

## Evaluation of Shear Strain Distribution In Polypropylene Fiber Reinforced Cement Concrete Moderate Deep Beams

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### ABSTRACT

This paper describes a study on evaluation of shear strain and its variation as well as distribution across the width and depths in Polypropylene Fiber Reinforced Cement Concrete (PPFRC) moderate deep beams having span-to-depth ratio 2.0, 2.4, 3.0 and 4.0. Using micro mechanical measuring device a complete shear strain distribution-variation along with its response to the load deflection, crack patterns and modes of failures were studied experimentally. Twelve beams were tested and results of shear strain variation along vertical axis were plotted at various sections. Parabolic nature of shear strain distribution was observed along the vertical axis of plains situated at various depths.

**Keywords:** Polypropylene Fiber Reinforced Cement Concrete (PPFRC), Moderate deep beam, crack patterns, modes of failures

### 1. Introduction

IS 456-2000 classifies beams into three categories: normal beams, moderate deep beams, and deep beams according to their span-to-depth or shear span-to-depth ratio. Moderate deep beams and deep beams have a wide application in structural engineering field. Numerous investigations have been carried out and reports were published regarding the strength and the load-deformation behavior of moderate deep beams and deep beams, but very few works have been reported on the study of evaluation of shear strain distribution due to its complex shear behavior. As moderate deep beams and deep beams are shear predominant members and generally fail in shear mode more of a brittle in nature, study of a strain deformational behavior is an important aspect towards the deeper understanding of shear behavior of beams under given loading conditions.

For optimum design of any structure, complete knowledge of its load deformational response is essential, which can be accomplished by its complete and careful analysis. Using sectional analysis one can obtain considerably accurate representation of the physical situation and load carrying capacity of structural element for given geometrical parameters like curvature, rotation, strain deformation and cracking characteristics. The present study is an attempt to generate understanding regarding the method of evaluation of shear strain distribution and cracking mechanism in Reinforced cement concrete moderate deep beams.

In the present investigation, visualization was made regarding the distribution and variation of shear strain along the vertical axis. In conventional approach, variation of shear strain distribution along the vertical plane is considered as parabolic in nature. Similar nature of

shear strain distribution was observed in the present investigation. The aim of the investigation is to provide a systematic and comprehensive study on the shear deformation behavior as well as shear strain distribution in Polypropylene Fiber Reinforced Cement Concrete moderate deep beams. Adapting triangular rosette pattern, an innovative hexagonal grid arrangement of Demec targets was created on specimens, which helps in evaluation of shear strain from concrete axial strain readings.

## 2. Objectives

The objective of the present experimental investigation is to study the evaluation of shear strain across the width and depths as well as representing its distribution and variation at various sections along vertical axis in Polypropylene Fiber Reinforced Cement Concrete moderate deep beams having varying span-to-depth ratio to obtain the clear information regarding the fundamental nature of shear failure and its behavior at various stages of loading.

## 3. Experimental Program

### 3.1 Test specimen

Twelve Polypropylene Fiber Reinforced Cement Concrete moderate deep beams, simply supported on effective span of 1200 mm were tested under two points loading. Length of the beams and width of the web were kept constant (1300 mm and 150 mm respectively). The beams were divided into four series having depths of 300 mm, 400 mm, 500 mm and 600 mm respectively. Each series comprised of three beams. The assumption plane stress condition underestimates the significance of the small compressive or tensile stresses that develop in the transverse direction from incompatible deformational response of consecutive concrete elements subjected to different states of stress, therefore, axial concrete strain was measured on surface planes situated at different depths of 0.0 cm (i.e. at the surface), 2.5 cm, 5.0 cm, and 7.5 cm across the width of the beams of each series, i.e. beam notation “D50 S2.5” denotes the beam having overall depth D of 50 cm and axial concrete strain measured on surface plane situated at a depth of 2.5 cm across the width of the beam.

### 3.2 Test materials

The cement used was ordinary Portland cement of grade 53. ordinary river sand having fineness modules of 2.8 and maximum size of 4.75 mm, and crushed basalt gravel having a maximum size of 20 mm were used as a fine and coarse aggregate respectively. The concrete mix of 1:1.5:3 (cement: fine aggregate: coarse aggregate) by weight with water cement ratio of 0.45 was used for all beams. Monofilament form of Polypropylene Fibers having melting point 1650 Celsius, tensile strength 670 N/mm<sup>2</sup> was homogeneously mixed with cement. Fiber content/Beam = 0.75% (By volume) of concrete. Longitudinal tension reinforcement consists of High yield strength deformed bars (415 N/mm<sup>2</sup>) used, Vertical Shear Reinforcement (stirrups) are not provided. Six cubes (150mm) and eight cylinders (four cylinders for compressive strength and four cylinders for splitting strength, 150mm diameter and 300mm height) were cast as control specimens from each mix. All specimens were cured at least for 28 days.

### 3.3 Concrete Strain And Crack Width Measurement

Aluminum discs having 10 mm outside diameter, 1.5 mm diameter hole at center and 3 mm thickness chamfered inside edges were used as Demec targets to measure a concrete surface strain and in-depth strain as well as cracks width at predefined locations. Modified mechanical type of Demec gauges with a gauge length of 200mm, least count 0.01mm and range of 30 mm were used. There were three gauges with knife edges of different length. The lengths were 25 mm, 50 mm and 75 mm to measure the concrete strain in the beam at the depth of 25 mm, 50 mm and 75 mm across the width of the beam through the holes created during casting. Adapting triangular rosette pattern, an innovative hexagonal grid arrangement of demec targets was created on specimen as shown in figure 1.

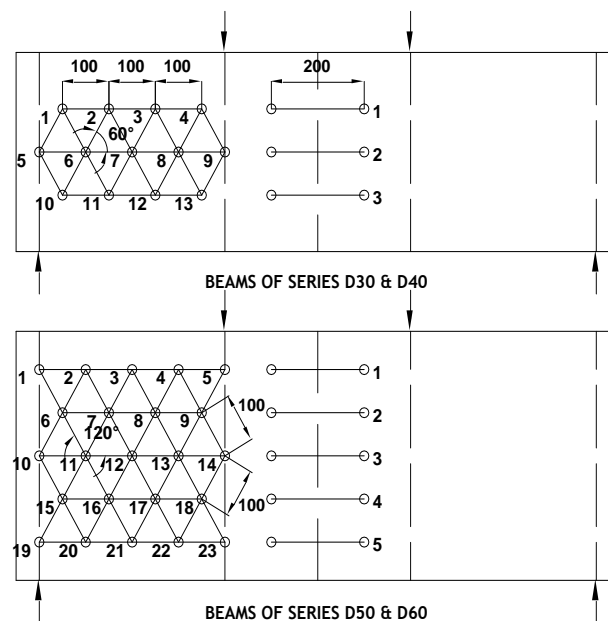


Figure 1: Hexagonal grid arrangements of demec targets

### 3.4 Testing

All the beams were tested under two point concentrated loadings positioned at one third spans. All the beams were simply supported with an effective span of 1200 mm. Beams were centered on platform and leveled horizontally and vertically by adjusting the bearing plates. Load was applied gradually.

Three dial gauges were used to measure the deflection at the center and under the points of loadings. Here, Delta rosette is used for measuring strains at different demec points in which three strains are required to calculate the shear strains and shear stresses. In D30 and D40 beams demec targets numbers are 6,7,8 and in D50 and D60 beams demec targets numbers are 7,8,11,12,13,16,17. Readings were taken at proper load interval. Deflections, concrete surface strains and in-depth strains in flexure and shear zones were measured using mechanical strain gauge.

Crack propagations were traced by pencil and their tips were marked corresponding to the load readings

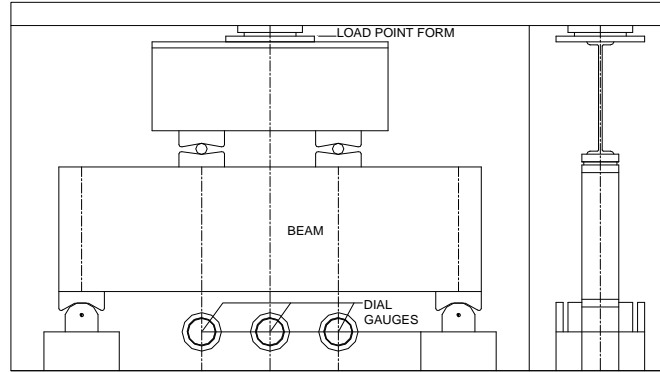


Figure 2: Test setup

#### 4. Discussion of Test Results

##### 4.1 Crack Patterns, Propagation, and Modes of Failure

In all the beams two types of cracks, namely flexure cracks and diagonal tension cracks were observed. Flexure cracks developed at the region of maximum moment. In all the beams of series D50 and D60 flexure cracks (fig. 3) were observed in the lower half depth of the beams. Flexure cracks were few and were very fine and hardly reached up to the mid-height of the beam. All the flexure cracks were almost vertical. In most of the beams of series D50 and D60 the width of the flexural cracks was less than 0.1 mm at failure. These cracks were found to have little effect either on the mode of failure or on the ultimate load. Beams of series D30 and D40 failed in flexure by yielding of longitudinal tension reinforcement. Size and propagation of flexure cracks (fig. 3) were predominant.

There were two types of diagonal tension cracks (fig. 3) observed in test specimens. The first type of diagonal tension cracks originated from the inner edge of the reaction bearing plate.

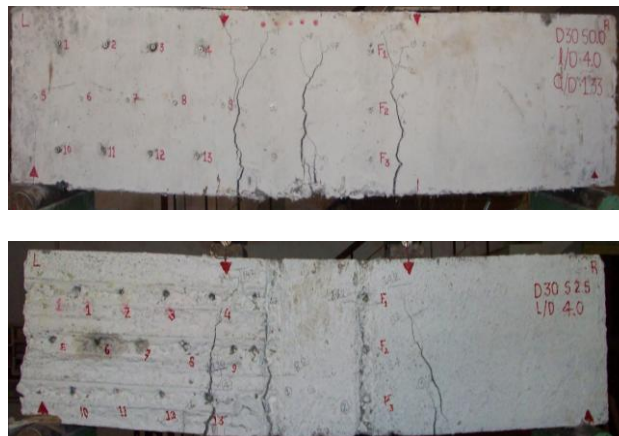




Figure 3(a): D30 specimen



Figure 3(b): D40 specimen



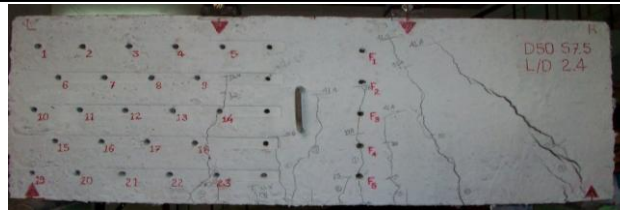


Figure 3(c): D50 specimen

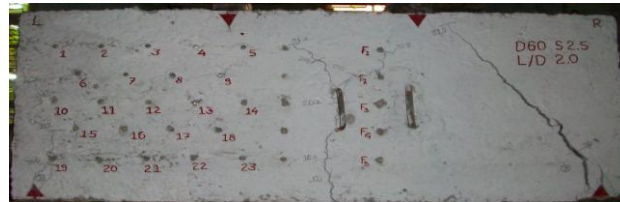


Figure 3(d): D60 specimen

to the outer edge of the loading plate. These cracks were either the immediate cause of failure of the beam or else they brought the beam to its eventual collapse.

The other type of diagonal cracks opened at a distance of  $\frac{D}{2}$  to  $\frac{D}{4}$  from the soffit. With load increments, the rate of progress of these cracks was as gradual as the diagonal cracks which originated in the vicinity of inner edge of the loading bearing plate. Any web reinforcement which crossed the diagonal cracks was helpful in arresting their propagation. These diagonal cracks so formed were nearly parallel to each other with a “strut like” appearance between the loading points.

The complete failure of the beams was observed to occur in one of the following ways:

- (i) The beams were collapsed by flexure with a flexural crack near to mid-span. This type of failure was observed in beams of D30 and D40 series.
- (ii) The diagonal tension failure, observed in majority of the beams of D50 and D60, was indicated by splitting of the beam in the direction of a line joining the inner edge of the reaction bearing plate at the support to the outer edge of the bearing plate.

Beams of series D50 mainly failed in flexure-shear mode, while beams of series D60 failed in pure shear mode.

The shear compression failure was indicated by crushing of the “strut like” portion of the concrete between two adjacent parallel diagonal cracks accompanied by splitting of the concrete along the plane of the diagonal cracks and was followed by crushing and bursting in the web. This type of failure was observed in some of the beams of D50 and D60 series.

## 5. Conclusion

The graphs plotted for the variation of shear strain (figure 4) at top surface and at in-depth surface along the vertical axes in shear zone shows D shape of shear strain distribution which shows a good agreement with the theoretical shear strain distribution of a parabolic nature along the vertical axes of a beam assuming a zero shear strain value at the top and bottom most edges of the beam.

The results also indicate that there is an enhancement in the ductility factor in beams of series S(0.0 + 2.5) (table 1) However, this factor has no appreciable influence on load –deflection, load-steel strain, shear force-shear strain or shear force-principle strain relationship in series of the beams. It was observed from the test results that the ultimate shear strength of the beam is mainly dependent on the diagonal cracking load and subsequent reserve of strength beyond the load due to the present of the longitudinal reinforcement, is significant in most of the beams (table 1). In the majority of the beams the cracks were initiated by splitting action and the phenomenon of failure was similar to that of cylinder under diametrical compression in the splitting test. This phenomenon is consistent with the theoretical assumption and also with the observations reported by others found true.

**Table 1:** Load characteristics of beams

BEAM NOTATIONS	LOAD AT YIELDING OF BEAM	ULTIMATE LOAD	DEFLECTION AT FIRST CRACK	DEFLECTION AT ULTIMATE LOAD	DUCTILITY AT ULTIMATE LOAD
	Wy (T)	Wu (T)	$\Delta y$ (mm)	$\Delta u$ (mm)	$m = \Delta u / \Delta y$
D30 S(0.0 + 2.5)	6.5	13.4	0.89	5.75	6.46
D40 S(0.0 + 2.5)	12.0	29.5	0.59	3.90	6.61
D50 S(0.0 + 2.5)	13.0	46.0	0.65	5.02	7.72
D60 S(0.0 + 2.5)	17.5	67.8	0.44	4.71	10.70
D30 S5.0	7.0	15.7	1.11	5.95	5.36
D40 S5.0	11.5	31.0	1.15	4.62	4.02
D50 S5.0	12.5	44.0	1.14	5.94	5.21
D60 S5.0	20.0	56.0	0.95	5.38	5.66
D30 S7.5	6.0	16.1	0.67	5.98	8.93
D40 S7.5	12.0	35.5	0.43	3.80	8.84
D50 S7.5	16.0	50.2	0.94	5.70	6.06
D60 S7.5	17.0	55.6	1.00	5.43	5.43

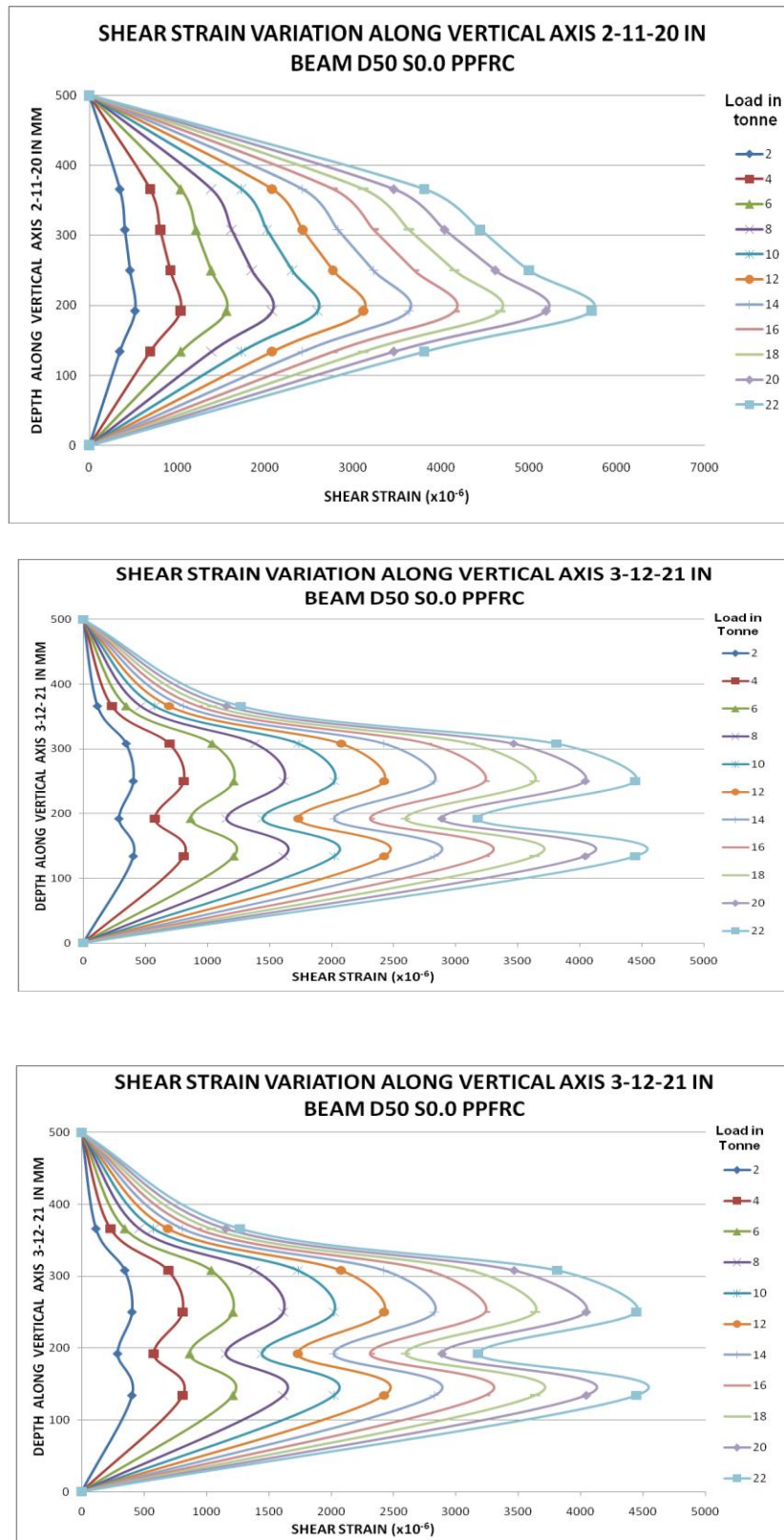


Figure 4: Shear strain distribution diagram



## 6. References

1. IS 456:2000, “Plain and Reinforced Concrete - Code of Practice”, Fourth revision, Bureau of Indian Standards (BIS 2000), Fifth Reprint August 2002.
2. Dally James W., And Rilay William F., “Experimental Stress Analysis”, International Student Edition, McGraw Hill Book Company.1965.
3. Batson G., Jenks E. And Spatney R., “Steel fibers as Shear Reinforcement in beam”, Title no. 69-61, ACI Journal, October 1972, V.69, No.10, pp. 640-644.
5. Patel S. N., And Damle S.K., “Behavior of Reinforced Concrete DeepBeams in Flexure and Shear”, PH.D. Thesis, M. S. University of Baroda, December 1976.
6. Korsoyos Michale D., “Behavior of Reinforced Concrete Beams with a Shear Span-to-Depth Ratio between 1.0 and 2.5”, Title no. 81-27, ACI Journal, May-June 1984,V.81,No.3, pp.279- 286.
7. Narayanan R., And Darwish I. Y. S., “Fiber Concrete Deep Beams in Shear”, Title no. 85-S17, ACI Structural Journal, March-April 1988, V. 85, No.2, pp.141-149.
8. Kong F. K., “Reinforced Concrete Deep Beams”. First edition, Blackie and Son Ltd., Alsogow and London, Published by Van Nostrand Reinhold, New York, June 1990.
9. Mansur M. A., And Ong., K.C.G., “Behavior of Reinforced Fiber Concrete Deep Beams in Shear”,Tittle no. 88-S13, ACI Structural Journal, V.,No.,January- February 1991,pp.98-105.
10. Tan K. H., Murugappan K., And Paramasivam P., “Shear Behaviour of Steel Fiber Reinforced Concrete Beams”, Title no. 90-S1, ACI Structural Journal, January-February 1993, V.89, No.6, pp. 3-11.