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The Use of Swimmer Bars as Shear Reinforcement in RC Deep Beams

Revathy S[1], Anup Joy[2]
[1,2]*(Department of Civil Engineering, Sree Buddha College of Engineering, Kerala, India)*

Abstract : *Beams with shear span to depth ratio (a/d) less than or equal to 2 are considered as deep beams. They have wide applications in pile caps, water tanks, shear walls, corbels etc. Their strength is controlled by shear. Shear failure progress rapidly and hence an undesirable mode of failure. The shear capacity of RC Deep beams are influenced by the shear span to depth ratio and the orientation of stirrups. To enhance the shear strength, alternative shear reinforcement patterns are adopted. Swimmer bars are small inclined bars, whose both ends are bent horizontally and welded to both top and bottom flexural reinforcement. Swimmer bars forming a plane crack interceptor system is effective in carrying shear. In this paper, an experimental investigation on the effectiveness of using swimmer bars as shear reinforcement in RC Deep beams is compared with that of vertical stirrups. Flexural strength is considered for the investigation. Crack pattern, load deflection behavior and failure modes are compared in this study.*
Keywords: *pure bending, shear failure, shear span, swimmer bars*

I. Introduction

Reinforced concrete beams are designed with adequate safety margins against bending and shear. The flexural members having shear span to depth ratio (a/d) less than 2 are considered as deep beams. RC deep beams are having wide applications in water tanks, bunkers, silos, shear walls, raft foundation, pile caps, corbels etc. These members are having greater shear strength due to the arch action between concrete and reinforcement forming a strut and tie model. The internal arch action transfers the load directly to a support through concrete struts. The reinforcement acts as a tie and, hence RC beams are analogous to steel trusses. The likely failure behavior of deep beams is due to shear, which is sudden and difficult to predict. Due to its complex shear behavior, RC deep beams are considered as non flexural members. To enhance the shear strength, alternative shear reinforcement patterns are to be adopted.

Shear reinforcement is usually provided in the form of stirrups or inclined bent-up bars. A combination of both types is also used. Lateral and inclined stirrups provided in the shear span enhance the shear strength more effectively than ordinary vertical stirrups. Swimmer bar system is an alternative shear reinforcement system, in which small inclined bars bent horizontally at both ends are used. These bends are either welded or bolted to the top and bottom longitudinal reinforcements. This can be provided in many ways like a single swimmer alone, two swimmers forming a rectangular shaped swimmer, rectangular shaped swimmer with cross bracings etc.

In this paper, the comparative study on the flexural strength, crack pattern and load-deflection charecteristics of deep beams reinforced with different patterns of swimmer bars and vertical stirrups is done.

II. Significance Of The Work

From the literature review conducted, it is understood that shear reinforcement in the form of vertical stirrups ensures ductile behavior of deep beams. Due to its closely spaced arrangement, congestion occurred at supports. Bent-up bars are also not preferred nowadays due to difficulties in construction. When horizontal or inclined stirrups are provided, it enhances the flexural strength. But the increase in ultimate load carrying capacity is very small when compared to the control beam. Hence alternatives for considerable increase in the flexural strength need to be explored. Also the effectiveness of swimmer bar system is experimented for ordinary beams. Behavior of deep beams with swimmer bars as shear reinforcement is unknown.

The methodology of the work is given below:

i. Selection of concrete grade M30.
ii. Mix design of M30 grade concrete.
iii. Casting of RC deep beams with different reinforcement patterns.
iv. Flexural testing of these beams under two point loading using 100T loading frame.

III. Preliminary Investigation Of Materials

Portland Pozzolana Cement (PPC), confirming to IS 12269 was used for the experimental work. Various laboratory tests like fineness, initial and final setting times, standard consistency etc were conducted on cement. The results are tabulated in TABLE.1

Table.1 Test Results Of Cement

TEST CONDUCTED	RESULT
Fineness, %	2.3
Standard consistency, %	32
Initial setting time, min	110
Final setting time, min	320
3 day compressive strength	23.84
7 day compressive strength	36.71
28 day compressive strength	46.62

M sand was used as the fine aggregate. Laboratory tests were conducted to determine its physical properties as per IS 2386 (Part III). 20 mm sized coarse aggregates were used in the present study. Various laboratory tests were conducted on coarse aggregates to determine the different physical properties as per IS 2386. Both the aggregates were tested for their gradation. The test results are tabulated in Table.2. The mix design is given in TABLE.3.

Table.2 Test Results Of Aggregates

TEST CONDUCTED	RESULT
Specific gravity of FA	2.63
Specific gravity of CA	2.65
Fineness modulus of FA	2.959
Specific gravity of CA	4.833
Water absorption (%) of FA	1.43
Water absorption (%) of CA	0.25

Table.3 M30 Mix Proportioning

Cement (Kg/m^3)	405
Fine aggregate (Kg/m^3)	638
Coarse aggregate (Kg/m^3)	1184
Water (litres/m^3)	159
Water cement ratio	0.39
Mix ratio	1:1.57:2.92

The various tests conducted on hardened concrete were compressive strength, split tensile strength, modulus of elasticity and flexural strength. The tests were conducted as per the specifications of IS 456:2000 and IS 516:1959. The results are shown in TABLE.4.

Table 4 Test Results Of Hardened Concrete

TEST CONDUCTED	RESULT (N/mm^2)
Compressive strength of concrete cube	36
Compressive strength of concrete cylinder	29
Splitting tensile strength of concrete cylinder	4.1
Flexural strength of PCC beam	4.2

IV. Experimental Investigation Of Deep Beams

4.1 Experimental Procedure

A total of 12 specimens were casted and tested. All the specimens had dimensions of 200mm x 200mm x 700mm with an effective span of 600mm. The beams were provided with same longitudinal reinforcement of 2 no of 12 mm dia bars at tension region and 2 hanger bars of 12 mm dia at top. Four different shear reinforcement patterns were tested. Three beams were casted for testing each pattern.

The beam was divided into three zones of 200 mm span. The middle span was considered to be undergoing pure bending under two point loading. Hence, this span is kept free of shear reinforcement. The control beam had vertical stirrups at both the shear spans. Specimens with single swimmer, rectangular shaped swimmer and rectangular shaped swimmer having cross bracings were the other patterns tested. The details of the specimens used are given in TABLE.5.

Table.5 Details Of Specimens

BEAM	a/d	REINFORCEMENT PATTERN USED
CB	1.15	Vertical stirrups at shear span at 100 mm spacing
SSB	1.15	4 no of single swimmer at shear span at 50 mm spacing
RSB	1.15	2 no of rectangle shaped swimmer at shear span at 100 mm spacing
RSXB	1.15	2 no of rectangle shaped swimmer with cross bracings at shear span at 100 mm spacing

Fig.1. Renforcement of Beam SSB

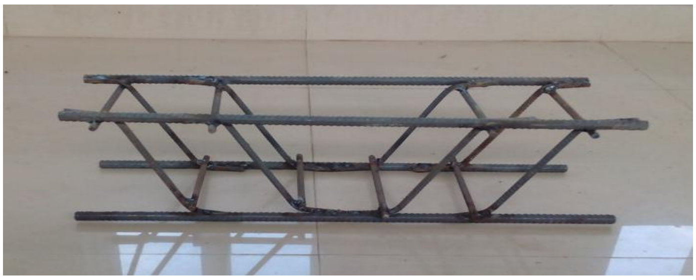

Fig.2. Reinforcement of Beam RSB

Fig.3. Reinforcement of Beam RSXB

The prepared mix was poured in the mould in three layers and well compacted. The de-molded specimens were left for curing and tested after 28 days.

4.2 Test Procedure

The specimens were tested using a 100t loading frame under two point loading. LVDT was used to determine the deflection at the center of the beam. Prior to testing, the positions of two point loads, supports and mid-point were deflection is to be noted were marked.

After marking the positions, the specimen was placed on a 100 t UTM. The bed of the testing machine was provided with two rollers of 100 mm diameter on which the specimen was supported. These were positioned at distance of 600 mm centre to centre making the effective span of the deep beam to be tested. The load was applied through two rollers of 50 mm diameter mounted at the third points of supporting span, and was spaced at 200 mm. The load was applied equally between the two loading rollers with the help of another roller of 50 mm diameter.

Fig.4. Test Setup

To study the deep beam behavior, the shear span to depth ratio was kept less than 2 for all the specimens. The load was increased uniformly and corresponding change in deflection were noted. Cracking behavior was carefully observed. The specimens were loaded up to the failure loads.

V. Experimental Results

5.1. Ultimate Load

The flexural strength of the specimens was inferred from its failure load. The only specimen which showed a decrease in failure load was RSXB which is having rectangular swimmer bars with cross bracings as shear reinforcement. The failure load of the beam was decreased by 8.33% in this case. Maximum load was carried when single swimmers were provided as shear reinforcement (SSB). The ultimate load increases by around 22% in this case. Beam RSB also showed an increase in failure load around 20%. The comparison of ultimate load of all specimens is shown in TABLE 6.

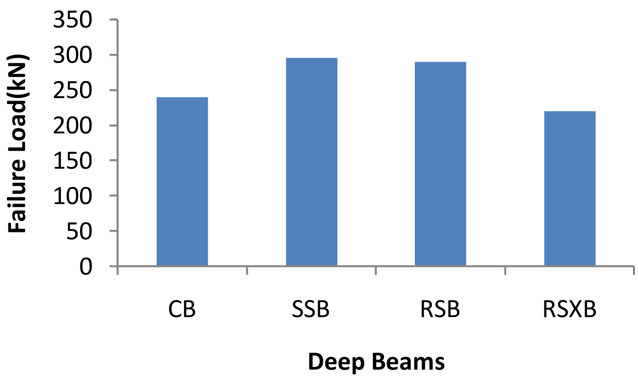

Fig.5. Comparison of Ultimate Loads

Table.6 Comparison Of Flexural Strengths Of Different Specimens

DESIGNATION OF THE SPECIMEN	FLEXURAL STRENGTH (kN)	%INCREASE IN FLEXURAL STRENGTH
CB	240	0
SSB	295	22.916
RSB	290	20.83
RSXB	220	-8.33

5.2. Crack Pattern

The failure load of the control beam was found to be around 240 kN. For this beam, some mid span bending cracks were formed at the early stages of loading. The first shear crack was formed in the lower part of the shear span. Failure occurred due to the propagation of a shear crack from the support towards the loading point. The crack pattern of CB is shown in Fig.6.

Fig.6. Crack Pattern of CB

In the case of beam reinforced with single swimmers, no cracks were formed at the early stages of loading. Due to further loading a diagonal shear crack originated from the support. As the loading was increased, the crack widened. This crack propagated from the support towards the loading point causing failure. The crack pattern of SSB is shown in Fig.7. Similar crack pattern was observed when rectangle shaped swimmer bars were provided. When the load was increasing, diagonal shear cracks propagated from the supports towards the compression zone. The diagonal shear cracks occurred in both the shear spans. Crack propagation of RSB is shown in Fig.8. When rectangle swimmers were provided with cross bracings, the beam failed at a load of 220kN. The diagonal crack formed at one of the support point widens upon further loading causing spalling of concrete in the along the line of propagation of cracks. The failure pattern of RSXB is shown in Fig.9.

Fig.7. Crack Pattern of SSB

Fig.8. Crack Pattern of RSB

Fig.9. Crack Pattern of RSXB

5.3. Load Vs Deflection Graph

The corresponding deflection for each load increment was noted and the load deflection graph was plotted. The consolidated Load Vs Deflection graph of the four types of RC deep beam patterns is shown in Fig.10.

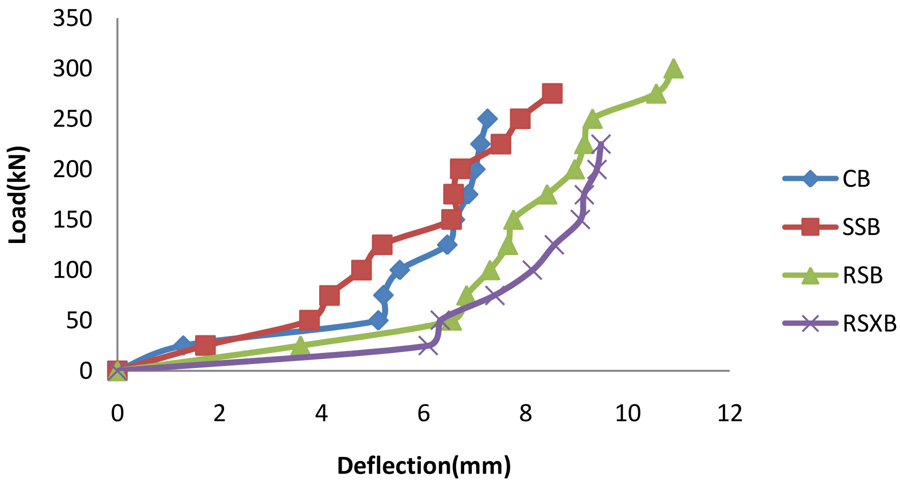

Fig.10. Load Vs Deflection Graph

5.4 Deflection

There was no considerable change in deflection observed at the initial stages of loading. The beams then deflected upon load increment. The maximum deflection observed for each specimen is plotted in the Fig.11.

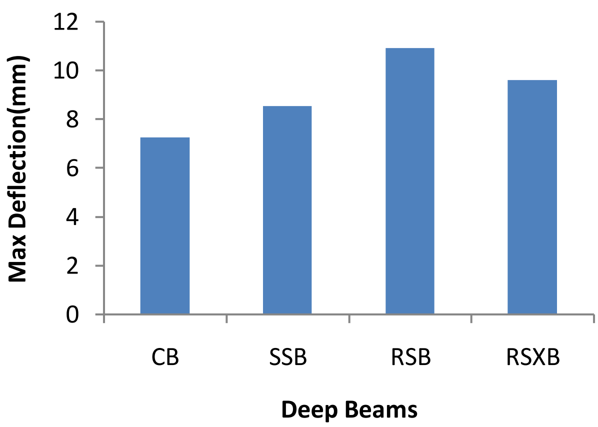

Fig.11. Comparison of Maximum Deflection

VI. Evaluation And Discussion

6.1. Crack Pattern

From the crack pattern of all the specimens, it is observed that all the beams failed by shear. Diagonal shear cracking leads to failure of the beams in all the cases.

6.2. Ultimate Load Carrying Capacity

The ultimate load value is increased for all the cases except for the beam RSXB. Maximum increase in flexural strength is observed for the beam SSB.

6.3. Load Deflection Relationship

From Fig.10, the load deflection relationship of CB and SSB are similar. Similar behaviour is observed for beams RSB and RSXB.

6.4. Deflection

Each specimens shows different behaviour of deflection due to the different shear reinforcements provided. CB shows higher resistance to deflection. Maximum deflection was observed for RSB. Hence it has least resistance to deflection. SSB is stiffer than RSXB but less stiff than CB.

VII. Conclusion

The main objective of this study was to find out the best shear reinforcement pattern for RC Deep beams. Flexural strength was considered for this experimental investigation. The following conclusions were drawn from the study

- a/d ratio less than 2 ensures deep beam behaviour.
- New swimmer bar system offered better performance than vertical stirrups in terms of flexural strength.
- Shear reinforcement in the form of vertical stirrups form more stiffer pattern than new swimmer bar system.
- Single swimmer bars showed more strength than rectangular shaped swimmer system.
- Flexural strength of deep beams increased around 22% when single swimmer bars are provided as shear reinforcement.
- Rectangular shaped swimmers are less resistant to deflection.
- Shear reinforcement in the form of single swimmers is the best alternative in terms of strength and stiffness.

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Authors Profile

Revathy S received B.Tech in Civil Engineering from Sree Buddha College of Engineering for Women in 2013. She is currently pursuing M.Tech in Structural Engineering from Sree Buddha College of Engineering.
Email: revathyssanjeev@gmail.com

Anup Joy received B.Tech in Civil Engineering from TKM College of Engineering in 2007 and M.Tech in Structural Engineering from NIT in 2012. He has been working as Design Engineer in Larson & Toubro Limited ECC Division, Chennai for over 2 years before joining Sree Buddha College of Engineering as Assistant Professor.