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The Behaviour of Reinforced Concrete Beams with Lap Splices Using Headed Bars

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ABSTRACT-The current study investigates the behaviour of headed bar lap splices in reinforced concrete beam tension zones. The effect of many variables affecting the behaviour of flexural members with lap splice in tension zone was examined. Using four point loading, seven simply supported concrete beams were tested until failure occurred. Beams used were having same dimensions (220 x 250x 1600 mm), concrete strength (25Mpa) and same longitudinal reinforcement (μ= 0.616%).

It was discovered that the behaviour of an RCC beam can be achieved in a spliced beam with a 100 percent cut off ratio when the splice length is equal to 27 db without any transverse reinforcement, or when the lap is equal to 15.5 db with transverse reinforcement. The analytical data from the research further reveals that, by using transverse reinforcement for the spliced zone, the mode of failure changed from brittle to flexure. It was also discovered that using the lap splice length specified by ACI 318-14 for headed bars without using confinement in the lap splice zone resulted in brittle failure of beams and reduced ductility.

KEYWORDS- Tension zone, Beam, Bar, Lap splice, Load, Failure.

I. INTRODUCTION

The use of bar splices in RC members cannot be avoided in few cases because the length of steel bars is limited. Steel bars must therefore be connected in the field to ensure reinforcement continuity. Welding is a method of splicing reinforcement, either with mechanical connectors or with enough lap splices.

Because of the long development lengths and large bend diameters of the reinforcing bars that are required, the anchorage of straight bars and hook may pose significant challenges. Straight bar anchorage and lap splices are sometimes impossible to fit into the available dimensions of elements. For short anchorage length hooked bars are used, It is necessary that the bend of hook should fit in the dimensions of a member, otherwise the hooks may create congestion problems. To make lap splice lengths short mechanical anchorage devices can be used.

The latest shape of steel reinforcement, bars with heads at the ends, is unavailable for commercial use in India. Because it shortens the length of the lap splice and because of the load transfer mechanism, headed bars are preferable to straight or hooked bars. When headed bars are used for lap splicing, the force in the bar is distributed evenly to the nearly concrete by a bearing at the end and bond stresses along the bar surface area in the splice zone. The headed bars that are used in lap splice joints increases the structural performance and ductility of anchorage bar. Bar length is reduced and congestion of steel reinforcement is minimized largely.

For splice bars provided with heads, no provision is available in the Indian Code IS:456-2000, Euro code 2-2004 , and BS 8110-1997 [3].But some specifications for the same were found in, ACI 318-14 and Canadian Standards CSA A23.3-04 .

According to studies, the anchorage capacity of headed bars increased as the side concrete cover was increased. It also confirmed that reinforcement increased the bearing capacity and ultimate load of the concrete. Previous research found that the shape of the head had little effect on capacity. It is not easy to control head orientation under field conditions, Head shape choice should be based considerations such as congestion and clearance. Current study, Headed bars with square head were used after welded locally but not widely used in India.

In the present study, an experimental investigation was carried out to find the strength of RC wide beams provided with headed bar lap splice of the tension steel reinforcement for which Seven simply supported reinforced concrete beams of dimensions (220 mm x 250 mm x 1600 mm) were tested. Comparison between spliced elements and non spliced elements was made to get the test results like ultimate load, shape of failure and deflection. The variables investigated were: lap splice length (8, 15.5, and 27 times bar diameter (db)); vertical stirrup spacing in the lap splice zone (150mm, 80mm, and 40mm; i.e. 2, 3, and 5 stirrups in the splice zone, respectively).

II. LITERATURE REVIEW

This current studies dealing with the behavior of headed reinforcement bars and its application requirements in reinforced concrete structures. It also includes the recommendations given by ACI 318-2008 [1], and Canadian Standards CSA A23.3-04 [2]. Previous studies, codal provisions, recent advancement and future scope all were taken into consideration.

Devries [4], conducted over 140 pullout testes to determine the effects of several variables on the anchorage of headed bars in concrete. This included: clear cover, corner placement, close spacing, concrete strength, embedment depth, development length, transverse reinforcement, bar diameter, head size, head shape, and head thickness. The concrete used was of nominal strengths 21 to 69 MPa, three reinforcement bar sizes (20, 25, and 35 mm diameter) and large relative headed bars area (5.7 and 7.4).

El-Azab [5]. tested sixteen High Strength Self Compacting beam specimens with two or three spliced bars. He studied the effect of reinforcement diameter, and ratio, splice length and casting position. He concluded that for improving the splice bond strength, a splice length of 40 times the bar diameter need to be taken as well as using smaller bar diameter for the same reinforcement ratio and avoiding top casting position.

Kang, et al [6], tested 12 pullout specimens and two full-scale reinforced concrete beam-column joint subassemblies to observe the influence of head size, shape, and head-attaching techniques on anchorage capacity and evaluate the seismic performance of exterior beam-column joints with small headed bars. The small head size used (Abrg/Ab = 2.7) substantially relieves reinforcing congestion and helps minimize column bar obstruction when inserting a beam reinforcing cage into the column cage. The embedment length of 10db was used for new pullout tests of single headed bars, and 15db was used for seismic tests of beam-column joints with multiple headed bars. Headed deformed bars with a bar diameter of 19 mm (D19) were used.

Chutarat and Aboutaha [7], tested four large-scale beam-column sub assemblages, with and without headed bars, under quasistatic cyclic lateral loads/displacements to investigate relocating potential plastic hinge regions away from the face of the beam column joints using headed bars .The test specimens represented a typical exterior beam-column connection in a concrete building frame. For specimens with a relocated beam plastic hinge region, the headed bars extended 20 in. into the beam.

Ghali, et al [8,9,10], made some studies to use shear studs as punching shear reinforcement in flat slabs. They found the current methods of slab shear reinforcement, which used small closed stirrups, to be structurally deficient and difficult to construct. They began to examine alternative methods of shear reinforcement and looked to double-headed shear studs as a possible solution. Initially, these headed studs were created by cutting thin sections out of steel I-beams, by fusion welding existing shear stud connectors to flat plates creating a prototype stud rail, or by welding square plates to both ends of short deformed bar lengths to create double headed ties as shown in Figure (2-12). The first method (I-sections) was found to be economically unfeasible and the second failed because the head sizes of the existing shear stud products were too small to properly anchor the heads into the top of the slab. The third method proved very effective. Eventually, the second and third methods were combined to create an improved stud rail with larger head areas. An important aspect of the research was the recommendation that a head size of 10 times the bar area was necessary for proper anchorage of the studs.

Mitchell, Cook [11], build five large-scale reinforced concrete columns and wall boundary elements to observe confinement performance provided by headed transverse reinforcement. The result of experimental showed that the specimens with headed bar as confinement reinforcement provided similar performance as the specimens use hoop and crossties. The substitution of seismic hoop to headed bar provide ease in construction process.

Phuong and Mutsuyoshi [12], performed tensile tests on six threaded couplers (TC). Five of the splices were intentionally assembled improperly. Only one of the splices was assembled as required by the manufacturer. Tensile test showed that only the correctly assembled splice exhibited almost same initial stiffness and strength as the reference unspliced reinforcing bar. Other specimens failed by bar pullout before reaching the ultimate strength.

III. MATERIALS AND METHODOLOGY

A. Testing Of Materials

The materials were checked to ensure that the material to be used for casting was of good quality. Physical testing for cement, fine aggregates, and coarse aggregates are included in the tests.

B. Fabrication Of Beams

Under identical environmental conditions, a total of 7 RC beams were cast. All beams had the identical size of 220 mm * 250 mm * 1000 mm. One of the seven beams was designated as a reference beam to provide a precise standard for comparison.

C. Cement

KHYBER brand Ordinary Portland Cement (OPC) was employed. It is bluish-gray in color. The specific gravity of this substance is 3.14.

D. Fine Aggregate

Fine aggregate with a specific gravity of 2.64 passes through a 4.75 mm sieve. According to Indian Standard requirements IS: 383-1970, fine aggregate is classified as zone III.Seive analysis of fine aggrates is shown in table 1

Table 1: Sieve Analysis of Fine Aggregate

Description of Sample	Specific Gravity	GRADING			Remarks
		Sieve Designation in mm	% PASSING		
			Obtained	Required	
Sand	2.67	4.75 2.36 1.18 .600 .300 .150	99.60 99.40 88.80 36.30 9.85 3.35	99-100 75-100 55-90 35-59 8-30 0-10	Sand comes under Grading zone II as per IS: 383-1970 specifications

E. Coarse Aggregate

Stones after crushing are used to make coarse aggregates. Quarried, crushed, and graded commercial stone Granite, limestone, and trap rock make up a large portion of the crushed stone used. Two grades of coarse aggregates are employed. One grade comprised aggregates retained on a 10 mm filter, whereas the other grade contained aggregates retained on a 20 mm sieve. As stated in table 2, the maximum size of coarse aggregate was 20 mm, with a specific gravity of 2.88, confirming to IS: 383-1970.

Table 2: Sieve Analysis of Coarse Aggregate

Description of Sample	Specific Gravity	GRADING			Remarks
		Sieve Designation in mm	% PASSING		
			Obtained	Required	
Coarse Aggregate (20mm ::10mm : 60 : 40 by weight)	2.69	40 20 10 4.75	100 95 32 0	100 95-100 25-55 0-10	Confirms to 20mm full graded Coarse aggregate as per IS: 383-1970 specifications.

F. Concrete Mix

Table 3, according to IS: 456-2000, shows the proportions in the concrete mix. The ratio of water to cement is regulated at 0.41. Concrete is used to combine the ingredients.

Table 3: Nominal Mix Proportions of Concrete

Description	Cement	Sand (Fine Aggregate)	Coarse Aggregate	W/C ratio
Mix Proportion (by weight)	1	1.51	2.84	0.41
Quantities of materials for one specimen (kg)	24.37	37.45	70.30	

G. *Water*

Concrete is usually made with water that is suitable for drinking. Acids, alkalis, oils, vegetables, and other organic contaminants should not be present in drinking water. Concrete that is made with soft water is more prone to cracking.

H. Preparing headed bar

As the headed bars aren't accessible in India, they were made locally. The approach proposed by Abudiena [13] was used to make the headed bars. Headed bars were made by welding steel plate (30mm x 30 mm x 10mm) to the main reinforcing bar. The headed bars used in this experiment were made by drilling a hole in the centre of the steel plate with a diameter of 14 mm, passing the bar through the hole and extending 10 mm from the other face of the plate, and then welding the bar on both faces of the plate as shown in Figure 1 and Figure 2. The test results are summarized in Table 4.

Figure 1: The head

Figure 2: The headed bar

Table 4: Results of trails carried out to fabricate headed bars

Specimen	Failure Load (kN)	Stress at Failure (N/mm2)	Yield Stress (fy) (N/mm2)	Tensile Strength (N/mm2)	Mode of failure
A	57.01	503.69	399.7	503.69	Failure occurred in bar
B	61.13	540.94	416.40	540.94	Failure occurred in bar

I. Parameters and Test Program

The current study examined 7 simply supported RC beams. Concrete strength, bar diameter, transparent concrete cover, relative head area, and reinforcement percentage were all kept at 25 N/mm2, 12 mm, 26 mm, 6.96, and 0.673 percent, respectively. Details of all the tested beams is shown in table 5 below

Table 5: Details of tested beams

Beam Name	Average concrete strength fck (N/mm2)	(Lo/db)*	Cut off ratio	Type of transverse reinforcement in lap zone	Transverse reinforcement spacing (mm)
CB	27.14	No Splice	Nil	None	Nil
TB1	26.30	15.45	100%	None	Nil
TB2	26.45	26	100%	None	Nil
TB3	27.34	9	100%	None	Nil
TB4	26.55	15.45	100%	Stirrups	42
TB5	28.18	15.45	100%	Stirrups	85
TB6	27.59	15.45	100%	Stirrups	155

* Lo = lap splice length, and db = bar diameter

IV. RESULTS AND DISCUSSION

In the current study, seven simply supported RC beams were tested. The values of concrete strength, bar diameter, clear concrete cover, relative head area, and reinforcement percentage were kept constant as 25 N/mm2, 12mm, 26 mm, 6.96, and 0.673% respectively. Cross section of all beams was same. The results obtained from tests are given table 6

Table 6: Test results

Beam Name	Average concrete strength fck (N/mm2)	(Lo/db)*	Cut off ratio	Type of transverse reinforcement in lap zone	Transverse reinforcement spacing (mm)	Age of testing (days)	First crack load Pcr (kN)	First crack load at head Pcrb (kN)	Ultimate load Pu (kN)
CB	27.14	No Splice	Nil	None	Nil	33	15.5	NA	78.15
TB1	26.30	15.45	100%	None	Nil	33	15.0	22.55	62.55
TB2	26.45	26	100%	None	Nil	33	20.75	26.30	79.60
TB3	27.34	9	100%	None	Nil	33	14.90	14.90	41.41
TB4	26.55	15.45	100%	Stirrups	42	34	19.0	19.0	84.22
TB5	28.18	15.45	100%	Stirrups	85	34	19.20	19.20	76.14
TB6	27.59	15.45	100%	Stirrups	155	34	17.50	17.50	74.19

CB- Control Beam , TB1- Test beam 1 , TB2- Test beam 2 , TB3- Test beam 3 , TB4- Test beam 4 , TB5 - Test beam 5 , TB6 - Test beam 6

* Lo - lap splice length, db - bar diameter

A. Crack Patterns and Mode of Failure

At a load of 15.6 kN, flexural cracks formed in beam CB without any splices or stirrups in the constant moment zone (about 20 percent of the ultimate load; Pu). Flexural cracks spread upward into the compression zone as the load was increased. With increasing load, cracks widened and expanded upward to around 88 percent of beam height, as well as along the span to cover the constant moment zone. With a load of 78.12 kN, the beam failed due to flexure.as Figure 3.

Figure.3: CB Crack pattern

Flexural cracks appeared at the constant moment zone of beam TB1 with 15.45 db lap splice length (195 mm) and no stirrups at a load of 15 kN. (about 24 percent of the ultimate load; Pu). At a load of 22.55 kN, flexural cracks appeared at the head of the spliced bar after increasing the load (about 36 percent of the ultimate load; Pu). Beam TB1's fracture pattern is depicted in Figure 4.

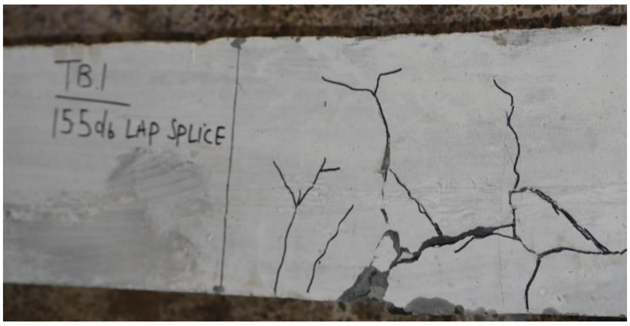

Figure.4: The TB1 crack patterns

For beam TB2, with 27.0 db lap splice length (340 mm) and without stirrups at constant moment zone, flexural cracks appeared at the constant moment zone at a load of 20.75 kN (about 26% of the ultimate load; Pu). As the load was increased, flexural cracks appeared at the head of the spliced bar at a load of 26.30 kN (about 33% of the ultimate load; Pu). Beam TB2's fracture pattern is depicted in Figure 5.

Figure.5: The TB2 crack patterns

For beam TB3, with 9 db lap splice length (110 mm) and without stirrups at constant moment zone, flexural cracks appeared at the constant moment zone and appeared at the head of the spliced bar at a load of 14.90 kN (about 36% of the ultimate load; Pu). Flexural cracks propagated upward to the compression zone as the load increased. Failure of the beam was a brittle side blow out failure and occurred by splitting of concrete in front the head of outer headed bars at load at a load of 41.41 kN. Beam TB3's fracture pattern is depicted in Figure 6.

Figure.6: The TB3 crack patterns

B. *Ultimate Load*

Figure 7 depicts the link between the ultimate (failure) load and lap splice length of the CB, TB1, TB2, and TB3 tested beams 78.12, 62.5, 79.6, and 41.4 kN, respectively, were the failure loads of beams CB, TB1, TB2, and TB3. The ultimate load of beams TB1, TB2, and TB3 was 80 percent, 102 percent, and 53 percent of that of beam CB, respectively.

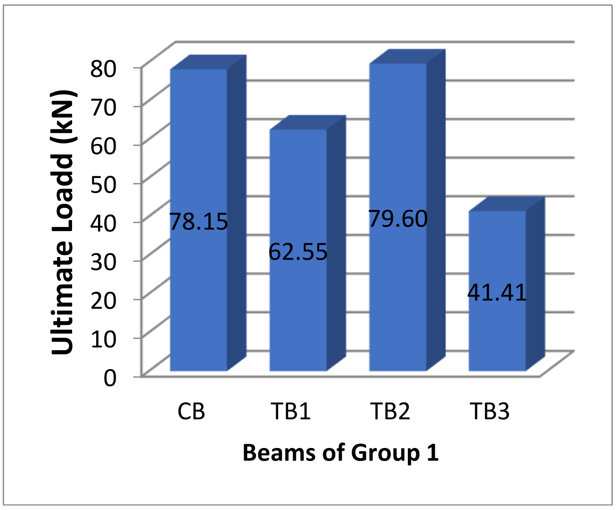

Figure.7: ultimate loads for beams in Group (1)

C. *Load – Deflection Relationship*

Figures 8 to Figure 12 depicts the relationship between. The greatest measured deflection at mid span of beam TB3 right before failure was nearly half that of the other beams in this group, The lowest lap length (8 db 100 mm) was found in beam TB3. The highest measured deflection at mid-span of beam TB2 (with 27 db lap splice) was almost 23% higher than that of beam TB1 under failure load (with 15.5 db lap splice). The load deflection curves for beam CB (no splice) and beam TB2 (27 db lap splice) were identical. After the initial cracking stresses, however, the behaviour of beams TB1 and TB3 was less stiff than that of beams CB and TB2. These findings show that using a 27-db lap splice length enhanced the maximum deflection at load before failure. The maximum deflection at load before failure was reduced by using an 8-db lap splice length.

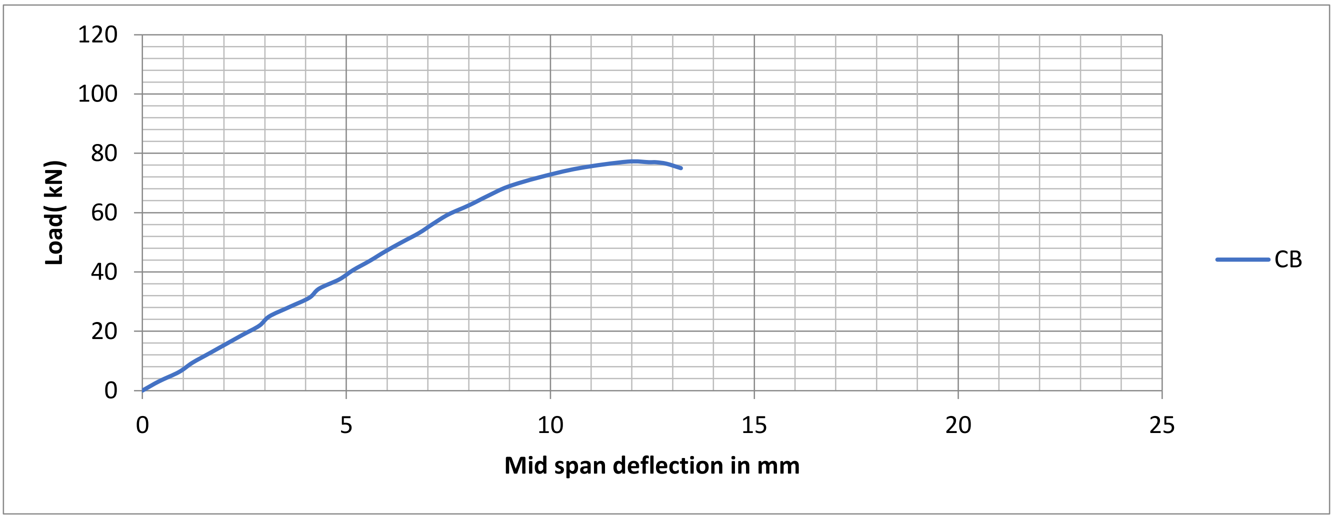

Figure.8: Relation between Mid-Span deflection and load for beam CB

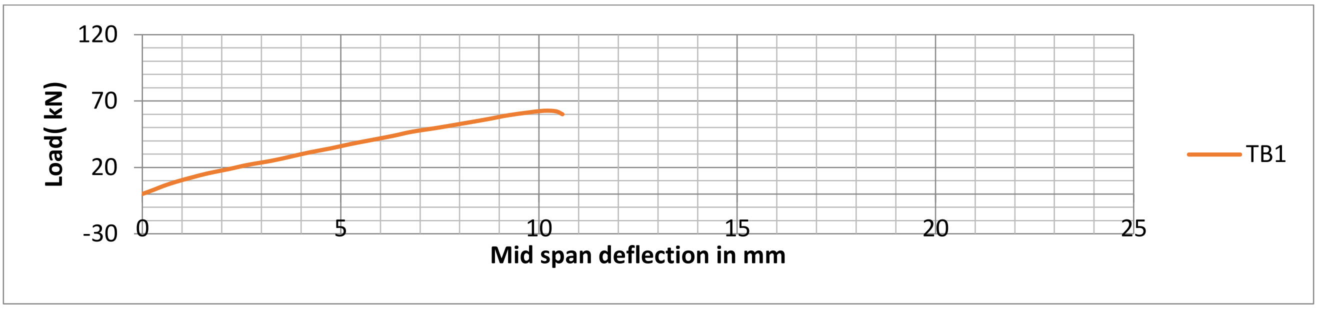

Figure.9: For beam TB1, there is a relationship between mid-span deflection and load.

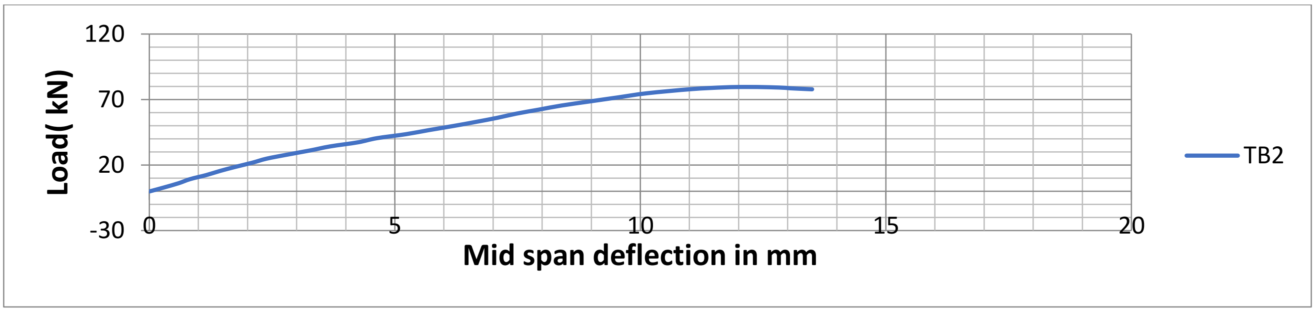

Figure.10: Relation between Mid-Span deflection and load for beam TB2

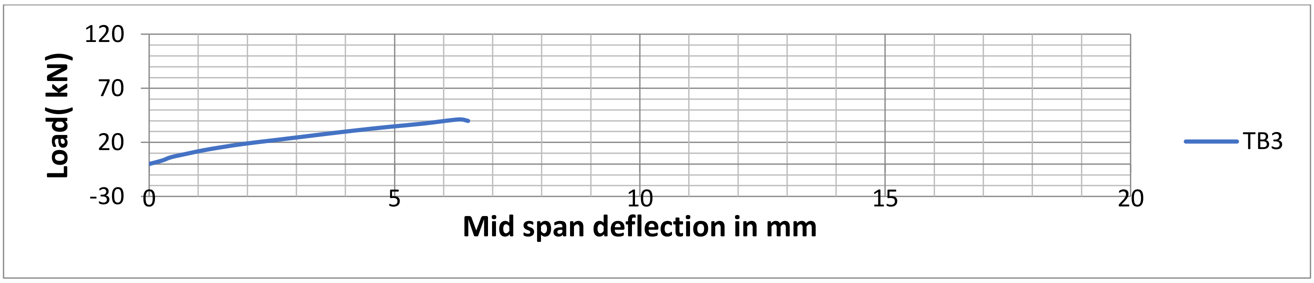

Figure.11: For beam TB3, there is a relationship between mid-span deflection and load.

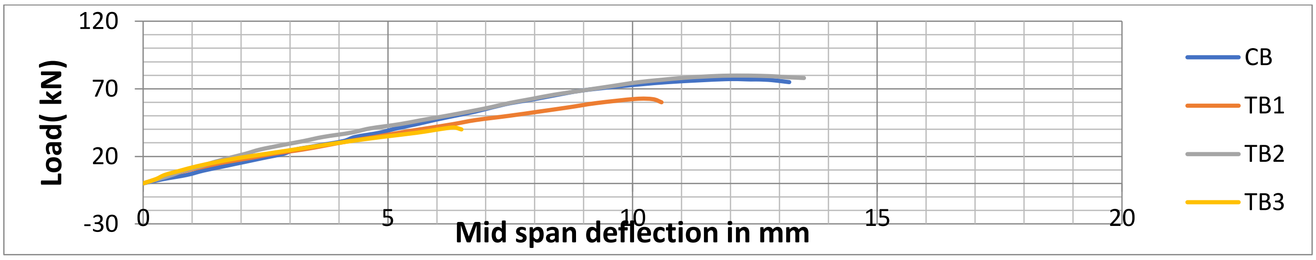

Figure.12: In Group 1, there is a relationship between mid-span deflection and load

Same experiments were conducted on group 2 beams that are TB4,TB5,TB6 and all the parameters were calculated like crack deflection, load deflection etc which are all mentioned in the above table 6.

V. CONCLUSIONS

Tested beams gave the following results:

1. The behaviour of an ordinary RCC beam without a splice can be achieved in spliced beams with a 100 percent cut off ratio when the lap splice length is 27 times the bar diameter without any transverse reinforcement (beam TB2), or when the lap length is 15.5 times the bar diameter with transverse reinforcement with spacing of 40 mm (i.e. S=0.20 d) (beam TB6).

2. According to the present study, the best performance (ultimate strength and ductility) for spliced beams was obtained when using the lap length equal 15.5 times the bar diameter with the use of transverse reinforcement with spacing equal to 40 mm (i.e. S=0.20 d) (beam TB4).

3. When spliced beams (TB4, TB5, and TB6) with lap splice length 15.5 times bar diameter, 100 percent cut off ratio, and transverse reinforcement (stirrups) for the spliced zone were compared to the reference beam with no stirrups in the lap zone and the same cut off ratio (100 percent), the mode of failure changed from brittle (side blow out failure) to flexural failure.

4. All beams with transverse reinforcement (TB4 and TB5) showed larger values of deflection at ultimate load

when compared to the reference beam. The maximum values of deflection at ultimate loads ranged from 1.32 and 1.07 times that of the reference beam, respectively. Higher values of maximum deflection at ultimate loads were recorded for beams provided with transverse reinforcement at spliced zone. At failure, a value of maximum deflection about span/84 was recorded (beam TB4). Also, increase of the lap splice length, increased the value of maximum deflection of beam TB2, at failure by about 2% compared as that of the reference beam.

5. Spliced beams with 100% cut off ratio, with lap length 8 times bar diameter (i.e. the one of the minimum required length recommended by ACI 318-08), and without transverse reinforcement (Beam TB3) resulted in a brittle side blow out failure with a reduction of the ultimate load by 46% compared with the unspliced beam. The maximum deflection before failure load of such spliced beam was less by 52% than of unspliced beam. This beam was less ductile than the unspliced beam in general. Brittleness was the failure.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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REFERENCES

[1] ACI Committee 318, Building Code Requirements for Structural Concrete (ACI 318-14), and Commentary, American Concrete Institute, Farmington Hills, Mich, 2014, p. 667.

[2] Canadian Standards Association, "Design of Concrete Structures," CSA A23.3-04, December 2004.

[3] Part 1:1997 of BS 8110 British Standard Institution, 1997, "Structural Use of Concrete, Part 1. Code of Practice for Design and Construction."

[4] R. A. DeVries, "Anchorage of Headed Reinforcement in Concrete," PhD Dissertation, University of Texas at Austin, December 1996.

[5] M.A. El-Azab "Effect of Tension Lap Splice on the Behavior of High Strength Self-Compacted Concrete Beams" Master Thesis Cairo University (2013).

[6] Bar Pullout Tests and Seismic Tests of Small-Headed Bars in Beam-Column Joints, ACI Structural Journal, Vol. 107, No. 1, January-February 2010, pp. 32-42. Kang, T. H., Ha, S. S., and Choi, D. U., "Bar Pullout Tests and Seismic Tests of Small-Headed Bars in Beam-Column Joints,"

[7] Chutarat, N., and Aboutaha, R. S. " Cyclic Response of Exterior Reinforced Concrete Beam-Column Joints Reinforced with Headed Bars – Experimental Investigation," ACI Structural Journal, V. 100, No. 2, March-April 2003, pp. 259-264.

[8] Mokhtar, A. S, Ghali, A, and Dilger, W.H, "Stud Shear Reinforcement for Flat Concrete Plates," Journal of the American Concrete Institute, Proceedings Vol. 82, No. 5, pgs. 676-683, Detroit, Michigan, September-October 1985.

[9] Elgabry A, and Ghali A, "Design of Stud-Shear Reinforcement for Slabs," ACI Structural Journal, Vol. 87-3, pp. 351-361, USA, 1990.

[10] Dilger, W.H. and Ghali, A., "Shear Reinforcement for Concrete Slabs," ASCE Journal of Structural Engineering, Vol. 107, No. 12, pgs. 2403-2420, New York, New York, December 1981.

[11] D. Mitchell, W. D. Cook, Y. Deng, and J. Liu, ASCE Journal of Structural Engineering, 140, pp. 1-9, (2014).

[12] Nguyen Dac Phuong and Hiroshi Mutsuyoshi "Experimental Study on Performance of Mechanical Splices in Reinforced Concrete Beams" ACI Structural Journal, Vol. 112-5, pp. 749-760, USA, 2015.

[13] A.A. Abudiena, Behaviour of reinforced concrete slabs using headed bars in lap splices, M.Sc. thesis, Faculty of Engineering, Alexandria University, Alexandria, Egypt, February 2015.