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EFFECT OF SPACING OF SINGLE SWIMMER BARS ON THE SHEAR BEHAVIOR OF HIGH STRENGTH CONCRETE BEAMS

Sreejith P S[1], P Eapen Sakaria[2]

[1]Sreejith P S, P G Student, Dept. of Civil Engineering, Saintgits College of Engineering, Kerala, India
[2] Prof. Eapen Sakaria, Professor Of P.G.Studies, Dept. of Civil Engineering, Saintgits College of Engineering, Kerala, India

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Abstract - *Reinforced concrete beams are important structural elements that transmit the loads from slabs, to columns. Beams must have an adequate safety margin against bending and shear forces, so that it will perform effectively during its service life. Shear failure of RC beams is distinctly different from their behavior by bending, which is considered to be unsafe mode of failure. The failure of beams due to shear is usually sudden without sufficient advanced warning, and the diagonal cracks that develop due to excess shear forces are considerably wider than the flexural cracks. High strength concrete is a more brittle, and the cracks will propagate more extensively than in normal strength concrete. In this study, two types of shear reinforcement are used, traditional stirrups and swimmer bars. Swimmer bar system is defined as inclined bars, with its both ends bent horizontally for a short distance and welded to both top and bottom flexural steel reinforcement. Six beams are tested, and the main variables investigated were spacing of single swimmer bars in addition to traditional stirrups.*

Test result showed that swimmer bar system showed 35.81% higher ultimate shear carrying capacity than the beam with normal shear reinforcement. The percentage reduction in shear capacity of the beam with increase in spacing of shear reinforcement is lesser in the case of beam with single swimmer as shear reinforcement compared to normal stirrups. It was also found that swimmer bars improve the stiffness of the beams up to 1.07%. The failure crack patterns of the beams with single swimmer bars as shear reinforcement and beams with vertical stirrups as shear reinforcement are similar and for all tested beams, shear crack angle varied between 30 to 45 degrees.

The objective of this study is to evaluate the effect of using single swimmer bars instead of traditional stirrups on improvement of shear performance in high strength concrete beams.

***Key Words*: Swimmer bars, Stirrups, shear, Crack pattern, Deflection**

1. INTRODUCTION

Reinforced concrete beams are important structural elements; it will perform effectively during its service life only when there is sufficient safety margin against bending and shear forces. At the ultimate limit state, the combined effects of bending and shear may exceed the resistance capacity of the beam causing tensile cracks. The shear failure is usually sudden, without sufficient advanced warning.

Shear failures in beams are caused by the diagonal tension crack which starts from the support and propagate towards point of loading. In high shear region near the supports, beams fail immediately upon formation of critical cracks. Whenever the value of actual shear stress exceeds the permissible shear stress of the concrete used, the shear reinforcement must be provided. Shear reinforcement is used to resist shear force in beams, and to increase beam ductility and subsequently the likelihood of sudden failure will be reduced.

In concrete building construction, stirrups are most commonly used as shear reinforcement, for their simplicity in fabrication and installation. Stirrups are spaced closely at the high shear region. Congestion near the support of the reinforced concrete beams due to the presence of the closely spaced stirrups increases the cost and time required for installation. Bent up bars are also used as shear reinforcement along with the normal stirrups in ordered to resist the applied shear force. In beams some of the tensile reinforcements were bent up in high shear region to form the inclined legs to resist the shear force. The use of bent-up bars is not preferred now a days .High-strength concrete is a more brittle material compared to normal-strength concrete. This means that cracks will propagate more extensively in high-strength concrete.

In this study, several reinforced concrete beams were tested using single swimmer bars as shear reinforcement system. Beams with normal stirrups as shear reinforcement were also tested in order to study the effectiveness of the single swimmer bar system. These beams are used as reference beams. In this investigation, all of the beams are designed to fail in shear, so adequate amount of tension reinforcement were provided to give sufficient bending moment strength. This study aims at investigating the effect of spacing single

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swimmer bars on the shear behavior high strength concrete beams. The main advantages of this type of shear reinforcement system are: flexibility, simplicity, efficiency, and speed of construction.

1.1 Swimmer Bars

A swimmer bar is a small inclined bar, with its both ends bent horizontally for a short distance, welded at the top and the bottom of the main reinforcement. There are three major standard shapes; single swimmers, rectangular shape, and rectangular shape with cross bracings. Single swimmer bars (fig.1) are the most effective form of swimmer bar system and several additions to these standard shapes can be explored, such as rectangular swimmer bars with horizontal stiffener bars, dividing the large rectangle horizontally and vertically into smaller rectangles. Additional swimmer bars can also be used. By combining two or more swimmer bar systems, the large rectangular shape will be divided vertically into two rectangles. Addition of two more swimmer bars will divide the large rectangle vertically into four small rectangles. Single swimmer bar systems are used in order to improve the shear performance of the reinforced concrete beams, reduce the amount of cracks, width of cracks, length of cracks and overall beam deflection.

Fig -1: Single Swimmer Bars

2. I S CODE PROVISION FOR SHEAR DESIGN

According to IS Code, the design of beams for shear is to be based on the following relation:

$$Vu = Vc + Vs$$

$$Vu=Tc*b*d+(.87*Fy*Asv*d/Sv)$$

Where Vu is the total shear force applied at a given section of the beam due to factored loads, Vc is the shear capacity of the concrete and Vs is the shear capacity of shear reinforcements

$$Vu =(.87*Fy*Asv*d/Sv)$$

And for inclined bars (swimmer bars designed as inclined bars)

$$Vu =(.87*Fy*Asv*d/Sv) (Sin\infty+\cos \infty)$$

Where Asv is the area of one stirrup, ∞ is the angle of the stirrup with the horizontal, and Sv is the stirrup spacing. The nominal shear strength contribution of the concrete

3. EXPERIMENTAL PROGRAMME

In order to investigate the above mentioned objectives, an experimental program was carried out to test six simply supported reinforced concrete beams. Three beams were made of normal stirrups as shear reinforcement and the remaining three were made of single swimmer bars as shear reinforcement. Detailed description of the specimens, the material properties, mix proportions, test set-up, test procedure, and measurements were presented in this section.

3.1 Test Specimens

The details of the tested beams are shown in Table 1. All beams were 250 mm height, 250 mm width, and overall length 2022.5 mm.

Table -1: Test specimen details

Specimen	Main Reinforcement (Bottom)	Shear reinforcement	
		Stirrups	Swimmer bar
BNS-8-300	3 -20 dia	8@300c/c	
BNS-8-250	3 -20 dia	8@250c/c	
BNS-8-200	3 -20 dia	8@200c/c	
BSW-8-300	3 -20 dia		8@300c/c
BSW-8-250	3 -20 dia		8@250c/c
BSW-8-200	3 -20 dia		8@200c/c

- BNS – Beam with normal stirrups as shear reinforcement
- BSW - Beam with single swimmer bars as shear reinforcement

The shear span to depth ratio (a/d) was constant for all beams and equal to 2.7. The variables in these beams are the shear reinforcement systems and spacing of shear reinforcement

Cubes of size 150 mm which had been cast along with the beams were tested on the same day on which the respective beams were tested (i.e. 28 days) to ascertain concrete compressive strength used in both normal strength R.C. beams and high strength R.C. beams. The cubes test was carried out in a compression testing machine of 2500 kN capacity.

3.2 Materials Properties

The cement used throughout this work was Ordinary Portland Cement (OPC) for all test specimens. Cement is tested and the test results satisfied IS Code of Practice requirements, the test results of used cement are given in Table 2. 20mm nominal maximum size used as coarse aggregate and Fe 500 garde steel is used for reinforcement and the fine aggregate was natural sand free from impurities

Table -2: Properties of cement

Sl no	Tests	Results
1	Initial setting time	38 min
2	Final setting time	5h 25min
3	3 days compressive strength	47.6N/mm^2
4	7 days compressive strength	73.33N/mm^2

Table -3: Mix proportions for high strength concrete

Sl no	Description	Result
1	Cement content (kg/m3)	572.49
2	Fine aggregate (kg/m3)	498.07
3	Coarse aggregate (kg/m3)	1219.42
4	Water content (kg/m3)	145.26
5	Silica fume (kg/m3)	40.07
6	W/(C +S.F.) ratio	0.25
7	Slump value (cm)	3

3.3 Test Procedure

Test setup is shown in Fig.2. All beams are tested to failure under two-point symmetric top loading using 5000 kN capacity testing machine. Vertical deflections at mid-span are monitored by LVDTs. Surfaces of the beam are painted in a white color with the objective of the observation of crack development during testing. At each load stage, the deflection readings are recorded and the cracks are marked on the surface of the beam.

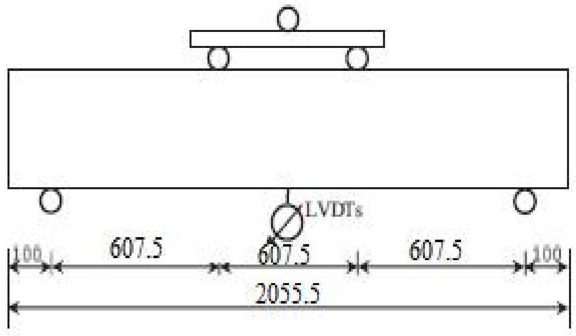

Fig -2: Two point loading

4. TEST RESULTS AND DISCUSSION

4.1 Load–deflection at mid span

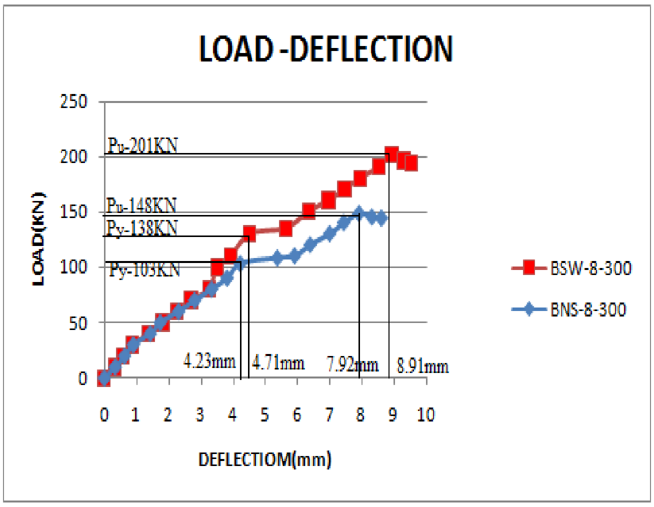

Fig -3: Load-Deflection curve of Bsw-8-300 and BNS-8-300

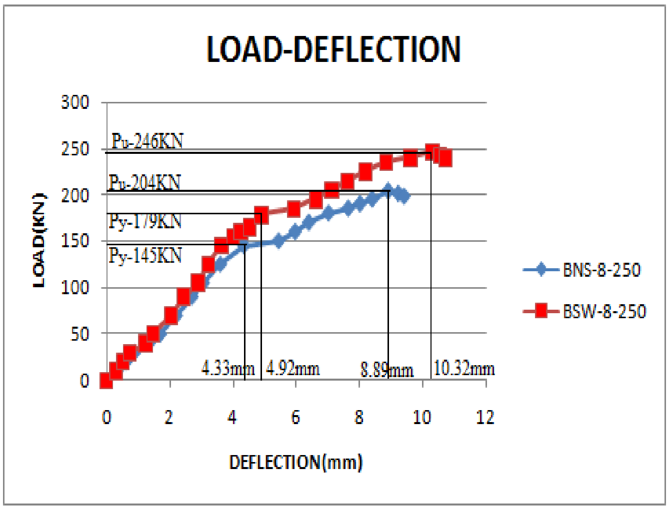

Fig -4: Load-Deflection curve of Bsw-8-250 and BNS-8-250

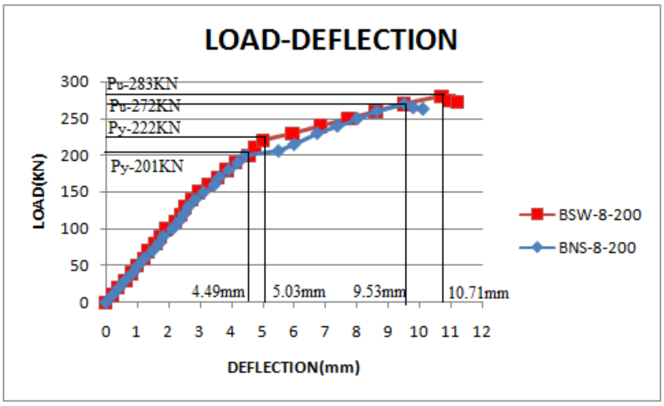

Fig -5: Load-Deflection curve of Bsw-8-200 and BNS-8-200

4.2 Ultimate Shear Capacity

The values of shear capacity for all test specimens are listed in Table 4. From table, one can notice that the use of single swimmer bars improve the shear capacity

Table 4: shear capacity

Sl no	Specimen	Shear Capacity(KN)	%Increase
1	BNS-8-300	148	35.81
2	BNS-8-250	201	
3	BNS-8-200	204	20.5
4	BSW-8-300	246	
5	BSW-8-250	272	4
6	BSW-8-200	283	

The ultimate shear capacity of beams with single swimmer bars as shear reinforcement was found to decrease from 283KN to 246KN and then to 201KN with the increase in spacing of single swimmer bars from 200mm to 250mm and then to 300mm respectively. Hence it is determined that shear capacity of beam with single swimmer bars as shear reinforcement decreases with increase in spacing of shear reinforcement

4.3 Effect of Spacing of Single Swimmer Bars on Shear Behavior

The rate of decrease in ultimate shear capacity of beam reinforced with normal stirrups is 25% when the spacing increases from 200mm to 250mm and the spacing increases from 250mm to 300mm the rate of decrease is 27.45% .But in the case of beam with swimmer bars as shear reinforcement the rate of decrease in shear capacity is only 13.07% when the spacing increases from 200mm to 250mm and when the spacing increased from 250mm to 300mm the rate of decrease in shear capacity is 18.29%.

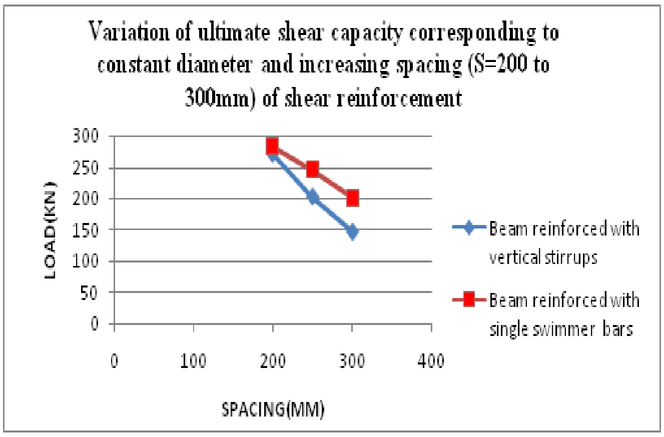

Fig -6: Ultimate shear capacity vs Spacing of shear reinforcement

It is found that in both cases shear capacity decreases with increase in spacing of shear reinforcement. The rate of decrease in shear capacity with spacing is lower for single swimmer bars compared with vertical stirrups. To achieve a particular required shear capacity, swimmer bars may be provided at a larger spacing than normal stirrups, imparting economy in design

4.4 Crack Pattern

Crack pattern of specimens at failure are shown in figure 7-8 respectively. The specimens are designed to fails in shear and specimens remains elastic until first crack take place. Inclined web shear crack formed between the loading point and support point. The failure crack patterns of the beams with single swimmer bars as shear reinforcement and beams with vertical stirrups as shear reinforcement are similar. All beams failed in diagonal tension mode of shear failure. For all tested beams, primary shear crack angle varied between 30 to 45 degrees regardless of diameter and type of shear reinforcement

Fig -5: Crack pattern of BNS-8-300

Fig -7: Crack pattern of BNS-8-250

Fig -8: Crack pattern of BNS-8-200

Fig -9: Crack pattern of BSW-8-300

Fig -10: Crack pattern of BSW-8-250

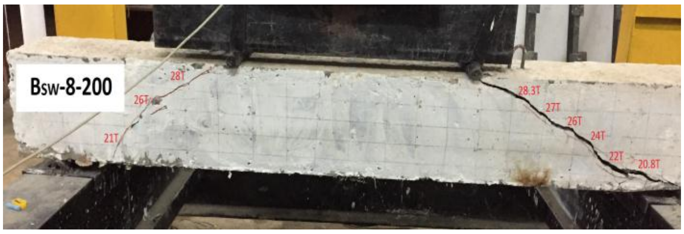

Fig -11: Crack pattern of BSW-8-200

4.5 Comparison of Ductility

Ductility ratio is defined as the displacement at ultimate load to displacement at yield point.

Table 5: Ductility factor

Sl no	Beam	Ultimate deflection(δu)	Deflection at yield point(δy)	Ductility factor (δu/δy)	Percentage increase
1	BNS-8-300	7.92mm	4.23mm	1.87	1.07%
2	BSW-8-300	8.91mm	4.71mm	1.89	
3	BNS-8-250	8.89mm	4.33mm	2.05	1.05%
4	BSW-8-250	10.32mm	4.92mm	2.09	
5	BNS-8-200	9.53mm	4.49mm	2.12	0.71%
6	BSW-8-200	10.71mm	5.03mm	2.13	

5. CONCLUSIONS

- Beam with single swimmer bars as shear reinforcement showed 35.81% higher ultimate load carrying capacity than the beam with normal stirrups as shear reinforcement
- The ultimate shear carrying capacity of beam with single swimmer bars a shear reinforcement was found to decrease from 283KN to 246KN with the increase spacing from 200mm to 250mm
- The ultimate shear carrying capacity of beam with single swimmer bars a shear reinforcement was found to decrease from 246KN to 201KN with the increase spacing from 250mm to 300mm
- The ultimate shear carrying capacity decreases with increase in spacing of single swimmer bars
- The maximum rate of decrease in ultimate shear carrying capacity with increase in spacing of single swimmer bars, for the beam with single swimmer bars(18.29%) is lesser than beam with vertical stirrups(27.45%) as shear reinforcement
- The failure crack patterns of the beams with single swimmer bars as shear reinforcement and beams with vertical stirrups as shear reinforcement are similar

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