Shear Strength, Compressive Strength and Workability Characteristics of Concretes Reinforced with Steel Fibres

Mr. Chandrashekharamurthy H. K
M.Tech.
Assistant Professor,
Acharya Institute of Technology,
Bengaluru-560090

Dr. Prema Kumar W. P
Ph.D.
Professor, School of Civil Engineering,
Reva University
Bengaluru-560064

Dr. Prathap Kumar M. T
Ph.D.
Professor and Head of the Department of Civil Engineering,
RNS Institute of Technology,
Bengaluru-560098

***Abstract* – The shear strength of concrete is an ability to resist forces that cause sliding of one part relative to the other at an internal plane. The shear strength depends on the grade of concrete, percentage of fibres and percentage of tension steel in beams. One of the objectives of the present experimental work is to determine the variation of shear strength of M30 and M60 grade concretes with no fibre and with various volume percentages of steel fibres using push-off specimens. The present studies indicate that an increase in volume percentage of steel fibres causes an increase in the shear strength for both the grades of concrete. The workability is observed to reduce as the percentage of fibres increases. The compressive strength of concrete is observed to initially increase with an increase in the percentage of steel fibres and then reduce beyond about one percent of steel fibres.**

Keywords- Shear strength, Compressive strength, Workability, Steel fibres, Push-off specimen, Concrete.

I. INTRODUCTION

Concrete is one of the most widely used structural materials in the world. It is made of fine and coarse aggregates, cement, and admixtures mixed with water. The shear strength of concrete is defined as an ability to resist forces that tend to induce sliding of one part over another at an internal plane. Many concrete members used in practice are subjected to shear forces in addition to bending moments. The shear strength depends on the grade of concrete, percentage of fibres and percentage of tension steel in beams. Push-off specimens may be used to determine the shear strength of concrete by subjecting them to uniaxial compression. Many investigators have carried out studies made on shear strength of concrete and a few are briefly mentioned here. *Rahele Naserian et al (2013)* observed that FRP strips increased the shear capacity of the push-off specimens. The slip (shear displacement) of specimens with FRP strips was lower than that of the control specimens for the same load. *Khanlou et al (2013)* observed that the ultimate shear capacity of steel fibre reinforced concrete with steel fibre dosage greater than 40 kg/m^3 increased the shear strength of concrete. *Al-Sulayvani and Al-Feel (2009)* observed that the addition of steel fibres to concrete increased the first crack strength and shear strength of concrete resulting in ductile failure of concrete. *Muhaned A. Shallal and Sallal R. Alowaisy (2008)* observed that the shear strength and ductility of concrete improved with the addition of steel fibres. Steel fibres in combination with steel stirrups can reduce the required amount of stirrups. *Mariano O. Valle (1989)* in his study used push-off fibre reinforced concrete specimens made of high strength and normal strength concretes. Two types of fibres were used viz., polypropylene and steel fibres. Fibres were found to be more effective in enhancing shear strength in high strength concrete than in normal strength concrete. *Tan K H and Mansur M.A (1990)* made experimental studies to determine the effect of percentage of steel fibres and steel stirrups on shear capacity of the push-off specimens. It was found that steel fibres were more effective in enhancing the shear strength and the load-deformation characteristics of the normal strength concrete. *Swamy R N et al. (1987)* have concluded, based on their studies, that the steel stirrups were more effective than the steel fibres to transfer the shear in normal weight concrete. Some more references are mentioned at the end of this paper. Available literature reveals that the steel fibres are more effective in enhancing the shear capacity of light weight concrete when compared with the normal weight concrete. Thus, it can be seen that steel fibres will improve the structural performance of concrete. Existing Literature also reveals that studies on the effect of steel fibres on the shear strength, compressive strength and workability of concrete are not many. Thus, the chief objective of the present experimental work was to study the shear strength of plain concrete and steel fibre reinforced concrete (SFRC) for

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various volume percentages of steel fibres (V_f). M30 and M60 grades of concrete were used. The variation in compressive strength and workability for various volume percentages of fibres was also studied.

II. MATERIALS USED

In the present work, ordinary Portland cement (OPC) of grade 53 was used. Fine aggregates passing through 4.75mm sieve size and entirely retained on 150μ sieve size were used. Locally available natural river sand was used as a fine aggregate. The specific gravity and fineness modulus of fine aggregate were determined in accordance with IS: 2386-1963. The specific gravity of fine aggregates was determined to be 2.63 and fineness modulus 3.65%. The fine aggregates used were found to conform to zone II as per Indian code IS: 383-1970. Crushed quarry stones with a nominal size of 20mm and down were used as coarse aggregates. The tests on coarse aggregates were conducted in accordance with IS: 2386-1963. The specific gravity of coarse aggregate was determined to be 2.59; fineness modulus 4.24 % and water absorption 0.45%. Superplasticizer “Master Glenium ACE 30(IT)" supplied by BASF India Ltd, Bengaluru was used. The manufacturer normally recommends a dosage range of 500 ml to 1200 ml per 100kg of cementitious material. Potable water was used for mixing and curing of concrete. Crimped round type steel fibres were used in this work. The physical properties of the OPC cement and the properties of the fibres used in this work are given in Table 1.

Table 1: Properties of Cement and Steel Fibres Used

Sl. No.	Particular	Value
	Properties of CEMENT	
1	Specific gravity	3.09
2	Fineness (%)	8
3	Normal consistency (%)	30
4	Setting time (in minutes) 1. Initial Setting time 2. Final setting time	55 385
	Properties of STEEL FIBRES	
1	Fiber type	Crimped
2	Length	30 mm
3	Diameter	0.5 mm
4	Density	7850 kg/m^3
5	Tensile strength	940 MPa
6	Aspect ratio	60

The mix proportions for grades M30 and M60 were obtained using IS: 10262-2009 method of mix design. The obtained mix proportion for M30 concrete was 1:2.20:2.96 with a w/c ratio of 0.40 and 1:1.73:2.46 with a w/c ratio 0.30 for M60 concrete along with superplasticizer [Master Glenium Ace 30(IT)]. Steel fibre content was varied from 0% to 1.5%. The superplasticizer (Master Glenium Ace 30 (IT) was added in dosages of 0.5 and 0.7 litre/100 kg of cement for M30 and M60 grades respectively. Table 2 show the quantities of ingredients used for M30 and M60 grade concretes.

Table 2: Ingredients of M30 and M60 Grades of Concrete

Sl. No.	Material	Quantity in kg/m^3
	M30 grade Concrete	
1	Cement	369.40
2	Fine Aggregate	814.00
3	Coarse Aggregate	1094.50
4	Water	147.75
5	Superplasticizer	1.85
	M60 Grade Concrete	
1	Cement	443.25
2	Fine Aggregate	767.46
3	Coarse Aggregate	1091.80
4	Water	141.82
5	Superplasticizer	3.10

III. METHODOLOGY AND TESTS

3.1 Compressive Strength and Workability of Concrete

The test specimens used for determining compressive strength were cubes of 150 mm × 150 mm × 150 mm size. They were subjected to axial compression in compression testing machine. Slump test was employed to determine the workability of fresh concrete in accordance with relevant Indian Standard specifications.

3.2 Shear Strength

Shear strength of concrete was determined by applying direct shear force on push-off specimen. The test for determining shear transfer strength for concrete employs a specimen of 230 mm × 150 mm × 150 mm size, which is subjected to uniaxial compression in a compression-testing machine. Shear strength of concrete is the ratio of ultimate shear force at which the specimen fails to the shear area of push-off specimen. The specimens were designed so as to ensure that the failure of concrete occurs in shear at the shear plane and undesirable failure modes due to bending or compression are avoided. Typical dimensions of push-off specimen and a failed specimen along the shear plane during loading are as shown in Fig.1.

Shear strength (τ) = Ultimate shear force/ Shear area (1)

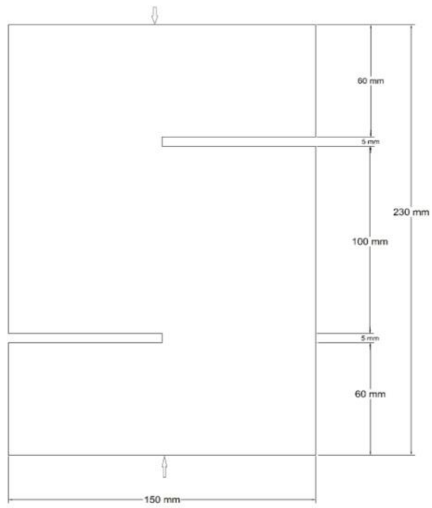

Fig.1: Typical Dimensions of Push-off Specimen Used and a Failed Specimen under Loading

IV. RESULTS AND DISCUSSION

4.1 Effect of Steel Fibres on Workability of M30 and M60 Grades of Concrete

Workability of both the grades of concrete was measured by standard slump test. Fig.2 shows the variation of slump value for both M30 and M60 grades of concrete with various fibre volume percentages (V_f). It is observed that, for M60 grade concrete, the slump value reduces to zero at about 1% of fibre volume percentage and remains at zero thereafter. In the case of M30 concrete, an increase in the volume percentage of fibres also reduces the slump value. It is seen that an increase in the volume percentage of fibres reduces the workability of concrete and this trend is in agreement with those of earlier investigations.

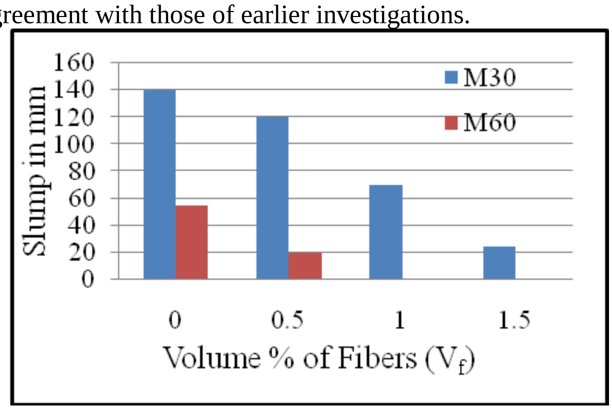

Fig.2: Slump Test Results for M30 and M60 Grades of Concrete

4.2 Compressive Strength of Concrete

The compressive strength test results for M30 and M60 grades of concrete are shown in Table 3 for both 14 and 28 days of curing. In the case of M30 grade, it is seen that the compressive strength initially increases, reaches a peak at 1% fibre content and later reduces for both 14 and 28 days of curing. In the case of M60 grade of concrete, the peak strength occurs at 0.5% of fibres for both 14 & 28 days of curing. The compressive strength drops beyond 1% of steel fibres.

Table 3: Results of Compressive Strength Test on M30 & M60 Grades of Concrete

Sl. No.	**Fibre Content (%)**	**Compressive Strength for M30 grade of concrete in N/mm²**		**Compressive Strength for M60 grade of concrete in N/mm²**	
		14days	**28days**	**14days**	**28days**
1	0.0	33.37	35.25	60.22	67.12
2	0.5	34.87	38.10	60.78	68.40
3	1.0	35.25	38.78	60.78	68.20
4	1.5	33.26	34.00	49.32	50.85

4.3 Shear Strength of Concrete Using Push-Off Specimens

Table 4 shows the values of shear strength obtained experimentally using push-off specimens in the present work for M30 and M60 grades of concrete for different volume percentages of fibres. It is seen that with an increase in fibre percentage the shear strength at 14 and 28 days of fibre reinforced concrete increases monotonically.

Table 4: Experimental Values of Shear Strength of M30 & M60 Grades of Concrete

Sl. No.	**Fiber Content (%)**	**Shear Strength (τ) for M30 grade concrete in N/mm²**		**Shear Strength (τ) for M60 grade concrete in N/mm²**	
		14days	**28days**	**14days**	**28days**
1	0.0	7.66	8.17	3.33	5.50
2	0.5	7.83	9.33	6.00	6.50
3	1.0	9.17	10.00	8.50	8.50
4	1.5	10.67	11.17	9.33	10.33

Fig.3 shows the shear strength at 14 days of curing for different percentages of fibers for both M30 and M60 grades of concrete. Fig.4 shows the shear strength at 28 days of curing for different percentages of fibers for both M30 and M60 grades of concrete. The test results show that, shear strength obtained for M60 grade of concrete is significantly smaller than that of M30 grade of concrete with 0% fiber content. This may be attributed to good aggregate interlocking with cement paste due to higher water-cement ratio used in M30 concrete that develops good bond strength and better shear transfer strength along the shear plane than M60 grade concrete. It can be observed that the introduction of fibers in both M30 & M60 grades of concrete increases the shear strength of concrete. The shear strength of concrete increases as the percentage of fibres is increased. The increase in shear strength of both M30 and M60 grades of concrete as fiber percentage increases is substantial.

It is to be noted the compressive strength decreases beyond 1% of steel fibres whereas the shear strength of concrete increases with an increase in the percentage of fibres. It is also to be noted that higher fiber % reduces the workability of concrete.

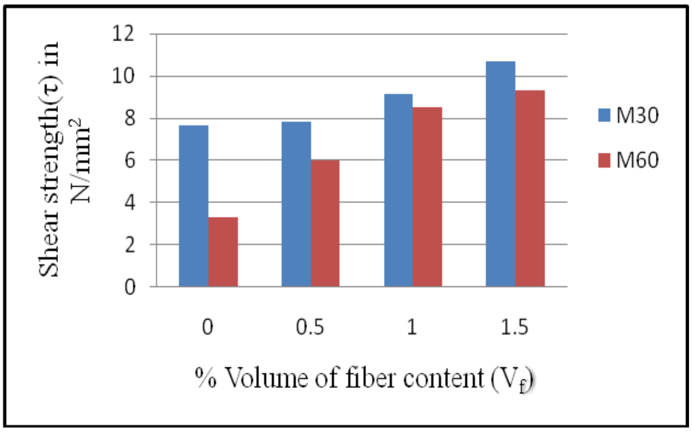

Fig.3: Variation of Shear Strength of M30 & M60 Grade of Concrete with Volume % of Fibres at 14 Days Curing

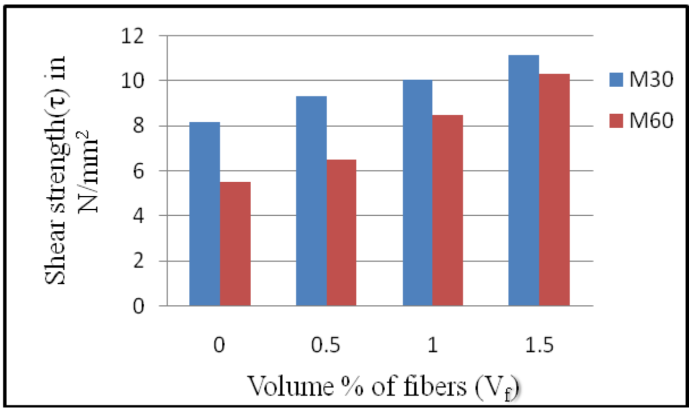

Fig.4: Variation of Shear Strength of M30 & M60 Grade of Concrete with Volume % of Fibres at 28 Days Curing

The first cracking load and the failure modes of specimens tested in the present work were also observed. The addition of fibres was observed to improve the first cracking load and failure modes. The failure modes of concrete specimens with no fibres in the case of both M30 and M60 grades of concrete were brittle with no warning before failure. These specimens lost their integrity breaking into several pieces.

V. CONCLUSIONS

Based on the present experimental work, the following conclusions are drawn:

1. The slump value/workability for both M30 and M60 grades of concrete decreases as volume percentage of fibres increases.
2. The compressive strengths at 14 days and 28 days of curing increase initially with increase in volume percentage of fibres for both M30 and M60 grades of concrete. The optimum fibre percentage from the point of view of compressive strength lies in the range 0.5 -1.0%. The compressive strength decreases beyond 1.0 percent.
3. An increase in the volume percentage of fibres increases the shear strength of concrete monotonically.
4. The issue of best fiber percentage to be used in practice has to be addressed by considering concurrently the shear strength, compressive strength and workability. If workability is addressed by adding superplasticizer, a value of 1% of steel fibers may be good and adopted in practice.
5. The addition of fibres improves the load at first cracking, ductility and the failure pattern of concrete.

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