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Experimentally Effectiveness of Shear Carrying Capacity of Reinforced Concrete Rectangular Beam by using Rectangular, Triangular and Spirally Stirrups.

V. S. Bhakare, C. P. Pise

***Abstract**: This paper presents a study of shear behavior of reinforced concrete beam. Generally, shear reinforcement of concrete beam consists of rectangular shape stirrups. when replacing the traditional stirrups by continuous spirally and triangular shape stirrup's the increase shear carrying capacity of spirally shape stirrups. The spirally shape stirrups reduce the labor cost as well as crack pattern. In this research paper the theoretically shear carrying capacity of rectangular shape stirrups as per design IS456:2000 and experimental shear carrying capacity of rectangular shape stirrups is obtained and that value compared to the spirally and triangular shape stirrups. The present experiment carries 27 beam having cross section 700mm x 150mm x 150mm each set consist 9 beam of rectangular, spirally and triangular shape shear reinforcement with spacing 70mm, 90mm, 110mm. all the beam was tested using four-point loading after 28 days curing. The test result include shear carrying capacity, load-deflection curve, crack pattern. Take a test after 28 days the spirally shear reinforcement improved shear carrying capacity as well as ductility of beam compared to the rectangular and triangular shape stirrups. Hence spiral shear reinforcement shows better result as well as crack performance also deflection at mid span.*

***Keywords:** Rectangular, spirally, triangular, shear reinforcement, shear carrying capacity, crack pattern, load-deflection curve.*

I. INTRODUCTION

The concept of optimizing of resources for reinforced concrete is now-a-days the leading research area in structural engineering. The section of structural member is subjected to shear force due to flexure, punching, or torsion. The shear associated with change of bending moment along the span is called flexural shear. The shear failure of RCC beam may not lead to immediate failure it reduces the flexural strength of member and thus it is a state of impending shear failure. The minimum shear reinforcement is necessary because of to prevent sudden shear failure also to prevent failure due to shrinkage, thermal stresses and internal cracking in the beam. The prevent the shear failure the shear reinforcement provided in the shape of vertical stirrups, inclined stirrup's, bent up bar. The inducing the crack in the RC beam is plays the most important role in the shear failure. The modes of crack are flexural cracks, shear cracks or diagonal tension crack, flexure shear crack, secondary rack or splitting crack. Sometimes the inclined crack propagates along the tension reinforcement towards the support such crack is referred to as secondary crack or splitting crack. Experimentally

The reinforced concrete beam subjected to shear force and shear crack which are diagonally towards axis of beam. To prevent the shear failure to provide shears reinforcement in individual vertical stirrups or inclined reinforcement.

In the inclined shape spirally shaped shear reinforcement is a valid alternative that could be used in international codes [3]. When wire mesh is used as shear reinforcement the exhibited less number of crack pattern compared beam with stirrups. [1]. The rectangular spiral shear reinforcement improved the shear capacity and ductility of beam compared with traditional individual closed stirrups beams. [4]. The beam with spiral transversal reinforcement with favorably inclined legs exhibited better performance [6]. the shear reinforcement steel is reduced to 12.71% in triangular shear reinforcement as well as increase the load carrying capacity.

The observation studied then this research paper is on shear reinforcement in RC beam in which the shape of shear reinforcement is spirally and triangular which compared to the rectangular shape stirrup's. the theoretical value is optioned by the IS456:2000 with considering spacing 70mm,90mm and 110mm. that value compared to the experimental value with test setup. Result is discussed on the shear carrying capacity ductility and load-deflection curve of all type shear reinforcement and finally concluded the effectiveness of shear reinforcement.

II. THEORETICAL VALUE

As per IS456:2000 design the shear carrying capacity of beam as per given data.

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* Correspondence Author
Vikram S Bhakare*, P.G Student civil engineering department, SKN Sinhgad college of engineering korti, pandharpur, Solapur university, Pandharpur,Solapur.India. Email: vikrambhakare671@gmail.com
Dr. C. P. Pise., Department of Civil Engineering, SKN Sinhgad college of engineering korti, pandharpur, Solapur university, Pandharpur, Solapur. India Email: cppise@yahoo.co.in

1) Total shear carrying capacity of RC beam with rectangular shape stirrups @spacing 70mm as per IS456:2000

Analysis of rectangular RC beam

Given-

1) RC beam size – 150mm x 150mm
2) Clear Cover – 20mm
3) Reinforced bar – 3-10mm@tension site and 3-10mm@compression site.
4) Stirrups – 2 legged 6mm diameter @70mm spacing.
5) M20, Fe500 for main bar and Fe250 for stirrups.

- To Find Shear Resistance Vu
- Step 1- Area of Steel (Ast)
  Ast = 6×π/4×10^2
  = 471.24mm^2
  - Step 2 - Area of Vertical Stirrups (Asv)
    Asv = 2×π/4×6^2
    =56.54mm^2
    Spacing of stirrups Sv = 70mm
  - Step 3 - Effective depth
    d = D – C - ø/2
    = 150-20-10/2
    = 125mm
  - Step 4 Design shear strength in concrete (τc)
    %Pt = 100 Ast/bd
    = 100×471.24/150×125
    = 2.51
    Referring table 19 of IS 456: 2000
    τc = 0.82 N/mm^2
  - Step 5 Shear capacity of concrete (Vuc)
    Vuc = τc b d
    = 0.82×150×125
    = 15375N
    = 15.375KN
  - Step 6 Shear resistance by vertical stirrups (Vus)
    Vus = 0.87 fy Asv d / Sv
    = 0.87 ×250×56.54×125/70
    = 21950 N
    = 21.95 KN
  - Step 7 Total shear capacity of RC beam
    Vu = Vuc + Vus
    = 15.37 + 21.95
    = 37.32 KN

2) Total shear carrying capacity of RC beam with rectangular shape stirrups @spacing 90mm as per IS456:2000

Analysis of rectangular RC beam

Given-

1) RC beam size – 150mm x 150mm
2) Clear Cover – 20mm
3) Reinforced bar – 3-10mm@tension site and 3-10mm@compression site.
4) Stirrups – 2 legged 6mm diameter @90mm spacing.
5) M20, Fe500 for main bar and Fe250 for stirrups.

- To Find Shear Resistance Vu
  - Step 1- Area of Steel (Ast)
    Ast = 6×π/4×10^2
    = 471.24mm^2
  - Step 2 - Area of Vertical Stirrups (Asv)
    Asv = 2×π/4×6^2
    =56.54mm^2
    Spacing of stirrups Sv = 90mm
  - Step 3 - Effective depth
    d = D – C - ø/2
    = 150-20-10/2
    = 125mm
  - Step 4 Design shear strength in concrete (τc)
    %Pt = 100 Ast/bd
    = 100×471.24/150×125
    = 2.51
    Referring table 19 of IS 456: 2000
    τc = 0.82 N/mm^2
  - Step 5 Shear capacity of concrete (Vuc)
    Vuc = τc b d
    = 0.82×150×125
    = 15375N
    = 15.375KN
  - Step 6 Shear resistance by vertical stirrups (Vus)
    Vus = 0.87 fy Asv d / Sv
    = 0.87 ×250×56.54×125/90
    = 17079 N
    = 17.079 KN
  - Step 7 Total shear capacity of RC beam
    Vu = Vuc + Vus
    = 15.37 + 17.079
    = 32.44 KN

3) Total shear carrying capacity of RC beam with rectangular shape stirrups @spacing 110mm as per IS456:2000

Analysis of rectangular RC beam

Given-

1) RC beam size – 150mm x 150mm
2) Clear Cover – 20mm
3) Reinforced bar – 3-10mm@tension site and 3-10mm@compression site.
4) Stirrups – 2 legged 6mm diameter @70mm spacing.
5) M20, Fe500 for main bar and Fe250 for stirrups.

- To Find Shear Resistance Vu
  - Step 1- Area of Steel (Ast)
    Ast = 6×π/4×10^2
    = 471.24mm^2
  - Step 2 - Area of Vertical Stirrups (Asv)
    Asv = 2×π/4×6^2
    =56.54mm^2
    Spacing of stirrups Sv = 110mm
  - Step 3 - Effective depth
    d = D – C - ø/2
    = 150-20-10/2
    = 125mm
  - Step 4 Design shear strength in concrete (τc)
    %Pt = 100 Ast/bd
    = 100×471.24/150×125
    = 2.51
    Referring table 19 of IS 456: 2000
    τc = 0.82 N/mm^2
  - Step 5 Shear capacity of concrete (Vuc)
    Vuc = τc b d
    = 0.82×150×125
    = 15375N
    = 15.375KN

- Step 6 Shear resistance by vertical stirrups (Vus)
  Vus = 0.87 fy Asv d / Sv
  = 0.87 ×250×56.54×125/110
  = 13974 N
  = 13.97 KN
- Step 7 Total shear capacity of RC beam
  Vu = Vuc + Vus
  = 15.37 + 13.97
  = 29.34 KN

Table 1. Theoretically shear carrying capacity

Spacing	@70c/c	@90c/c	@110c/c
Total shear carrying capacity	37.32	32.44	29.34

III. EXPERIMENTAL PROGRAM

The experimental include testing of 27 beams under static loading. The beams are tested under the four-point loading system the strength of M20 was found and further casting the beam. The major parameter used were type of shear reinforcement namely rectangular, spirally and triangular shape stirrups.

1)Material Properties:

a) Cement: Ordinary Portland cement was used. Which is specific gravity is 3.15[17]

b) Fine aggregate: Locally obtained natural river sand of 2.36 mm size with a specific gravity of 2.46 as per IS 2386 was used.

c) Coarse aggregate (CA): The aggregates used ranges between 12.5 mm to 20 mm of specific gravity 2.70 using IS 2386

d) Water: Tap water was used for mixing and curing of concrete.

e) Reinforcement: Steel bars of Fe 500 grade was used and Fe250 mild steel used as shear reinforcement.

) Mix proportions:

Concrete mix was done in accordance with IS 10262:2009 [15] and IS 456:2000 [16] was done for M20 grade. The proportions arrived as 1:1.15:2.06 The w/c ratio was maintained as 0.38. The specimens such as cubes and beam are casted to achieve better strength.

c) Casting

Total 27 RC Beam specimens were cast with size of 700mm × 150mm × 150 mm to study the behavior of beams. All beams were reinforced with 3- 10 mm diameter on tension zone and 3-10 mm diameter on compression zone, 2- 6mm diameter stirrups are provided at 70 mm, 90 mm, 110 mm spacing center to center with shape of rectangular, spirally and triangular. Concrete were placed in the well lubricated mould and compacted well and the specimens were left at room temperature for 24 hrs and the specimens were placed in curing tank for 28 days. The beams were classified based on the details given in the Table. Fig. 1-3 gives the reinforcement details

Table 2. Beam details

Specimen ID	Details
R70,R90,R110	RC beam with rectangular shape stirrups @70,90,110 mm c/c spacing.
SP70,SP90,SP110	RC beam with spirally shape stirrups @70,90,110 mm c/c spacing.
T70,T90,T110	RC beam with triangular shape stirrups @70,90,110 mm c/c spacing.


Fig.1 Rectangular shape stirrups @70 mm c/c spacing


Fig.2 Rectangular shape stirrups @90 mm c/c spacing


Fig.3 Rectangular shape stirrups @110 mm c/c spacing


Fig.4 spirally shape stirrups @70 mm c/c spacing


Fig.5 spirally shape stirrups @90 mm c/c spacing

Fig.6 spirally shape stirrups @110 mm c/c spacing

Fig.7 Triangular shape stirrups @70 mm c/c spacing

Fig.8 Triangular shape stirrups @90 mm c/c spacing

Fig.9 Triangular shape stirrups @110 mm c/c spacing

Test setup:

All the beam specimens were tested under four-point loading in the Universal testing machine of 1000 kN capacity. The effective span of the beam was 600 mm. During testing, formations of cracks were marked on the surface of the beams. To perform the test in the beam specimens, the rate of loading considered during the test was 10 kN/min until the beam reached the peak load. During test the structural behavior deflection, strains, crack propagation, failure is measured and recorded The Fig.4 gives the test set-up of the beam.

Fig.10 Beam test set-up

IV. RESULT AND DISCUSSION

1)Ultimate load

The load in the beam was given at an incremental and corresponding crack pattern and load deflection was recorded. The first crack was developed at the soffit of the beam.

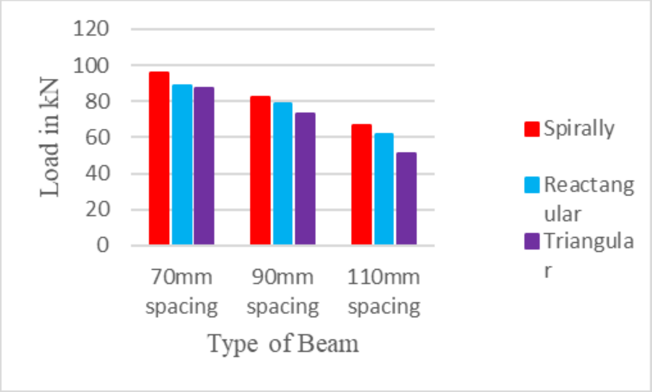

Fig.11 Ultimate load

Table.2 Experimental Shear carrying capacity of RC beam

Sr. No.	Spacing	Shear Carrying Capacity Vu (KN)		
		Spirally	Rectangular	Triangular
1	70@c/c	47.85	44.18	43.74
2	90@c/c	41.36	39.25	36.45
3	110@c/c	33.16	30.99	25.44

The specimen SP70 means spirally shape stirrups @70 mm c/c spacing take maximum load 95.71 KN and it failed in flexure. The result indicates that the shear carrying capacity of spirally shape stirrups are most favorable than the rectangular and triangular type of stirrups. This proves that continuous spiral stirrups take maximum shear carrying capacity

2)Crack pattern:

When the all the beam is tested and observed the crack performance then it will be well in both shear and flexure. Crack were developed which are found to be more near the supporting end because of shear at the support end. The first shear crack is observed at shear zone of RC beam and crack observed identical both side. The spirally shape stirrups performed better than the rectangular and triangular shape stirrups' RC beam as shown below fig.

Fig.12 Spirally shape stirrups RC beam

Fig.13 rectangular shape stirrups RC beam

Fig.14 Triangular shape stirrups RC beam

3) Load Deflection Behavior

The deflection of beam is observed at mid span and plotting the graph against applied load. The graph shows the linear which indicate the load is directly proportional to deflection And due to further increasing the load graph does not show linear mean beam enter in the elasticity to the plasticity. Its shows the spirally shape stirrups beam take maximum load and deflection is minimum as compared to the rectangular beam and triangular shape stirrups' take minimum deflection. Its means that the result indicate that the triangular shape stirrups' better performance than the spirally and rectangular shape stirrups.

The load deflection behavior is shown in the fig below.

Table 3 : Load-deflection behavior @70mm c/c spacing

@70mm c/c spacing			
	Spirally	Rectangular	Triangular
Maximum Load (Kn)	95.71	88.36	87.48
Maximum Deflection (mm)	11.5	13.8	8

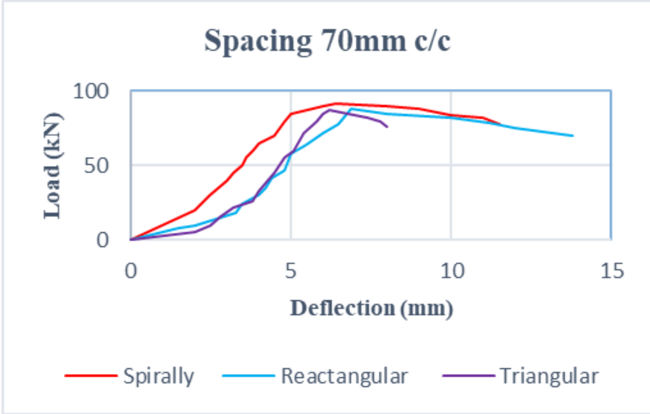

Fig.15 load deflection for 70 mm c/c spacing.

Table 3 : Load-deflection behavior @90mm c/c spacing

@90mm c/c spacing			
	Spirally	Rectangular	Triangular
Maximum Load (Kn)	82.36	78.5	72.9
Maximum Deflection (mm)	11.7	12.05	9.5

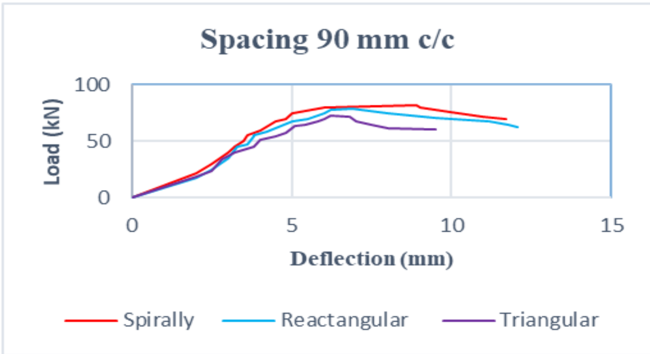

Fig.16 load deflection for 90 mm c/c spacing

Table 3 : Load-deflection behavior @110mm c/c spacing

@110mm c/c spacing			
	Spirally	Rectangular	Triangular
Maximum Load (Kn)	66.33	61.98	50.88
Maximum Deflection (mm)	7.35	7.2	5.5

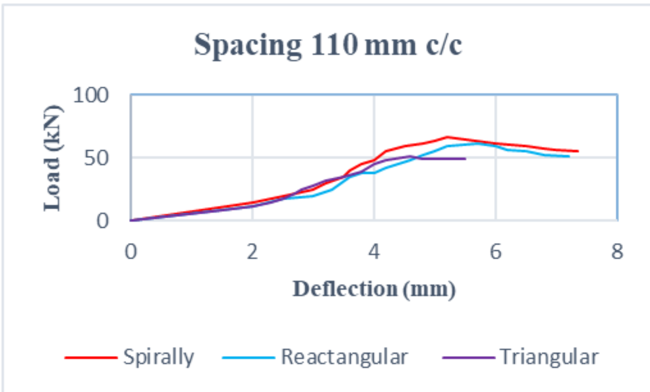

Fig.17 load deflection for 110 mm c/c spacing.

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V. CONCLUSION

A series of 27 beam have been tested by using four-point bending set-up to study of spirally, rectangular and triangular shape stirrups. The finally studied of behavior of load-deflection curve, shear carrying capacity, crack propagation. Based on theoretical and experimental results following conclusion are drawn.

•The beams using spirally shape shear reinforcement have more shear carrying capacity as compared to the rectangular and triangular shape shear reinforcement.

•The use of spirally shape stirrups have effect on delayed the initial crack and reducing the crack width.

•Beam using the triangular shape shear reinforcement the deflection performance is low and after spirally and finally rectangular shape shear reinforcement.

•By using the continuous spiral shape shear reinforcement can reduce the labour cost for production of the reinforced cage.

•Increase the ultimate flexure strength and ductility by using the spirally shape shear reinforcement stirrups'.

•The shear carrying capacity of RC beam with rectangular shape stirrups with theoretically and experimentally result are approximately match.

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AUTHORS PROFILE

V. S. Bhakare is pursing M.E. in Structural Engineering branch of SKN Sinhgad collage of engineering Korti, pandharpur, Solapur. As a part of thesis submission this experimental work conducted in the structural engineering lab of sinhgad collage of engineering under guidance of Dr. C. P. Pise. E mail id: vikrambhakare671@gmail.com

Dr. C. P. Pise was awarded Ph.D. in Civil Engineering. Presently He have working as professor and HOD in the department of civil engineering in SKN sinhgad collage of engineering Korti, Pandharpur, Solapur. E mail id: cppise@yahoo.co.in

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