Effect of Stirrup Ratio on the Shear Behavior of 1/2 Scale RC Beams

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***Abstract*—The shear behaviour of reinforced concrete beams is playing important role for reinforced concrete structures. For this reason, reinforced concrete beams are needed to be tested under various loads. The shear capacity of reinforced concrete beams with low shear strength can be increased by reduce the spacing of stirrup. Therefore, four 1/2 scale reinforced concrete beams were tested under four-point loading system and stirrup effect was investigated in this study. The shear capacity of test specimens were investigated after the experiments. In addition to this, the experimental results, deformation and cracking patterns were evaluated, interpreted and suggestions of the design recommendations were proposed.**

***Index Terms*— reinforced concrete beams, stirrup effect, simply support, experimental study, cracking patterns.**

I. Introduction

The shear behaviour of reinforced concrete beams is playing important role for reinforced concrete structures. For this reason, reinforced concrete beams are needed to be tested under various loads. The shear capacity of reinforced concrete beams with low shear strength can be increased by reduce the spacing of stirrup.

Beams, being an important part of structure support system, transfer loads from structural elements like floor and loads directly coming upon them to columns. Fracture mechanism that may occur on beams against loads affecting structures is quite important in terms of building behaviour. That's why, beam elements should be tested under various loads. Many studies have been made about beams in literature. Beam behaviour under various loads has been tried to be identified [1]-[9].

Four 1/2 scale specimens were tested to be able to identify real beam behaviour within the scope of this study. Test elements were tested on 4-point loading mechanism. Under the experimental studies, one test element without stirrup B-1, one with ϕ6/200 mm stirrup B-2, one with ϕ6/100 mm stirrup B-3, and one with ϕ6/50 mm stirrup B-4 were tested to research about the stirrup effect on beams. Load-displacement graphs about test elements tested were drawn and interpreted. Interpretations were made about beam behaviour by examining fractures occurring during tests.

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II. Material and Method

Within the scope of this study, 4 full-scale beam specimens were tested on 4-point loading mechanism. Experimental studies were conducted in Selcuk University Earthquake Laboratory. The loading mechanism designed is shown in Fig. 1. Loading is done with the help of hydraulic cylinder fixed to the steel profiles. A load cell was put at the end of hydraulic cylinder in order to identify loads given to the beam. Load cell was fixed to a loading beam made of steel profiles. Loading points were identified by putting miller on specific points of the beam. The length of the loading point/effective depth ratio was considered as (a/d)=3 while identifying loading points.

Figure 1. Test setup.

Test elements were produced in the same size and properties. The only difference between them is the stirrup ratio. No stirrup B-1 was found in the first test element, while stirrup was found in B-2 at 200 mm, in B-3 at 100 mm and in B-4 at 50 mm intervals. Test elements were designed as 1/2 scale. Test elements were produced 2500 mm in length. The distance between beam support points was 2000 mm. Beam cross-section was designed as 125-250 mm. 3ϕ8 mm longitudinal reinforcement was used on beams. There is no other reinforcement on the beam with no stirrup (B-1). In the other test element, 3ϕ8 mm longitudinal reinforcement, 2ϕ8 mm montage reinforcement and ϕ6/200 mm stirrup were found (B-2). In B-3, 3ϕ8 mm longitudinal reinforcement, 2ϕ8 mm montage reinforcement and

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ϕ6/100 mm stirrup were found and in the last test element (B-4), 3ϕ8 mm longitudinal reinforcement, 2ϕ8 mm montage reinforcement and ϕ6/50 mm stirrup were found. Size and reinforcement properties of test elements are shown in Fig. 2.

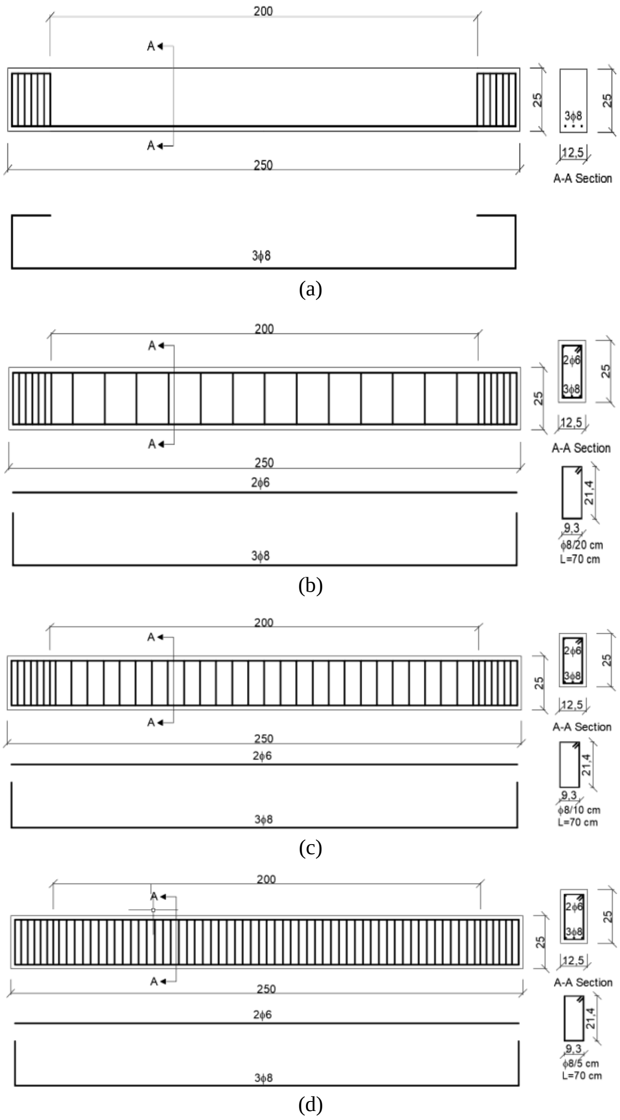

Figure 2. Properties of specimens (a) B-1 (b) B-2 (c) B-3 (d) B-4

The concrete class was chosen as C30 and reinforcement class as S420. Properties of the materials used in test elements are shown in Table I and Table II.

TABLE I. PROPERTIES OF REINFORCED CONCRETE

Reinforced Concrete				
No	Cube Strength (MPa)	Average Cube Strength (MPa)	Cylinder Strength (MPa)	Average Cylinder Strength (MPa)
1	38.53	36.10	30.82	28.88
2	33.78		27.02	
3	36.00		28.80	

TABLE II. PROPERTIES OF STEEL

Steel						
	No	Yield Strength (MPa)	Average Yield Strength (MPa)	Tensile Strength (MPa)	Average Tensile Strength (MPa)	The Place of Use
ϕ6	1	320.9	337.3	552.4	483.4	Stirrup
	2	351.4		402.0		
	3	339.7		495.8		
ϕ8	1	335.2	318.9	439.1	428,3	Montage and Longitudinal Reinforcement
	2	309.3		423.6		
	3	312.3		422.2		

Test elements were produced in a Selcuk University Earthquake Laboratory. Reinforcements were prepared according to beam properties. Reinforcements prepared were put in steel molds in the laboratory. Thereafter, they were molded into concrete molds ordered from the concrete plants and test elements were created. Test elements need to stay in laboratories for 28 days to provide prescribed strength. Hence, the tests were done after this period. Production process is shown in Fig. 3.

Figure 3. Production process.

III. RESULTS AND DISCUSSION

Experimental studies within the scope of this study were made in Selcuk University Earthquake Laboratory. Tests were subjected to 4 point bending test. Tests started with load control and continued with displacement control after nominal current value. 5 kN load increments and 5 mm displacement increments were experimented in the tests.

The first crack in the B-1 test element occurred at about 25 kN load value. Yield in the test element occurred at 48 kN load value and 13.84 mm displacement value. Maximum load was measured as 50 kN for this test element. Mid-point displacement at maximum load was measured as 20.00 mm. Shear fracture occurred after maximum load and the amount of load was decreased suddenly. Load-displacement graph of the test element is shown in Fig. 4. Fractures on the test element that occurred at the end of the test are shown in Fig. 5.

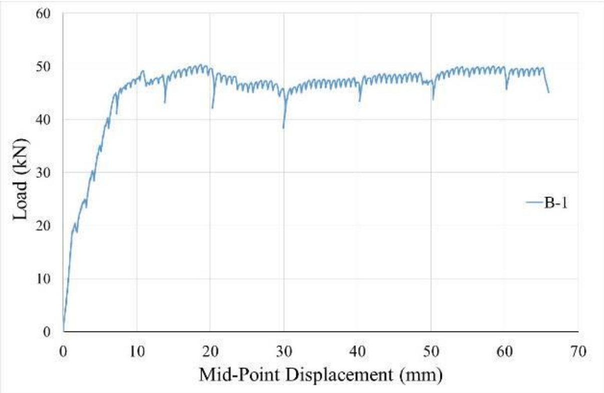

Figure 4. Load-Mid Point Deflection Curve (B-1)

Figure 5. Fractures in specimen (B-1)

The first crack in the B-2 test element occurred at about 25 kN load value. Yield in the test element occurred at 50 kN load value and 11.60 mm displacement value. Maximum load was measured as 55 kN for this test element. Mid-point displacement at maximum load was measured as 180.00 mm. The test was ended after reaching the maximum load because of reaching the maximum capacity of the loading mechanism. Load-displacement graph of the test element is shown in Fig. 6. Fractures on the test element that occurred at the end of the test are shown in Fig. 7.

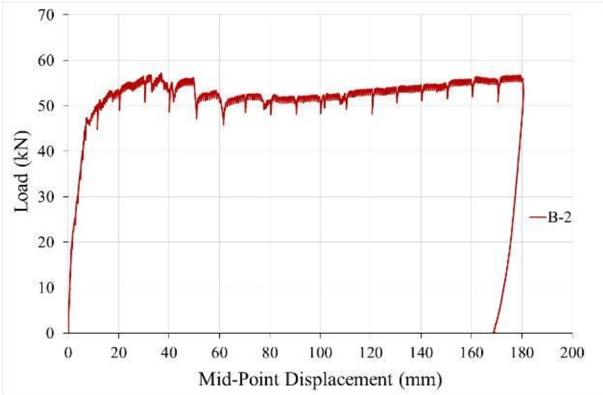

Figure 6. Load-Mid Point Deflection Curve (B-2)

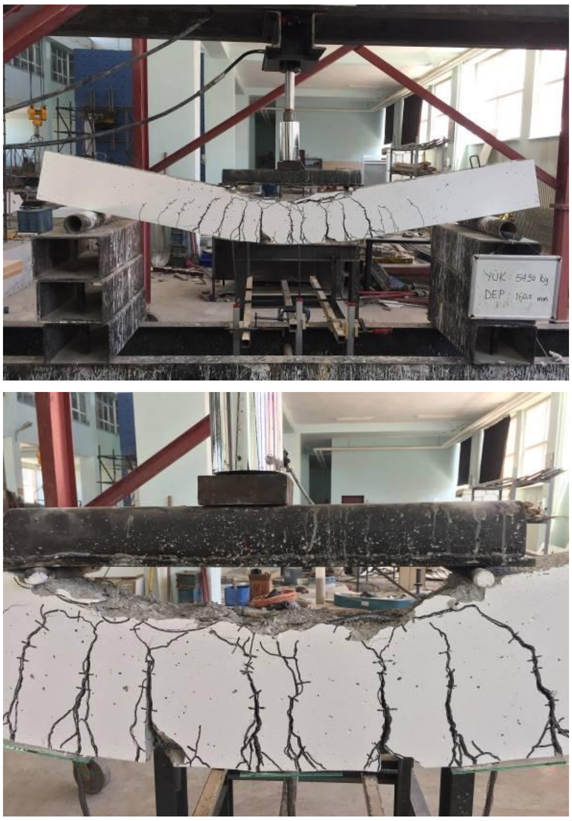

Figure 7. Fractures in specimen (B-2)

The first crack in the B-3 test element occurred at about 20 kN load value. Yield in the test element occurred at 48 kN load value and 10.00 mm displacement value. Maximum load was measured as 53.70 kN for this test element. Mid-point displacement at maximum load was measured as 40.00 mm. The test was ended after reaching the maximum load because of reaching the maximum capacity of the loading mechanism. Load-displacement graph of the test element is shown in Fig. 8.

Fractures on the test element that occurred at the end of the test are shown in Fig. 9.

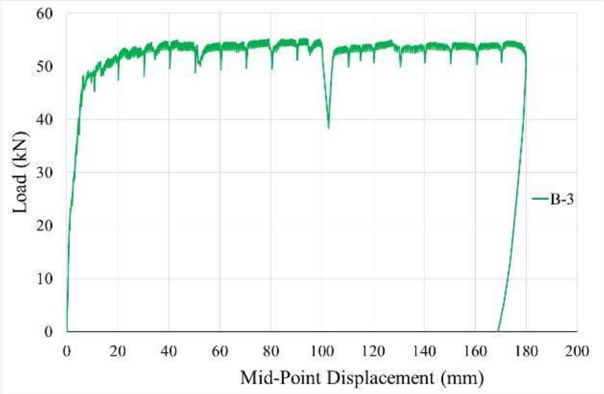

Figure 8. Load-Mid Point Deflection Curve (B-3)

Figure 9. Fractures in specimen (B-3)

The first crack in the B-4 test element occurred at about 20 kN load value. Yield in the test element occurred at 50 kN load value and 7.45 mm displacement value. Maximum load was measured as 54 kN for this test element. Mid-point displacement at maximum load was measured as 50.00 mm. The test was ended after reaching the maximum load because of reaching the maximum capacity of the loading mechanism. Load-displacement graph of the test element is shown in Fig. 10. Fractures on the test element that occurred at the end of the test are shown in Fig. 11.

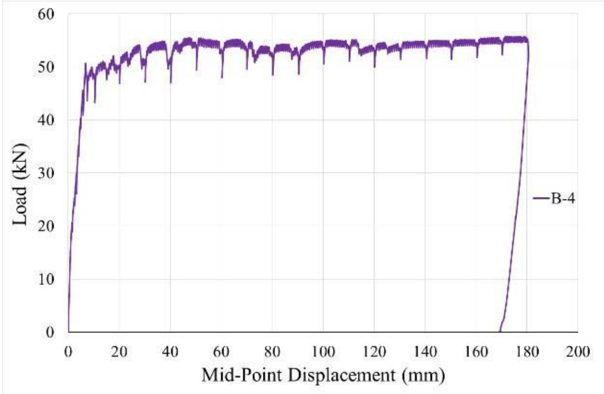

Figure 10. Load-Mid Point Deflection Curve (B-4)

Figure 11. Fractures in specimen (B-4)

Load- displacement curves of all specimens is shown in Fig. 12.

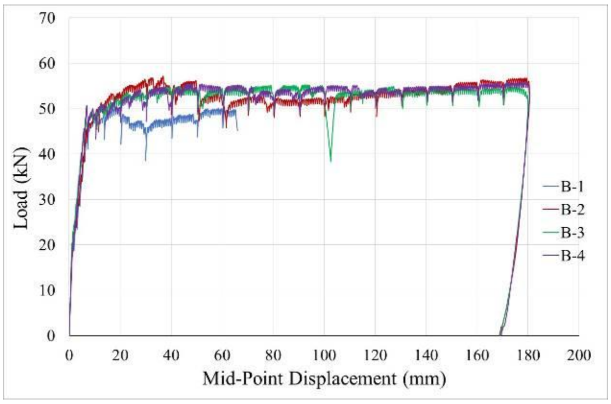

Figure 12. Load-Mid Point Displacements of all specimens.

IV. Conclusion

The purpose of this study was to examine the stirrup effect on 1/2 scale reinforced concrete beams. For this purpose, four test elements produced and tested on 4 point beam bending mechanism. The first crack values and yield point values of B-1, B-2, B-3 and B-4 gave quite similar results. However, B-2, B-3 and B-4 test elements had higher displacement values with compared to B-1 because of the stirrup effect. Shear behaviour was observed in B-1 test element, while bending behaviour was observed in B-2, B-3 and B-4 because of the stirrup effect. B-1 test element reached 50 kN load bearing capacity, B-2 test element reached 55 kN load bearing capacity, B-3 test element reached 53.70 kN load bearing capacity and B-4 test element reached 54 kN load bearing capacity. As a result of these observations, B-2, B-3, B-4 test element seemed to be more ductile with compared to B-1. Cracks on B-3 and B-4 test element spread over the surface of the beam as seen on the photos taken at the end of the test. It can be said that the presence of the stirrup on B-3 and B-4 test element increased the number of cracks and the energy absorption capacity.

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