IMPROVING THE BEHAVIOR OF REINFORCED CONCRETE BEAM WITH VARYING LAP SPLICES LENGTH

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ABSTRACT- The main objective of this paper is to study the behaviour of lap splice of steel reinforcement in tension zones in reinforced concrete beams. An experimental program is conducted on fifteen simply supported concrete beams. The main studied variable is splices length in the splice zone. There is an increase in ductility of beams when transverse reinforcement was used.

Keywords: Development Length, Yield Stress, Ultimate Stress, Splice Length, D1 Dial Gauges.

INTRODUCTION

When reinforcement is spliced together within a concrete beam, it is necessary to overlap the bars long enough for tensile stresses in one bar to be fully transferred to other bars without inducing a pull-out failure in the concrete. Most design codes allow the use of bars with lap splice and specify minimum length of the lap as well as the required transverse reinforcement. According to ACI 318-05, the minimum length of lap for tension lap splices for Class A=1.0 L_d and =1.3 L_d for class B. Stirrup area in excess of that required for shear and torsion is provided along each terminated bar or wire over a distance from the termination point equal to three-fourths the effective depth of member. Most of design codes do not specify a specific shape of transverse reinforcement required for spliced bars.

Ferguson and breen (1965) studied thirty five beams focusing on bar diameter, stirrups and concrete strength. From these tests, they concluded that stirrups increased splice strength, minimum stirrups as much as 20%, heavy stirrups up to 50%. The splitting prior to failure gradually developed over the full splice lengths seemed almost to stabilize with a substantial centre length remaining un-split until a final catastrophic failure occurred.

Jeanty et al. (1988) tested thirteen specimens to the effect of transverse reinforcement on the bond performance among other variables. [1] The main conclusion of this research were that for beams with and without transverse reinforcement crossing the plane of splitting , the top bar factor was found to be 1.22 , which means that the required lap splices length must be increased by 22% for spliced top tension bars . The presence of transverse reinforcement across the plane of potential splitting reduce significantly the require development length for both bottom- cast and top cast bars.

Hamad et al (2006) investigated eighteen full scale beam specimens. In this study, the amounts of transverse reinforcement, bar size and bar type (black or galvanized) were considered. They concluded that in beams without transverse reinforcement in the splice region, surface of black and galvanized bars were relatively clean with limited signs of concrete crushing in the vicinity of very few bar lugs. In beams with transverse reinforcement in the splice region. however , there were relatively more signs of concrete crushing adjacent to the bar lugs indicating the positive role of confinements by transverse reinforcement in mobilizing more bar lugs in the stress transfer mechanism between the steel bars and the surrounding concrete.

OBJECTIVE

A) To study the behaviour of reinforced concrete simply-supported beams with lap splice of tension steel reinforcement zones with different lap splice lengths.

B) To obtain a spliced beam that can achieve at least the same strength and ductility of the same Beam without any splices using transverse reinforcement with different shapes.

EXPERIMENTAL PROGRAM

Fifteen simply supported reinforced concrete beams of dimension 150mm x 250mm x 2500mm were tested in Structural Engineering Lab, Madan Mohan Malaviya Engineering College. All specimens had the same concrete strength and the same longitudinal reinforcement. 2, 10 mm-diameter 500 high strength steel were used in tension reinforcement. Stirrups of 6mm-diameter of 420 grade were used . The rest set up of the studied beam is shown in figure 1. Figure 2 shows reinforcement details of some of the test beams.

Figure 1.Testing Frame

TEST GROUP

The tested beams are divided in to five groups. According to different lap splices length.

1. Group 1 no lap splices
2. Group 2 lap splice of 300mm
3. Group 3 lap splice of 600mm
4. Group 4 lap splice of 900mm
5. Group 5 lap splice of 1200mm

Table1.Details of Tested Beam Specimens

Beam	Average cube strength(N/mm^2)	Splice length
B-1A	30.22	NO LAP
B-1B	30.66	NO LAP
B-1C	30.44	NO LAP
B-2A	30.71	300 mm
B-2B	31.82	300 mm
B-2C	30.46	300 mm
B-3A	31.54	600 mm
B-3B	31.22	600 mm
B-3C	32.22	600 mm
B-4A	30.14	900 mm
B-4B	31.32	900 mm
B-4C	30.57	900 mm
B-5A	32.31	1200 mm
B-5B	31.25	1200 mm
B-5C	31.62	1200 mm

TEST PROCEDURE AND INSTRUMENTATION

Figure 1 shows the details of the test rig. The load applied using a calibrated hydraulic jack of 100 KN capacity. A strong spreader I-beam was used to transfer the vertical load to the tested beam through two concentrated loads 800 mm apart. 5 dial gauges of .01mm accuracy were used to record deflection at the centre of the beams as well as under position of two loads. The load is applied in increment equal to 5KN.

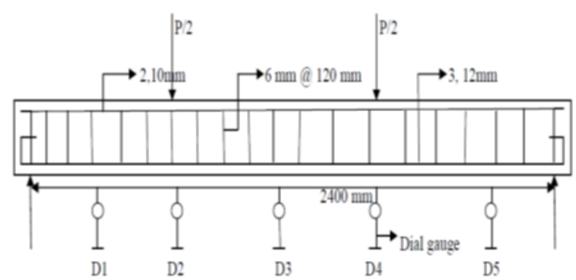

Figure 2.Detail of Tested Specimen

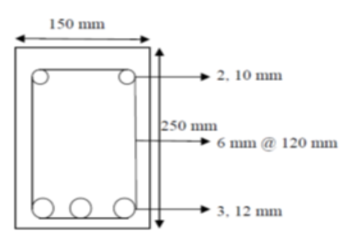

Figure 3. Sections

Figure 4. Spreader I- Beam Used To Perform 2 Point Loading

TEST RESULT AND DISCUSSIONS

The main obtained results are given in table- 1. All group are tested as the control beam group 1 the beam B-1 with no lap flexure test starts as the test progress the readings are taken after every 5 KN , as the control beam is being designed for 44 KN. After 46 kn the hair line cracks are visible first which visible at the bottom near 800 mm and 1600 mm as on when load is on 50 kn the hair line begins in the centre in flexure zone.

For beam B-2 with lap splice length 300mm flexure crack propagated upward to the compression zone at a load 44 KN, a horizontal splitting crack along the lap splice length appeared and a bond failure occurred at a load of 47.5 KN. As shown in figure 5. Bottom fibber cracks of tension zone in beam.

Table 2. Main test results.

BEAM	AVERAGE CUBE STRENGTH N/mm²	ULTIMATE LOAD P_u, KN	DEFLECTION AT YEILD LOAD IN D3 Y_y, mm	DEFLECTION AT ULTIMATE LOAD IN D3 Y_u, mm
B-1A	30.22	82.5	6.54	12.48
B-1B	30.66	79.6	7.13	11.87
B-1C	30.44	81.1	5.08	12.56
B-2A	30.71	47.8	NY	7.24
B-2B	31.82	43.2	NY	6.92
B-2C	30.46	45.8	NY	7.21
B-3A	31.54	58.4	4.86	12.65
B-3B	31.22	62.3	3.26	11.53
B-3C	32.22	60.3	5.12	11.46
B-4A	30.14	73.2	5.04	12.1
B-4B	31.32	71.8	3.06	11.34
B-4C	30.57	72.3	5.12	11.86
B-5A	32.31	67.5	5.85	14.5
B-5B	31.25	69.3	5.10	12.58
B-5C	31.62	71.9	5.56	13.23

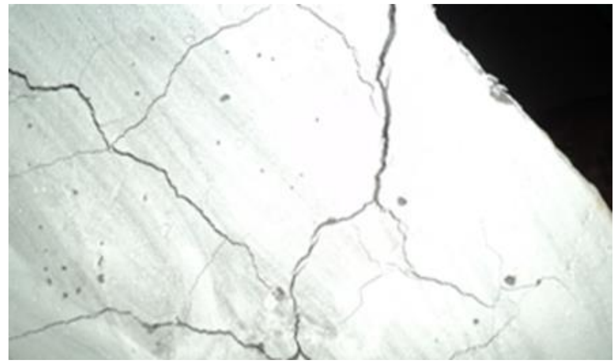

Figure 6. Crack pattern of beam B-2 in centre at bottom layer of tension zone.

For beam B-3 which had lap length equals to L_d that is 600 mm. As the loading on this beam propagates the hair line are start appears at the load of 28 KN and soon after 48 KN hair line cracks converted in to large cracks. Firstly the cracks are visible at the end of splices bars where the overlapping of the bars ended. Means 300 mm away from the centre to its right and left. As shown in figure 6. The cracks propagates and end in compression zone.

Figure 6. Bottom crack pattern of beam B-3

For beam B-4 which had lap length equals to 1.5 L_d shows better behaviour than previous group beam. In these group beams hair line cracks are start from 34 KN and its ultimate failure too is 73 KN which is better than the entire group and its ductility to be better than all groups. Its ultimate load deflection by yield load deflection is 2.4 which are nearly equals to the control beam.

For beam B-5 which had lap length equals to 2 L_d. this beam shows almost same result as previous group except in this beam hair line cracks starts at 39 kN. In this beam crack start from 400 mm and 2000 mm which are near the end point of spliced bars and cracks propagates towards the loading point as shown in figure 7. Below.

Figure 7. Crack propagation shown with black paint B-5.

The relationship between load and mid-span deflection for the tested beams .B-3A, B-4A, B-5A reached an ultimate load of that of the reference beam B-1A. It is clear that beam B-2A, with a lap length of 300 mm did not reach the ultimate load. Figure shows that after cracking B-1A and B-5A shows nearly the same behaviour up to the sudden failure. Beam B-4A shows lower deformation as compared to other lapped beams. More deflection shown in B-3A, B-5A group beams. These results indicate that the use of lap splice length equals to the recommended by the Indian code (600 mm) or greater (900 mm, 1200 mm) increased the maximum deflection at ultimate load. The ratio between the maximum deflection at ultimate load and the deflection at yield load : u/y was 1.91 , 2.6 , 2.4 , 2.48 for beams B-1A , B-3A , B-4A , B-5A respectively . This shows B-4A was most ductile beam.

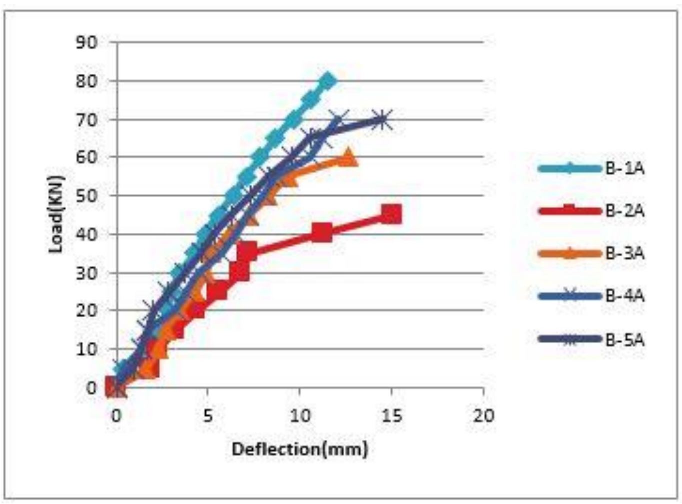

Figure 8. Load and deflection curve

Summary and Conclusion

Fifteen concrete beams were tested to study the effect of lap splice of tension reinforcement with different splice lengths. From the results of the studied beams, the following conclusion were obtained:

1. The use of a lap splice with 100% cut off ratio, with length of 300 mm resulted in much earlier failure then required.
2. As the beam have same transverse reinforcement but if the transverse reinforcement is not there in spliced zone then there will be more severe failure like brittle bond failure can be occurred.
3. All the beams with spliced bars shows large deflection with respect to the no lap beam.
4. The behaviour of a beam without any spliced beam can be achieved in a spliced beam of lap length $2L_d$ and for the economical and nearly achieving the same strength as control beam the value 1.5 L_d can as spliced length.

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