International Journal of Engineering Research and Development
ISSN: 2278-067X, Volume 1, Issue 1 (May 2012), PP 16-21
www.ijerd.com

Ultimate Shear Strength of Fibrous Moderate Deep Beams without Stirrups

Mr. V. R. Patel[1], Bhavin R. Mojidra[2], Dr. I. I. Pandya[3]
[1,2]*ME civil (Structural Engineering), Assistant Professor, Applied Mechanics and Structural Engineering Department, Faculty of Technology and Engineering. The M.S.University, Vadodara.*
[3]*Reader, Applied Mechanics and Structural Engineering Department, PhD (Structural Engineering), the M.S.University, Vadodara.*

Abstract—This paper investigates the shear strength of Steel Fiber Reinforced Concrete (SFRC) moderate deep beams without stirrups having span to depth ratio 2.0, 2.4, 3.0, 4.0. The 12 numbers of beams were tested. 12 numbers of beams were tested to failure under two point symmetrical loading. A complete shear deformational behavior along with load-deflection response, crack patterns and modes of failure is studied experimentally. Shear strength is evaluated using empirical equations proposed here in this work for estimation of ultimate shear strength of moderate deep beams without stirrups. Experimental results of ultimate shear strength are compared with theoretical results calculated from proposed equation proposed. The comparison shows that the equation proposed here provides the most accurate estimates of shear strength. In addition to concrete strength, the influence of other variation such as fiber factor, span to depth ratio, longitudinal steel ratio and size effect is considered in the proposed equation.

Keywords— Steel Fiber Reinforced Concrete, Moderate deep beams, Ultimate shear strength, Crack patterns and modes of failure.

I. INTRODUCTION

ACI-ASCE[1] committee 426 classifies a beam with a shear span-to-depth ratio a/D less than 1.0 as a deep beam and a beam with a/D exceeding 2.5 as an ordinary shallow beam. Any beam in between these two limits is categorized as a moderate deep beam. An attempt has been made through the study to understand the complex but most significant shear response of moderate deep beams under fibrous matrix. Because of their proportion they develop mechanism of shear transfer quite different from that in slander beams and their strength is likely to be controlled by shear rather than flexure provided with nominal amount of longitudinal reinforcement. Prominent researchers[4, 5, 6] have carried out numerous investigations and reports were published regarding the strength and the load-deformation behavior of R.C.C. deep beams but a very few research work have been done to study shear behavior of FRC moderate deep beams particularly using steel fibers. Moderate deep and deep beams are shear predominant members and generally fail in brittle shear mode[7, 8, 10]. The addition of steel fibers to a reinforced concrete beam is known to increase its shear strength and, if sufficient fibers are added, a brittle shear failure can be suppressed in favor of more ductile behavior. The use of steel fibers is particularly attractive if conventional stirrups can be partially eliminated, which reduces reinforcement congestion. Investigators[2, 3, 9] have also developed empirical expressions for calculating shear strength.

II. RESEARCH SIGNIFICANCE

The application of fiber to R.C.C. structural members would be one of the major areas of use in structural engineering. The fibers to R.C.C. have got an existing future in construction in days ahead. The objective of the present experimental investigation was to evaluate ultimate shear strength of Steel Fiber Reinforced Concrete moderate deep beams without stirrup. The purpose of this article is to present the results of investigations where the stirrups were replaced by steel fibers as shear reinforcement. The object was also to understand the deflection and the cracking behavior of SFRC moderate deep beam without stirrups.

III. EXPERIMENTAL INVESTIGATION

Test materials

Ordinary Portland cement of 53 grade, natural river sand having fineness modulus of 2.8 and maximum size of 4.75 mm as a fine aggregate, and natural basalt gravel of maximum size 20 mm as coarse aggregate were used. The concrete mix proportion was 1:1.5:3.0 (cement: fine aggregate: coarse aggregate) by weight with fiber volume fraction of 1 % by volume of concrete and water cement ratio of 0.45 kept constant for all beams. The Flat corrugated type (FCT) Steel fibers were used. All beams were provided with anchor bars along with nominal 0.38 % by volume of concrete HYSD bars of grade Fe 415 as main longitudinal tension reinforcement without any web reinforcement. There were three series of beams and for each series six cubes (150 mm x 150 mm x 150 mm) and eight cylinders (four cylinders for compressive strength and four cylinders for splitting strength, 150 mm diameter and 300 mm height) were cast as control specimens. All specimens were cured at least for 28 days.

Specimen Details

Testing was carried out on 12 beams, Beams were simply supported on constant effective span of 1200 mm. 12 numbers of beams were tested under two point concentrated symmetrical loads. All the beams were having constant overall span and width of 1300 mm and 150 mm respectively. There were four series of beams having different depths of 300 mm, 400 mm, 500 mm, and 600 mm and each series comprised of three beams. The beam notation "D50 S1" denotes the beam having overall depth D of 50 cm and S1 denotes series 1.

Testing Procedure

The beams were kept on universal testing machine and leveled horizontally with level tube. The beams were tested under gradually applied load on Universal Testing machine (UTM). Three dial gauges (Least Count = 0.01 mm) were used at the bottom of beam to measure the deflections as shown in **Fig. 1**. Initiation or appearance and propagation of cracks, first crack load, ultimate load and modes of failure of beam were noted. At every stage of loading the process of detecting and marking of new cracks and measuring the propagation of all cracks were continued up to the failure of the beam.

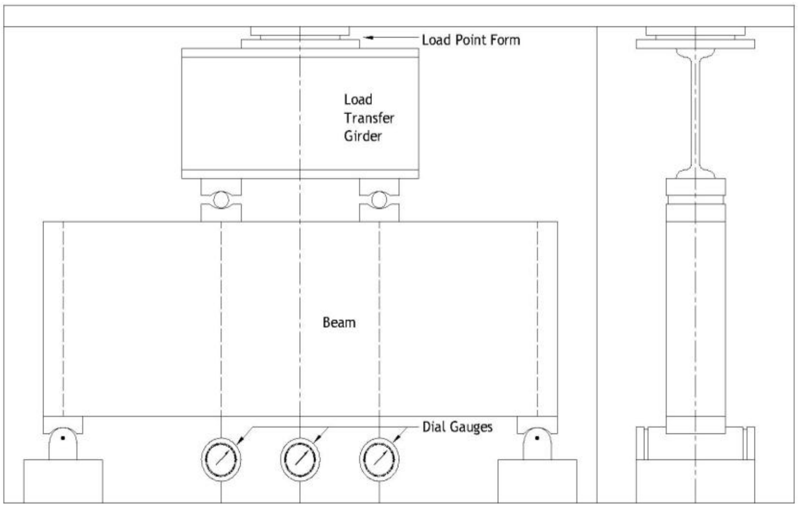


Fig. 1– Loading diagrams for 2P arrangement.

IV. ANALYTICAL INVESTIGATION

Proposed equation

The improvement in shear strength of fibrous concrete depends on four factors. These are Density of fiber (ρf), length of fiber (lf), diameter of fiber (df), and the extent of bond between the fiber and matrix (β). The influence of these four factors incorporated in to combined parameter called Fiber factor F given by

$$F = (\rho f\ lf\ \beta)^{df} \quad \text{(A)}$$

Where β is the bond factor that accounts for differing bond characteristics of the fiber. Based on large pullout tests β has been assigned a relative value of 0.5 for fibers having circular cross section, 0.75 for crimped or hooked fibers and 1.0 for indented fibers.

In the present study the ultimate shear strength of steel fiber reinforced concrete moderate deep beams was defined as the sum of shear strength contribution by concrete and shear strength contribution by fibers.
The ultimate shear strength of Steel fibers (Flat Corrugated Type) Reinforced concrete moderate deep beam [SFRC (FCT)] is calculated as:

$$V_u = V_{u_c} + V_{u_{frc}} \quad \text{(1)}$$

Where,

$$V_{u_c} = \tau_c\ Bd \quad \text{(2)}$$

And

$$Vufrc = 13.3\left[\frac{Ast}{bD}\left\{Fspf^{\frac{D}{L}}\right\}Fcr\left\{L^{\frac{a}{D}}\right\}\right] + \frac{7}{6}\left[Vf^{2.59}F^{0.5}\right] X10^{-6} \quad \text{(3)}$$

V. COMPARISON OF PREDICTION AND EXPRIMENTAL RESULTS

The theoretical values of ultimate shear strength of SFRC (FCT) moderate deep beams are calculated for all beams and compared with experimental values. **Table 1** shows the comparison of test results.

Table 1 Comparison of test results for 2P

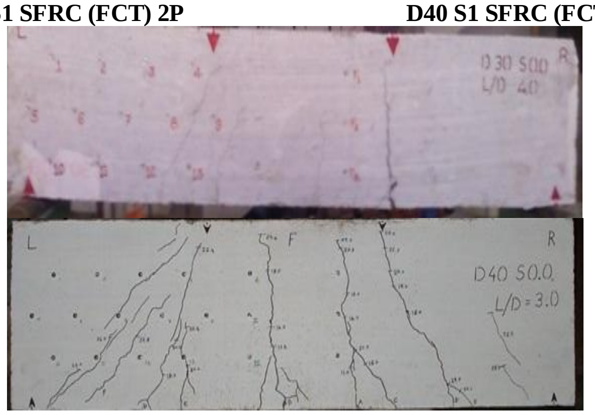
SR NO	BEAM NOTATIONS		a/D	L/D	Unit: tonne		Unit: KN		% DIFFERENCE
					V_{uexp}.	V_{utheo}	V_{uexp}.	V_{utheo}	
1	S1	D 30	1.33	4.00	12.50	9.966	125.00	996.60	25.42
2		D 40	1.00	3.00	23.50	19.830	235.00	198.30	18.51
3		D 50	0.80	2.40	39.75	33.869	397.50	338.69	17.36
4		D 60	0.67	2.00	53.90	53.497	539.00	534.97	0.75
5	S2	D 30	1.33	4.00	12.45	9.966	124.50	996.60	24.92
6		D 40	1.00	3.00	23.30	19.830	233.00	198.30	17.50
7		D 50	0.80	2.40	39.10	33.869	391.00	338.69	15.44
8		D 60	0.67	2.00	53.15	53.497	531.50	534.97	-0.65
9	S3	D 30	1.33	4.00	12.40	9.966	124.00	996.60	24.42
10		D 40	1.00	3.00	23.10	19.830	231.00	198.30	16.49
11		D 50	0.80	2.40	38.85	33.869	388.50	338.69	14.71
12		D 60	0.67	2.00	52.95	53.497	529.50	534.97	-1.02

VI. EXPERIMENTAL RESEARCH AND DISCUSSION

Crack patterns and modes of failure

In all the beam specimens, initiation of flexure cracks **(Fig. 2)** was from the bottom of the beams. In most of the cases, all the flexure cracks were almost vertical, while most of the shear cracks **(Fig. 2)** were inclined and their direction of propagation was towards the nearest load point irrespective of its place of origin. From the observation and photographs of tested specimen regarding crack width and its pattern it reveals from **Fig.2** that for the beams having l/D ratio 3 or more (i.e.D30 and D40 series beams), wide and distinct flexure cracks were observed. The predominant crack was observed in the flexure zone. Few thin cracks were observed in shear zone of D30 and D40 beam series, which shows that the shear strength is higher than flexural strength in D30 and D40 series beams. In case of D50 and D60 series beams (l/D ratio less than 3) it was observed from **Fig.2** that predominant crack occurs in shear zone, but flexure cracks were formed prior to shear cracks and flexure cracks were few and thin. In D50 series of beams the shear cracks are comparable to flexural crack and in D60 series of beams the failure was pure shear failure because shear cracks are wide and predominant. In majority of beams of series D50 and D60; it was observed that the major diagonal shear cracks were formed all of a sudden before Ultimate load. These cracks were initiated by splitting action and the phenomenon of failure was similar to that of cylinder under diametrical compression [split cylinder test].

D30 S1 SFRC (FCT) 2P **D40 S1 SFRC (FCT) 2P**

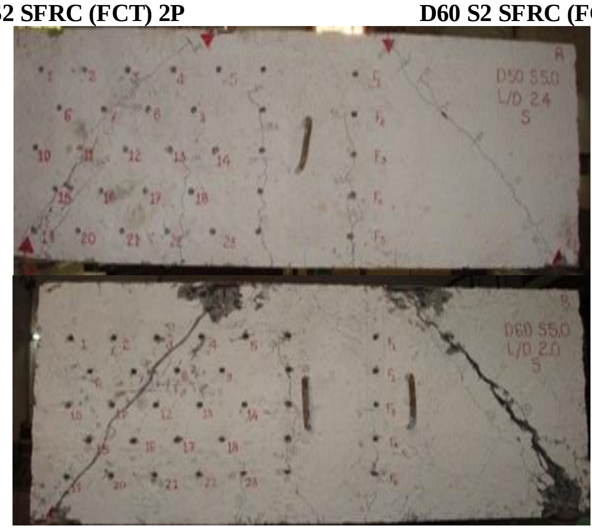


D30 S2 SFRC (FCT) 2P **D40 S2 SFRC (FCT) 2P**


D30 S3 SFRC (FCT) 2P **D40 S3 SFRC (FCT) 2P**


D50 S1 SFRC (FCT) 2P **D60 S1 SFRC (FCT) 2P**


D50 S2 SFRC (FCT) 2P **D60 S2 SFRC (FCT) 2P**



D50 S3 SFRC (FCT) 2P **D60 S3 SFRC (FCT) 2P**

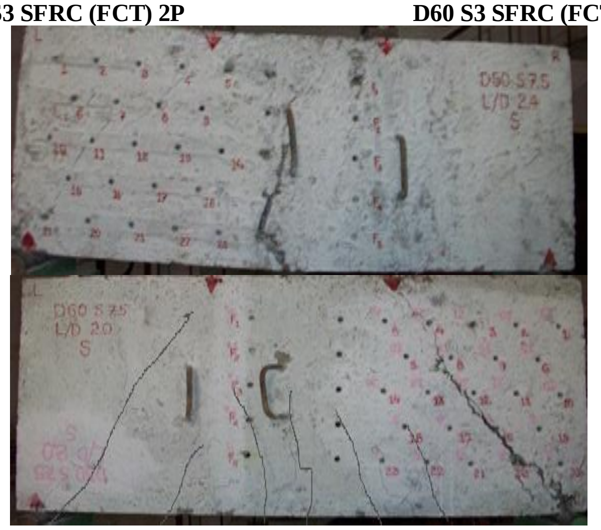


Fig. 2 –Photographs of tested beams

VII. CONCLUSIONS

1. Inclusion of steel fibers (Flat Corrugated Type) in the concrete beam improves the shear strength of R.C.C. beams without stirrups.
2. Steel fibers can be used to replace stirrup partially with proper design of concrete.
3. The replacement of vertical stirrups by steel fibers provided effective reinforcement against shear failure.
4. For L/D ratio 2.00 to 4.00, the ultimate shear strength of SFRC (FCT) moderate deep beams without stirrups evaluated by proposed equation is within $\pm$ 25% of the experimental values, which is good agreement.

NOTATION:

ρf = density of fiber, Kg/m³.
a = shear span, mm.
a/D = shear span-to-depth ratio.
A_{st} = Total area of longitudinal steel provided in beam cross-section, mm².
b = width of beam, mm.
d = effective depth of beam, mm.
D = over all depth of beam, mm.
F = fiber factor.
F_{spf} = average split cylinder strength, N/mm².
F_{crf} = modulus of rupture of concrete, N/mm². ($F_{crf} = 0.7\sqrt{F_{cuf}}$)
F_{cuf} = average cube compressive strength of fibrous concrete at 28 days, N/mm².
L = length of beam, mm.
l_f = length of fiber, Meter
d_f= diameter of fiber/1000

V_f = volume of fiber, cm³.
V_u = total ultimate strength of beam, ton.
V_{uc} = shear resisted by concrete, ton.
V_{ufrc} = shear resistance offered by steel fibers, ton.
τ_c = Design shear strength of concrete, as per ACI 318-2008 in N/mm^2.
U.L. = Ultimate load, ton.

REFERENCES

[1]. ACI 318-2008, "Building Code Requirements for Structural Concrete and Commentary, Appendix A, Strut-and-Tie Models", American Concrete Institute, Farmington Hills.
[2]. Ashour, A. F., "Shear Capacity of Reinforced Concrete Deep Beams", Journal of Structural Engineering, ASCE, Vol. 126, No.9, September 2000.
[3]. Narayanan, R., and Darwish, I.Y.S., "Fiber Concrete Deep Beams in Shear", ACI Structural Journal, Title no. 85-S17, April 1988, pp. 141-149.
[4]. Madan, S.K., Rajesh Kumar, G., and Singh, S.P., "Fibers Replacement Of Web Reinforcement For RCC Deep Beams In Shear", Asian Journal Of Civil Engineering (Building And Housing) Vol. 8, No. 5 (2007).
[5]. Aguilar, Gerardo, Matamoros, Adolfo b., Parra-Montesinos, Gustavo J., Ramfrez ,Julio A. and Wight, James K., "Experimental Evaluation of Design Procedures for Shear Strength of Deep Reinforced Concrete Beam", ACI Structural Journal, Title No.99s-56, August 2002, pp. 539-548.
[6]. Wang, Wei, Jiang, Da-Hua and Thomas Hsu, Cheng-Tzu ,"Shear Strength of Reinforced Concrete Deep Beams", Journal of Structural Engineering, ASCE, February 1992, pp. 2294-2312.
[7]. Woo, Kim and White, Richard N., "Initiation of Shear Cracking in Reinforced Concrete Beams with No Web Reinforcement", ACI Structural Journal, Title no. 88-S32, June 1991, pp. 301-308.
[8]. Sachan, A. K., & Kameswara Rao, C. V. S., "Behavior of Fiber Reinforced Concrete Deep Beams", cement & concrete composites, Elsevier Science Publishers Ltd, England, January 1990.
[9]. Kukreja, C.B., Kaushik, S.K., Kanchi, M.B., and Jain, O.P., "Shear characteristics of reinforced fiber concrete", Journal of Structural Engineering, ASCE, September 1984, pp. 99-105.
[10]. Roberts, T. M. and Ho, N. L., "Shear Failure of Deep Fiber Reinforced Concrete Beams", International Journal of Cement Composites and Light Weight Concrete, Construction Press, August 1982.