increased ductility that may be employed in applications of high impact and fatigue loading without the fear of brittle concrete failure. The main objective of this investigation is to assess the shear behavior and failure modes of concrete beams without shear reinforcement by varying the coarse aggregate size and with the addition of steel fibre of different percentages.

II. MATERIALS

The materials used in experimental investigation are:
1. 43 grade Ordinary Portland Cement (OPC)
2. Fine Aggregate
3. Coarse Aggregate (Natural aggregate)
4. Potable water
5. Steel fibre

The properties of the materials are presented in following sections.

A. Cement:

Cement is the main constituent of Concrete. The cement used throughout the experimental investigation was Ordinary Portland Cement of 43 grade confirming to IS 8112:1989 specifications. The results of the tests on cement are shown in Table I.

TABLE I. PHYSICAL PROPERTIES OF CEMENT

S. No	Property	Values
1.	Normal consistency	30%
2.	Specific gravity	3.12
3.	Fineness of cement	7.6%
4.	Initial setting time	90 minutes
5.	Final setting time	330 minutes

B. Fine Aggregate:

The locally available river sand confirming to zone-II of IS 383-1970 has been used as fine aggregate. The various tests conducted on fine aggregate and the results are shown in the Table II.

TABLE II. PROPERTIES OF FINE AGGREGATE

S. No	Property	Values
1.	Specific gravity	2.6
2.	Fineness modulus	3.8
3.	Grading of sand	Zone-II

C. Coarse Aggregate:

Coarse aggregate of nominal size 20 mm and 12 mm, obtained from the local quarry confirming to IS 383:1970 specifications were used. The properties of Coarse aggregate are shown in Table III.

TABLE III. PROPERTIES OF COARSE AGGREGATE

S.No	Property	Size(mm)	value
1.	Fineness modulus	20 12.5	7.29 6.49
2.	Specific gravity	20 12.5	2.67 2.70
3.	Water absorption	20 12.5	0.49% 0.80%

D. Steel fibre:

In this present investigation loose hooked end steel fibre is used which is obtained from kasturi metal composites, Amravati. Steel fibre is shown in fig. 1 and the properties of steel fibre given by the supplier are shown in table IV.

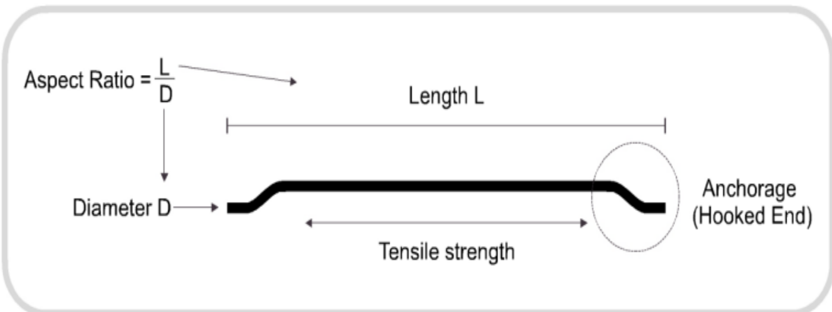

Fig. 1 Steel fibre

TABLE IV. PROPERTIES OF STEEL FIBRE

Material	Low carbon drawn wire
Aspect ratio	50
Length	30mm
Diameter	0.60mm
Tensile strength	>1300 Mpa
Modulus of Elasticity	200 Gpa
Specific Gravity	7.5
Suitable application	Tunnel shotcrete, precast elements, road & pavement

E. Water:

The water used for casting and curing of Concrete test specimens was free of acids, organic matter and impurities which when present can adversely affect the strength of Concrete. The properties of the water tested are shown in table V.

TABLE V. PROPERTIES OF WATER

S.No	Property	Value	Limitations
1	pH	7.8	>6
2	Acidity	20ppm	--
3	Alkalinity	420ppm	<1000ppm
4	Chlorides	213ppm	<2000ppm –PCC <500ppm--RCC
5	Hardness	480ppm	--
6	Sulphates	80ppm	<400ppm
7	Total dissolved salts	900ppm	<15000ppm

III. CONCRETE MIX PROPORTION

Concrete mix design is the process of finding right proportions of cement, sand and aggregates for concrete to achieve target strength in structures. So, concrete mix design can be stated as Concrete Mix = Cement:Sand:Aggregates. M20 and M25grade of concrete mix were used in the present investigation. The mix design was done as per IS: 10262 -1982 specifications.

TABLE VI. MIX DESIGN OF M20 GRADE CONCRETE

GRADE	AGGREGATE SIZE (mm)		CEMENT	F.A	C.A	WATER
M20	12.5	Quantity (kg/m^3)	330	915.2	950.4	171
		Mix Proportion	1	2.77	2.88	0.52
	20	Quantity (kg/m^3)	330	691.60	1158.78	165
		Mix Proportion	1	2.09	3.51	0.5
	Graded aggregate	Quantity (kg/m^3)	330	691.60	1158.78	165
		Mix Proportion	1	2.09	3.51	0.52

TABLE VII. MIX DESIGN OF M25 GRADE CONCRETE

GRADE	AGGREGATE SIZE (mm)		CEMENT	F.A	C.A	WATER
M25	12.5	Quantity (kg/m^3)	350	823.68	1045.44	164
		Mix Proportion	1	2.35	2.98	0.48
	20	Quantity (kg/m^3)	350	587.26	1228.89	165.76
		Mix Proportion	1	1.70	3.56	0.47
	Graded aggregate	Quantity (kg/m^3)	350	587.26	1228.89	165.76
		Mix Proportion	1	1.70	3.56	0.5

IV.EXPERIMENTAL SETUP

Beams of size 700x150x150mm providing effective span of 600mm were cast. In order to obtain the shear failure i.e.., diagonal cracking, no shear reinforcement is provided. Further the beams were designed with adequate flexural reinforcement so as not to fail the specimen in flexure. The specimens were tested as simply supported beams under four-point loading condition in universal testing machine, with loading distant 200mm and also from the end support. The experimental setup was shown in fig.2 with all dimensions are in mm.

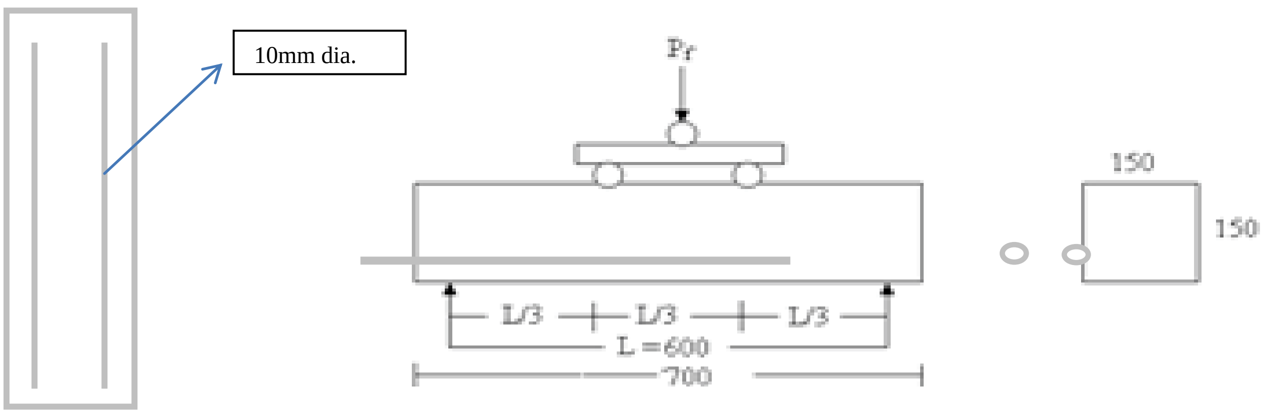

Fig. 2 Experimental setup

V. EXPERIMENTAL RESULTS

Compressive strength:
Concrete Cubes of size 150 mm × 150 mm × 150 mm were casted by varying the coarse aggregate size for both M20 and M25 grade concrete. Concrete cubes were tested as per IS 516:1959.
The test was conducted in compression testing machine. The load was applied at the rate approximately 140kg/cm^2/min until the failure of the specimen. The average compressive strength results of 28 days cubes were shown in the graph.

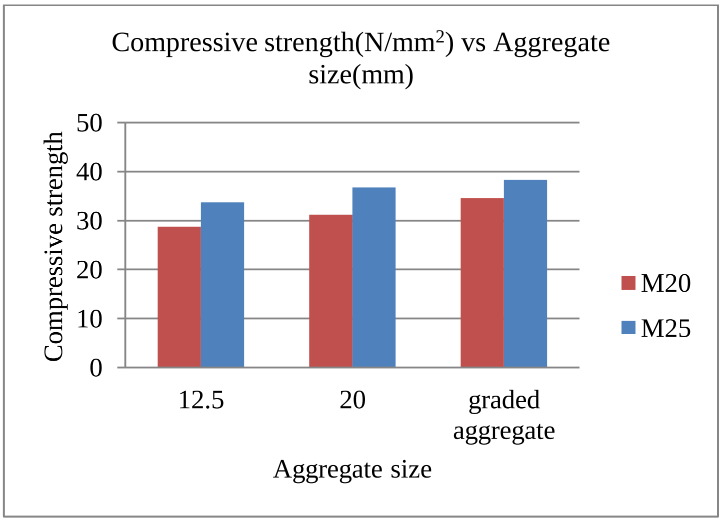

Fig 3. Cube compressive strength by varying coarse aggregate size

The average compressive strength of 12.5mm of M20 concrete is 28.7N/mm2 and for M25 concrete is 33.7N/mm2. The average compressive strength of 20mm of M20 concrete is 31.2N/mm2 and for M25 concrete is 36.7N/mm2. Average compressive strength of M20 concrete with 20mm&12.5mm is 34.3N/mm2 and for M25 concrete is 38.3.N/mm2 The graded aggregate in both grades of concrete M20 and M25 showed better results of compressive strength compared to 20mm and 12.5mm single size aggregate.

Flexural Strength:

The Flexural Strength Test was carried out on plain concrete beams cured for 28 days and confirming to IS: 516:1959. Flexural strength is calculated using the following formula. When fracture initiates in the tension surface (i.e., the bottom surface) within the middle third of the beam

Flexural strength = PL/bd^2

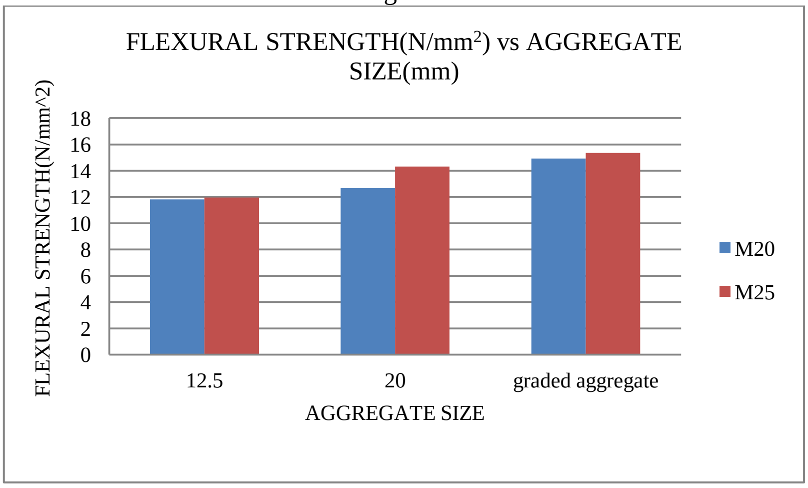

Fig 4. Variation in flexural strength vs Aggregate size

The flexural strength of M20 concrete with 12.5mm aggregate is 11.8N/mm2, with 20mm aggregate is 12.6N/mm2 and with graded aggregate (20mm & 12.5mm) is 14.9N/mm2. In the case M25 concrete with 12.5mm aggregate is 12N/mm2, with 20mm aggregate is 14.3N/mm2 and with graded aggregate is 15.3N/mm2.Fromthe results it is noticed that there is increase in flexural strength with increase in aggregate size, aggregate combination and with increase in grade of concrete.

Shear strength:

The strength of a material or component against the type of yield or structural failure when the material or component fails in shear. A shear load is a force that tends to produce a sliding failure on a material along a plane that is parallel to the direction of the force.

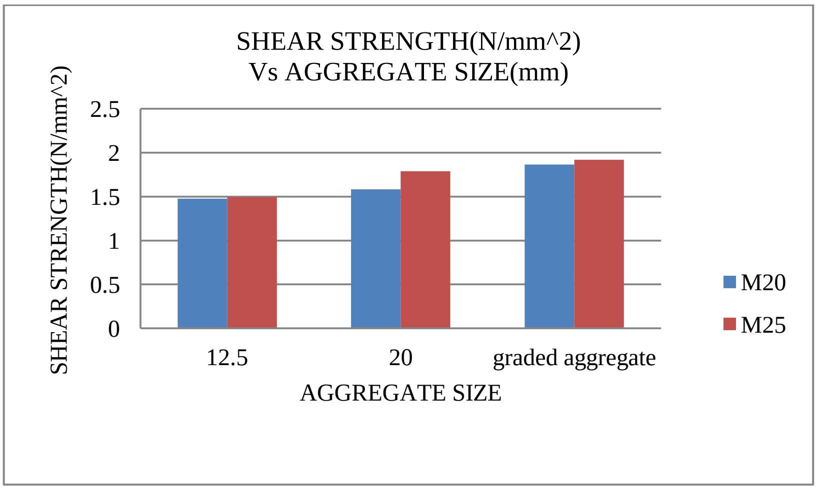

Fig .5 Variation in shear strength vs aggregate size

The shear strength of M20 concrete with 12.5mm aggregate is 1.47N/mm2, with 20mm aggregate is 1.58N/mm2 and with graded aggregate (20mm & 12.5mm) is 1.86N/mm2. The shear strength of graded aggregate was increased about 17.7% compared to shear strength for 20mm aggregate and shear strength of 12.5mm aggregate was decreased about 7.4% compared to shear strength of 20mm aggregate size. In the case M25 concrete with 12.5mm aggregate is 1.5N/mm2, with 20mm aggregate is 1.78N/mm2 and with graded aggregate is 1.91N/mm2. The shear strength of graded aggregate was increased about 7.3% compared to shear strength for 20mm aggregate and shear strength of 12.5mm aggregate was decreased about 18.5% compared to shear strength of 20mm aggregate size. The similar pattern was in the flexural strength.

Flexural strength of SFRC beams:

From the shear strength and flexural strength results compared to 12.5mm and 20mm aggregate, graded aggregate showed the better results. In order to observe the shear behavior, steel fibre is added to improve the crack control. Steel fibre is added upto six percentages as 0, 0.25, 0.5, 0.75,1 and 1.25% respectively.

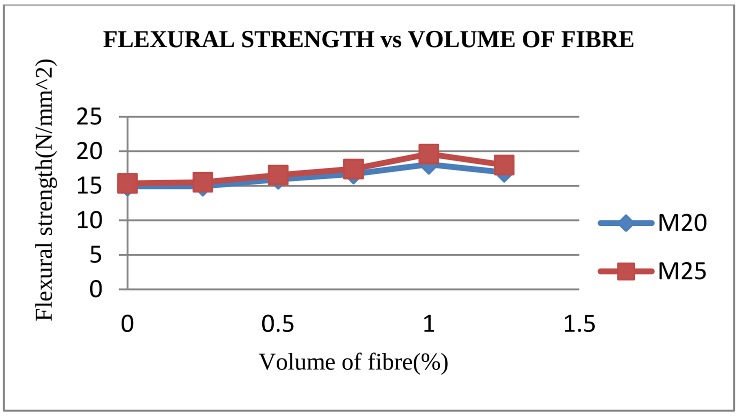

Fig 6. Variation of flexural strength with percentage of volume of fibre

Reinforced concrete beams with various percentages of steel fibre were cast. The flexural strength of M20 concrete with steel fibre about 0%,0.25%,0.5%,0.75%,1% and 1.25% is 14.93,14.94,15.94,16.7,18.1,and 16.95N/mm2. The flexural strength of M25 concrete with steel fibre about 0%,0.25%,0.5%,0.75%,1% and 1.25% is 15.35,15.52,16.55,17.43,19.59 and 18 N/mm2. The graph between the flexural and percentage of volume of fibre shows that the flexural strength was gradually increasing upto 1% of volume of fibre and thereby decreases. The flexural strength for M20 and M25 concrete was maximum at 1% of steel fibre. The mode of failure is shear-flexural failure upto 1% of steel fibre and for 1.25% steel fibre is flexural failure.

Fig 7. Shear-flexural mode of failure

Fig.7 shows the shear-flexural mode of failure of Steel fibre reinforced concrete beam.

Shear strength of SFRC beams:

Fig.8 shows variation of shear strength with percentage of volume of fibre

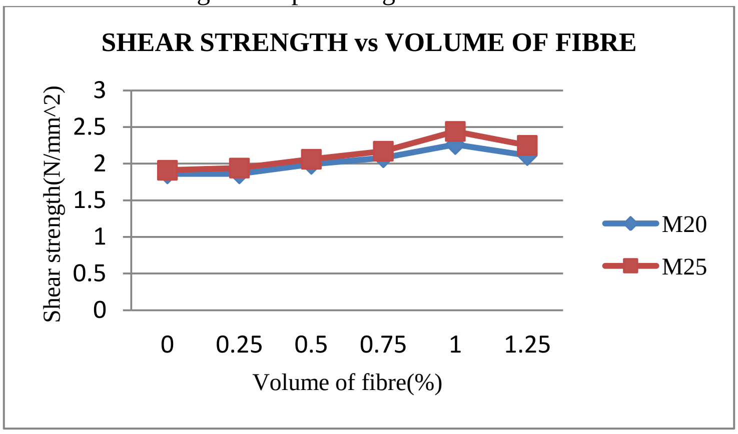

Fig 8 Variation of shear strength with percentage of volume of fibre

The shear strength of M20 concrete with steel fibre about 0%,0.25%,0.5%,0.75%,1% and 1.25% is 1.86,1.87,2.0,2.08,2.26 and 2.11N/mm2.The shear strength of M25 concrete with steel fibre about 0%,0.25%,0.5%,0.75%,1% and 1.25% is 1.91,1.94,2.06,2.17,2.44 and 2.25N/mm2. The graph between the shear strength and percentage of volume of fibre shows that the shear strength was gradually increasing upto 1% of volume of fibre and thereby decreases. The shear strength for M20 and M25 concrete was maximum at 1% of steel fibre.

Fig 9. Shear mode of failure

Fig.9 shows the shear mode of failure of Steel fibre reinforced concrete beam.

VI. CONCLUSIONS

The results of the experimental investigation indicate that as changes in coarse aggregate size will affect the strength of the concrete and addition of steel fibre will improve the shear behavior and strength of the concrete.

- The percentage change at 28 days for single size aggregate with 20mm to that of graded aggregate is increased by 10%. whereas single size aggregate with 12.5mm to that of graded aggregate is decreased by 8.4% for M20 concrete.The percentage change at 28 days for single size aggregate with 20mm to that of graded aggregate is increased by 4.35%. whereas single size aggregate with 12.5mm to that of graded aggregate is decreased by 8.8% for M25 concrete.
- The shear strength M20 concrete with graded aggregate was increased about 17.7% compared to shear strength for 20mm aggregate and shear strength of 12.5mm aggregate was decreased about 7.4% compared to shear strength of 20mm aggregate size.The shear strength M25 concrete with graded aggregate was increased about 7.3% compared to shear strength for 20mm aggregate and shear strength of 12.5mm aggregate was decreased about 18.5% compared to shear strength of 20mm aggregate size.
- The maximum aggregate size had effect on the compressive strength of concrete, and it also improves the shear capacity of beams without shear reinforcement.As the addition of steel fibres, the ultimate load and shear strength gradually increases upto 1% volume of fibre in both M20 and M25 grade concretes.Shear strength of M20 and M25 grade concrete was increased about 21.5% and 27.74% at 1% volume of fibre and thereby decreases with increase in volume of fibre.
- By observing the mode of failure, which is shear failure initially then changes to shear-flexure failure and flexure failure with increase in volume of fibres. Using steel fibres alone (SFRC beams without stirrups) led to a considerable post cracking load capacity and this was due to the fibres shear mechanism in which the existence of fibres across the diagonal crack restricted the crack propagation throughout the web.

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