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Experimental Study of the Behavior of Reinforced Concrete Beams with Composite Dapped End under Effect of Static and Repeated Loads

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Abstract

In this study, the structural behavior and performance of the dapped end beams with composite section under effect of static and repeated loads was investigated by experimentally tested and included ten simply supported beams with dapped in one of ends. The parameters that have been taken into consideration represented by studying the effect of reparation longitudinal tensile reinforcement by steel sections, effect of repeated loads, different types of composite steel sections, and influence of increased the shear span to depth ratio (a/d) more than one on the composite dapped end region. The study focused on determining the first cracking load, ultimate strength (Pu), deflection at service and ultimate load, failure mode, load-deflection behavior, ductility ratios, and crack pattern at failure load.

The results presented that using the composite I-section instead of normal section in dapped end beams developed the shear capacity for dapped end region and enhanced the first crack appearances about 33.33, and 39.42 % for shear span to depth ratio 1.0, and 1.5 respectively.

Keywords: dapped end, composite embedded beam, repeated loads effect

1. Introduction

Beam is an important part of structures where was to carry the loads along it and transport loads to the supports. Usually in pre-cast system, the depth of beams are reduced at the end to sit on the supports, this technical called the beam with dapped end, it is very widely used in building, bridges, and used to connected two precast beams together.

For simply supported pre-cast concrete beam, when need to make large span the depth of beam must be increase to satisfy the strength for flexural in mid span and shear at the ends, but the larger depth of beam when site on the corbel or on inverted T-beam, the total depth will be very much. Therefore, the technical of dapped end will be necessary and useful in those cases, but this region will be very weak to resistance the concentrated stresses. So many researchers study the strength of this portion by many technical and material, the first researchers in this field were at (1969), by Reynold, worked on the developed suitable reinforcement details by evolving a design procedure for dapped-end members and suggested some detailing guidelines for dapped end members. After that, Mattock & Chan recommended that the nib of dapped end beams might designed similar to an inverted corbel, and the shear span measured from center of reaction force at support to the center of hunger reinforcement. Also Wen et al. study the effect of shear span-to-depth ratios (a/d) larger than one and showed that the dapped-end beams failed in flexure when the (a/d) increased so they suggested that dapped-end beams be designed using high-strength concrete with low ratio of flexural tensile reinforcement to ensure a ductile flexure failure.

Most researchers recommended to do not increased ratio of shear span to depth (a/d), but in some time, needed to increased (a/d) of dapped end as shown in figure 1, when the pre-cast beam with dapped end sit on spandrel inverted T-beam so needed to increased (a/d) to reduce the torsion on the spandrel beam. So that let us to study the effect of increased (a/d) more than one and strength for dapped end region by used composite embedded steel section.

Figure 1. Pre-cast beams with dapped end sit on spandrel beam

The composite embedded of I & box steel sections would invested to increase the strength of dapped region. The main objective of the study to check the extent of their effect on the strength of dapped end region.

2. Experimental Work

2.1 Materials Properties

The materials used to product the specimens are

1- Self-compacted Concrete

The materials used in producing self-compacting concrete are locally available, which include:

- Ordinary Portland cement (Type I) manufactured by Kufa Company.
- Semi-crushed gravel with maximum size 19 mm as coarse aggregate.
- Natural sand with maximum size of 4.75 mm imparted from Al-Najaf zone.
- Powder of limestone with maximum size less than 0.125 mm passed through sieve (NO. 100) used as an inert mineral filler in order to improve the segregation resistance, increase the amount of powder (cement + filler) and to increase the workability and density of concrete. This type of filler conformed to ACI 237R.
- High range water-reducing admixture the (EPSILONE HP 580) high performance concrete hyper-plasticizer admixture, used in concrete mix. It meets with the requirements of ASTM C494 Types F and G
- Clean tap water.

All materials mixing according to weight of components and the mechanical properties of SCC shown in Table 1, the method of mixture based on an ACI Committee 237R-07.

Table 1. Concrete Mix Contents and mechanical properties of SCC

Component	Amount for (m3) of mixture	Slump Flow (mm)	J-Ring (mm)	Column Segregation (%)	f'c (Mpa)
Cement (kg)	470	560	45	9.4	30.15
Lime stone powder (kg)	100				
Coarse aggregate (kg)	800				
Fine aggregate (kg)	880				
Super plasticizer (lit.)	7.5				
Water paste ratio (%)	0.175				

2- Steel Bars Reinforcement

Three sizes of deformed ordinary steel bars are used. The properties of steel bars tested depending on the ASTM A615-5a, and the results shown in Table 2.

Table 2. Steel Bars Properties

Nominal Diameter (mm)	Measure Diameter (mm)	Yield Stress (MPa)	Ultimate Strength (MPa)
8	8.3	513.74	639.2
10	10.26	540.49	657.03
16	15.6	475	743.13

3- Characteristic of Steel Sections

Two types of steel section used. The test doing according to the ASTM A370-14 and the results would listed in Table 3.

Table 3. Steel sections Properties

Type of Section	Dimensions (mm)				Area of section (mm2)	Yield Stress (MPa)	Ultimate Strength (MPa)
	b_f	h	t_f	t_w			
Box section	50	100	3		900	262.2	393.01
I-section	56	100	4.25	3.65	834	189.6	528.89

2.2 Specimens Details

All specimens having the same dimensions, with total length 1650mm, overall depth of 400mm, and width 200mm. each beams have one dapped end with dimensions 260mm in length and 200mm in depth. The reinforcement beams with dapped end were tested and they are:

1. The first group consists of three beam with non-composite ends, the details of reinforcement of typical beams of this group shown in Figure 2.

2. The second group consists of seven beams with composite dapped ends as follows:

   a) Three with an embedded box section, filled with SCC by making two openings at the top of box section, the dimensions of openings (40*100) mm, the details shown in Figure 3.

   b) Four specimens with an embedded I-section, as shown in Figure 4.

   For two types of composite, the sections welded with (160*160) mm square steel plate at the free end of beams to prevent the slip between the embedded section and concrete.

The details of all specimens listed in Table 4.

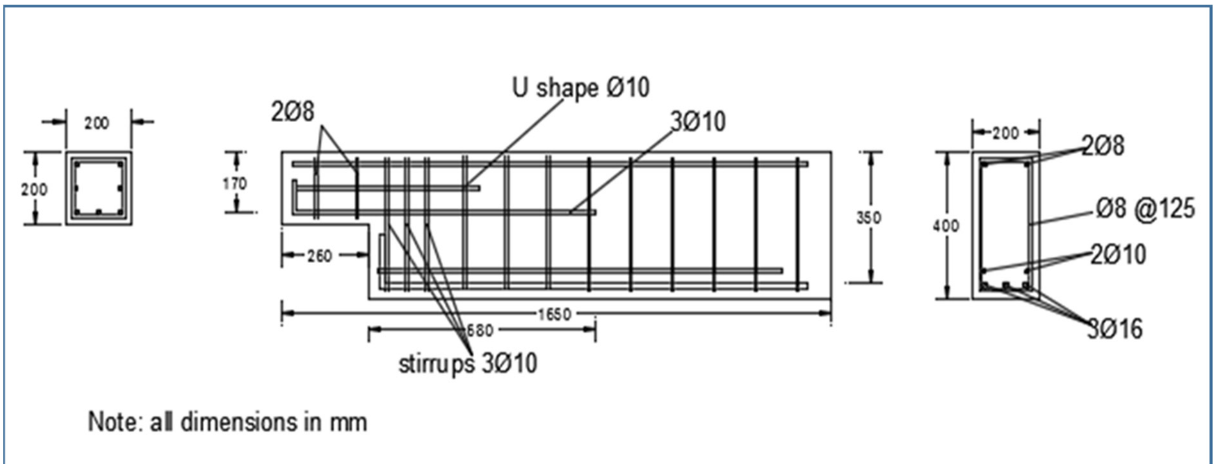

Figure 2. Details of beams with non-composite ends (DBNCS1.0, DBNCS1.5, and DBNCR1.5)

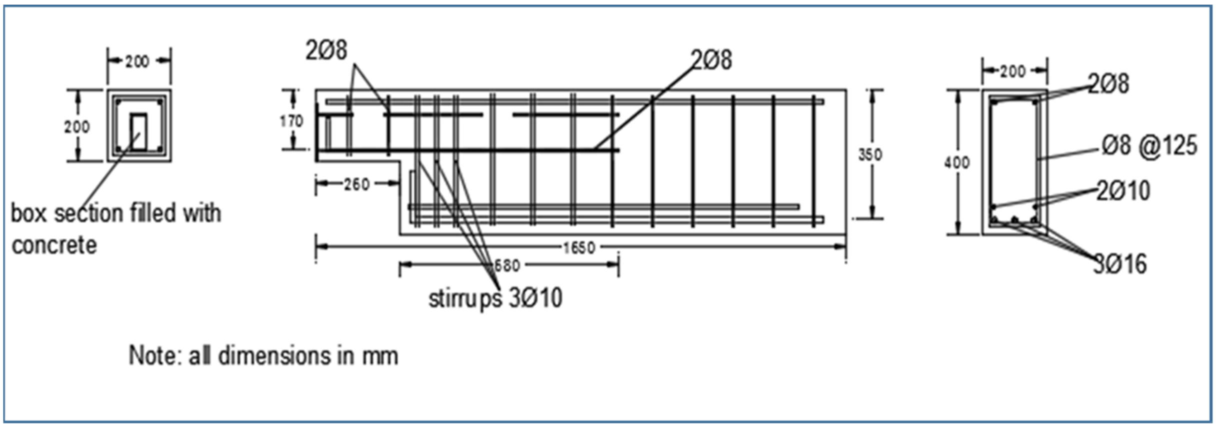

Figure 3. Details of beams with box-section composite end (DBCBS1.0, DBCBS1.5, and DBCBR1.5)

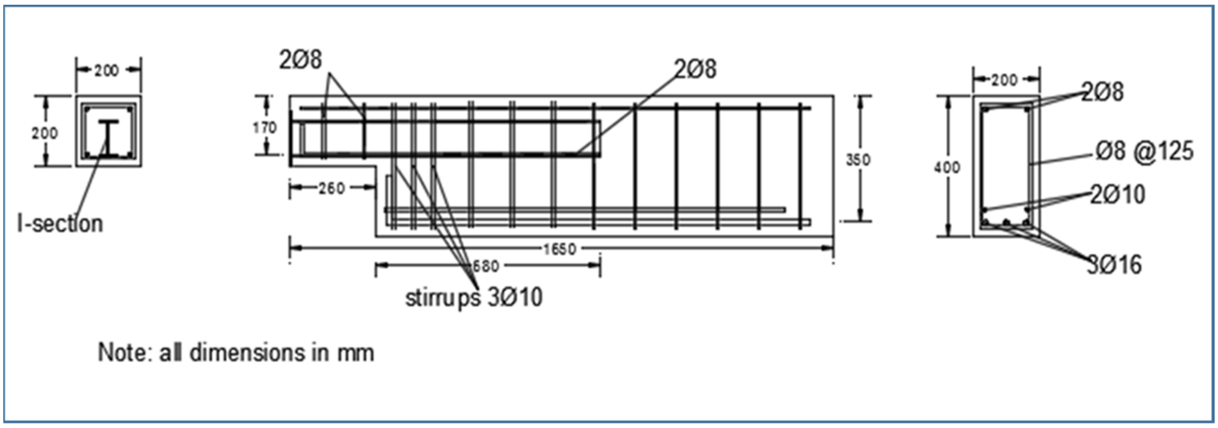

Figure 4. Details of beams with I-section composite end (DBCIS1.0, DBCIS1.5, DBCIS1.75, and DBCIR1.5)

Table 4. Details of specimens

Symbol	Type section	Type of load	a/d	Hanger reinforcement (Ash)	Flexure reinforcement for mane body	Vertical reinforcement in nib region (Av)	Horizontal reinforcement in nib region (As)+(Ah)
DBNCS1.0	Non-composite	Static	1.0	3 Ø 10 mm stirrups	3 Ø 16 mm + 2 Ø10 mm	2 Ø 8 mm stirrups	3 Ø 10 mm + 1U Ø10 mm
DBNCS1.5		Static	1.5				
DBNCR1.5		Repeated	1.5				
DBCBS1.0	composite with box-section	Static	1.0				2 Ø 8 mm
DBCBS1.5		Static	1.5				
DBCBR1.5		Repeated	1.5				
DBCIS1.0	composite with I-section	Static	1.0				
DBCIS1.5		Static	1.5				
DBCIS1.75		Static	1.75				
DBCIR1.5		Repeated	1.5				

2.3 Testing Procedure

The hydraulics machine available in the Faculty of Engineering at the University of Kufa was used in the test of the specimens. To complete the test requires preparing the supports, setting the specimen on them, and fixing the dial gauge under the point of load that has an accuracy of 0.01 as shown in Figure 5. Then start the applying load and every 5-kN the displacement recording until failure of specimen. So to test the beams with dapped end have malty ratio of shear span to depth (a/d), needed to make the support (A) moveable left and right to change the (a) value.

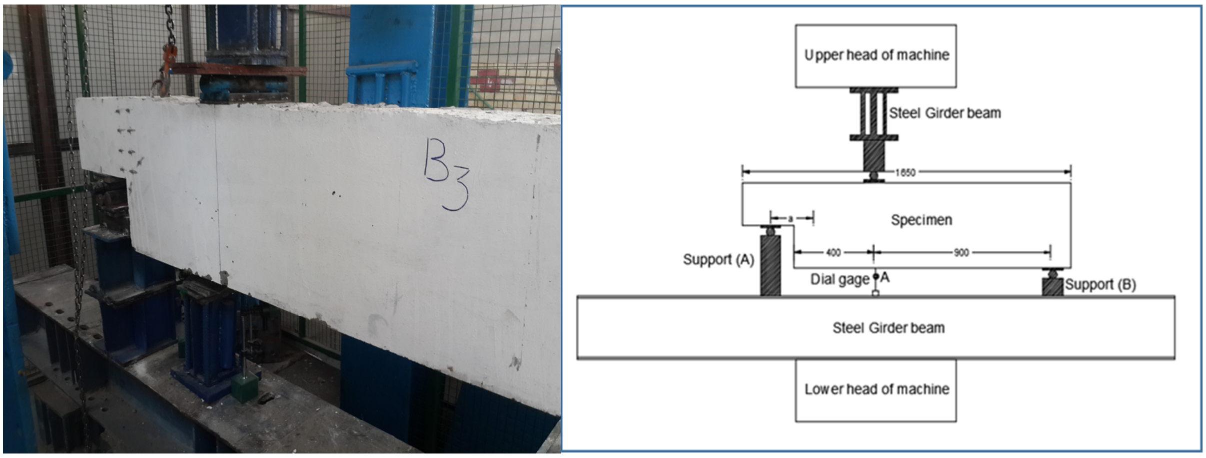

Figure 5. Specimen during testing

3. Results and Discussion

The tests showed the general behavior of simple supported beams with dapped end in one of ends, the results of tests beams as shown below according to the following parameters:

3.1 Effect of Shape Steel Section on the Composite Dapped End

The compression between types of composite sections was investigation to determine the effect of changed the shape steel section on structural behavior of dapped end beams.

For the beams DBCBS1.0, DBCIS1.0 specimens, the first crack was occurred within the reentrant corner at the reaction force level (29.37, 30.67) KN respectively. After that, the width of crack will be increase and more cracks occurred with increased load up to failures at reaction force levels (156, 172.33) KN respectively. The crack pattern for specimens showed in Figures 6, 7 respectively. The mode of failure for beams DBCBS1.0 and DBCIS1.0 it is the crushing at the top of beam and shear within the reentrant corner.

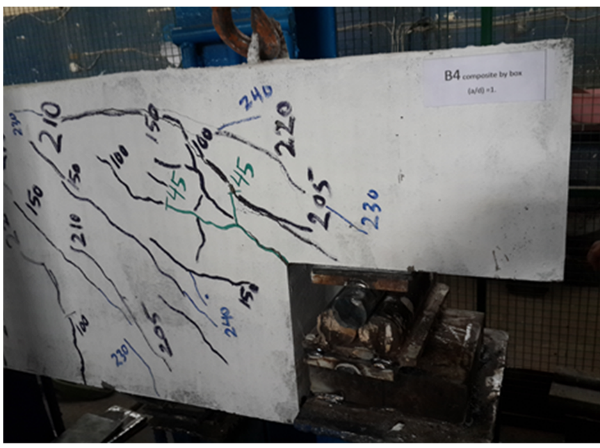

Figure 6. Cracks Modality for specimen DBCBS1.0

Figure 7. Cracks Modality for specimen DBCIS1.0

The deflection for beams DBCBS1.0, DBCIS1.0, at the ultimate load were (7.17, 6.84) mm respectively, so the decrease in deflection about (18.44%, 42.13%) respectively, as compared with control non-composite dapped end beam at the same load as shown in Figure 8.

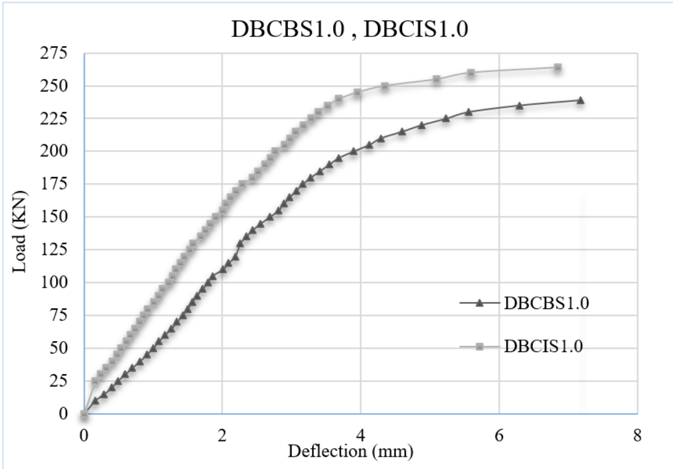

Figure 8. Load-Deflection Curve for DBCBS1.0, DBCIS1.0

So for the beams DBCBS1.5, DBCIS1.5 specimens the first crack also occurred at the reentrant corner of specimens at reaction force level (30.67, 27.6) KN respectively. Then, width of crack increased and more cracks developed up to failure at reaction force (138, and 141.1) KN respectively. The crack pattern for beams DBCBS1.5, and DBCIS1.5 showed in figures 9, and 10. The mode of failure for beams DBCBS1.5 and DBCIS1.5 it is the crushing at the top of beam.

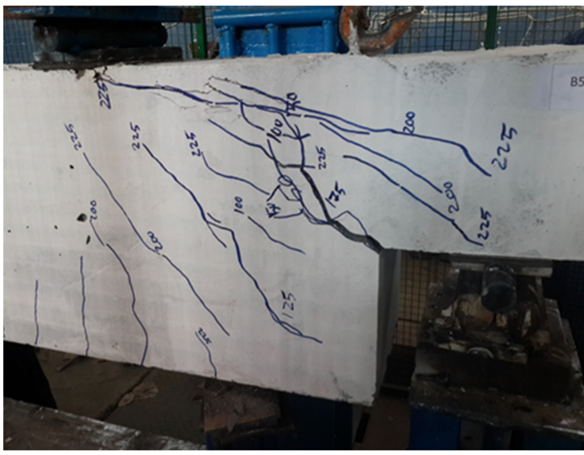

Figure 9. Cracks Modality for specimen DBCBS1.5

Figure 10. Cracks Modality for specimen DBCIS1.5

The deflection for beams DBCBS1.5, and DBCIS1.5, at the ultimate load were (6.99, 6.81) mm, so the decrease in deflection about (34.46%, 36.80%) respectively, as compared with control non-composite dapped end beam at the same load as shown in Figure 11.

The results summary of this group shown in Table 5. So could noticed that the composite dapped end with I-section for different shear span to depth ratio, carried more ultimate load, while the yield stress for it was less than yield stress for box section, so the composite dapped end with I-section was more efficient to strengthening this region.

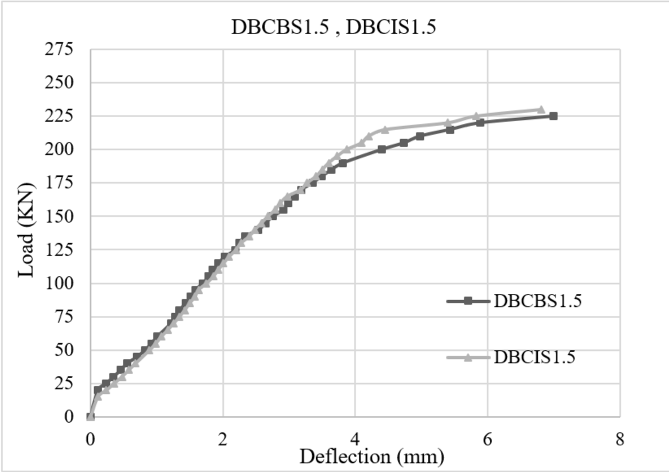

Figure 11. Load-Deflection Curve for DBCBS1.5, and DBCIS1.5

Table 5. Summary of results for effect of steel section on the composite dapped end

Specimen	Vcr. (KN)	Ultimate Reaction Force (KN)	Improvement in Shear capacity %	Reduce in Deflection %	Ductility Ratio	Crack width at load (100KN) (mm)	Mode of Failure
DBNCS1.0	24.15	129.25	control	control	1.14	0.45	Shear at the reentrant corner
DBNCS1.5	24.54	101.2	control	control	1.29	0.30	Arch rib and shear compression
DBCBS1.0	29.37	156	20.69	18.44	1.53	0.20	Crushing at the top of beam and shear within the reentrant corner
DBCBS1.5	30.67	138	36.36	34.46	1.50	0.30	
DBCIS1.0	29.37	172.33	33.33	42.13	1.58	0.20	
DBCIS1.5	27.60	141.1	39.42	36.80	1.50	0.15	Crushing at the top of beam

3.2 Behavior of Composite and Non-Composite Dapped End Beams with Different Value (a/d).

It was noticed that the ultimate shear force (reaction in dapped end) for the beams DBNCS1.0, and DBNCS1.5 are 129.25 kN, and 101.2 kN respectively, while for beams DBCIS1.0, and DBCIS1.5 it 172.33 kN, and 141.1 kN respectively, the increased in ultimate capacity equal to 33.33 % and 39.42 % as compared with non-composite beams.

So the used of composite dapped end beam with steel I-section develop shear capacity for dapped end region and enhanced the first crack appearances about 21.6 % and 12.5 % respectively, and making the cracks spread on the large area of beam before failure. The slope of crack is reducing with horizontal in DBCIS1.5 because of the involvement of the I-section making the cracks closer to horizontal. The summary of results listed in Table 5.

Also the deflection for DBNCS1.0 , and DBNCS1.5 at the ultimate load was 4.77 mm, and 4.70 mm respectively but for DBCIS1.0, and DBCIS1.5 specimens the composite section make to enhanced the stiffness and decreased the deflection about 42.13 %, and 36.80% respectively, according to the same ultimate load for non-composite sections as shown in Figures 12, and 13.

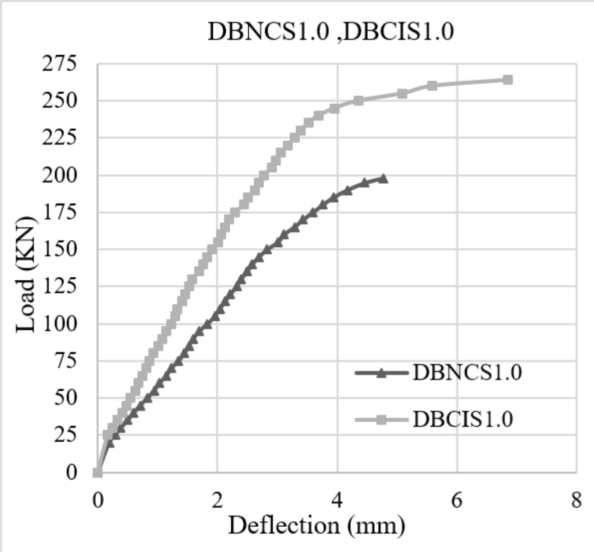

Figure 12. Load-Deflection Curve for DBNCS1.0, DBCIS1.0

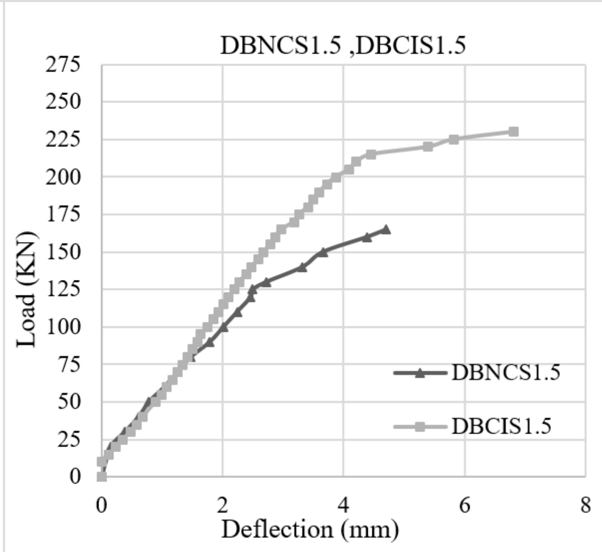

Figure 13. Load-Deflection Curve for DBNCS1.5, DBCIS1.5

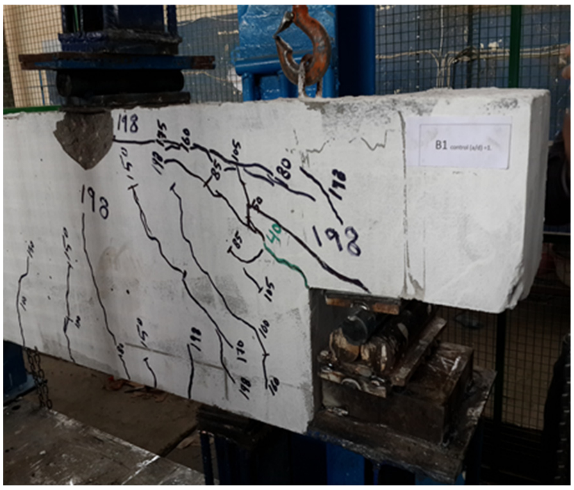

Figure 14. Cracks Modality for specimen DBNCS1.0

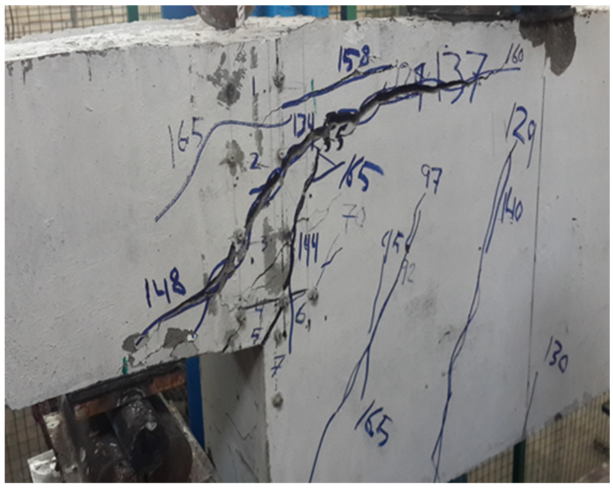

Figure 15. Cracks Modality for specimen DBNCS1.5

3.3 Effect of Shear Span to Depth Ratio (a/d) on the Composite Dapped End Beam

This parameter included three beams with composite dapped end by I-section and having different (a/d) values 1.0, 1.5 and 1.75. The objective of this group was to determine the range of influence the shear span to depth ratio on structural performance of composite dapped end beams by I-section.

The first crack occurred at the reentrant corner of composite dapped end beams at reaction force (32.64, 30.67, and 26.84) kN respectively. Then, the width of crack increased and more cracks occurred with increase load up to failure at reaction force levels (172.33, 141.1, and 107.4) KN for specimens DBCIS1.0, DBCIS1.5, and DBCIS1.75 respectively, and the crack pattern for specimens showed in Figures 7, 10, and 16.

The failure occur at the top compression stress area of beam with shear mode failure, it is founded when the shear span to depth ratio increased the compressive stress at the top extreme fiber increased because accretion the flexural moment in dapped region as shown in Figure 17.

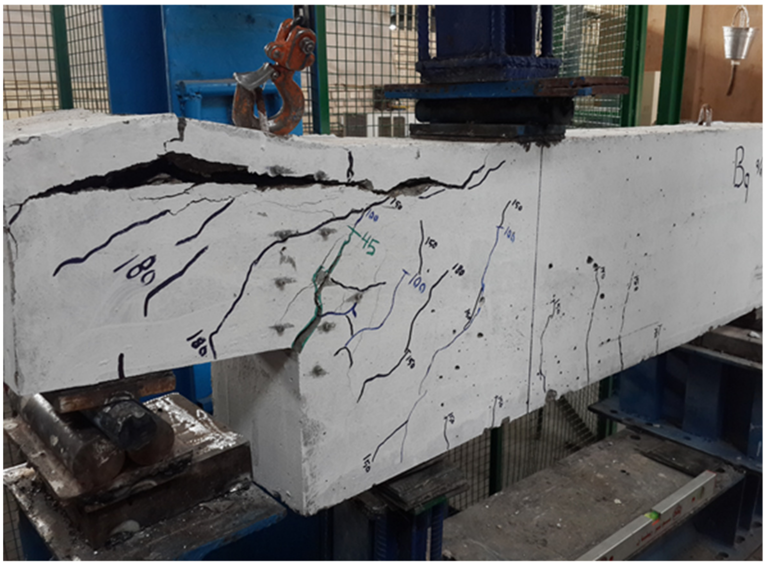

Figure 16. Cracks Modality for specimen DBCIS1.75

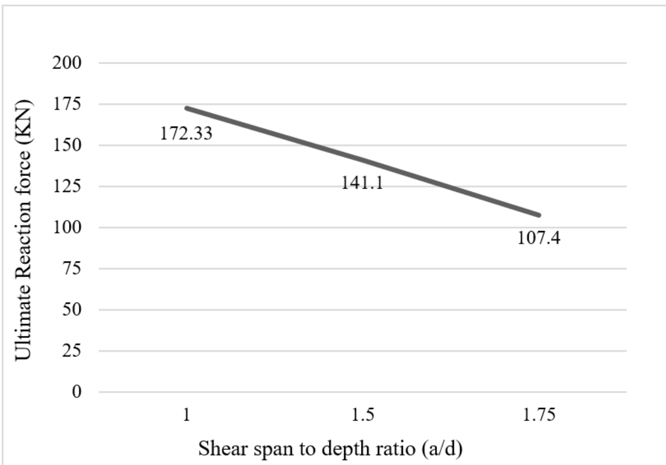

Figure 17. Effect of (a/d) on ultimate capacity of composite dapped end beams with I-section

So the deflection recorded at the ultimate reaction force were (6.84, 6.81, 5.95) mm for beams DBCIS1.0, DBCIS1.5, and DBCIS1.75 respectively, the Figure 18 show the comparisons between the beams in reaction force with deflection curve. The summary of experimental results for this group showed in Table 6.

Table 6. Summary of results for effect of change (a/d) on the composite dapped end beam

Beams	(a/d) ratio	Ult. Reaction Force (KN)	Reduce in Shear capacity %	Ductility Ratio (Δ ultimate /Δ yield)
DBCIS1.0	1.0	172.33	control	1.58
DBCIS1.5	1.5	141.1	18.12	1.50
DBCIS1.75	1.75	107.4	37.67	1.42

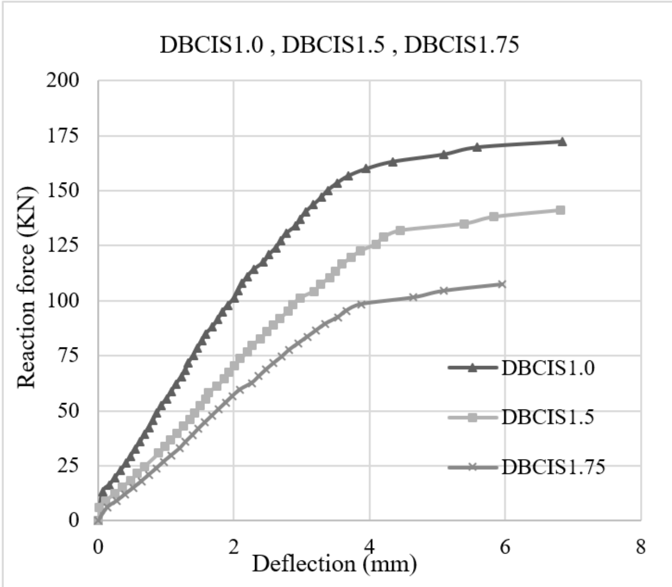

Figure 18. Load-Deflection Curve for DBCIS1.0, DBCIS1.5, and DBCIS1.75 show the Effect of (a/d) Ratio on response of Composite dapped end beams

3.4 Loading Type (Static and Repeated Loads) Effect

This parameter consists comparison between the beams DBNCR1.5, DBCBR1.5, and DBCIR1.5 (under repeated loading), with the corresponding beams DBNCS1.5, DBCBS1.5, and DBCIS1.5 (under static loading). The objective of this comparison is to recognize the effect of repeated loading on structural behavior of reinforcement concrete beams with composite and non-composite dapped ends.

Beams DBNCR1.5, DBCBR1.5, and DBCIR1.5 were tested under repeated loads according to first crack load that is usually 0.25 Pu of DBNCS1.5, DBCBS1.5, and DBCIS1.5 respectively. The procedure of loading is apply the load in three steps for (0.25 Pu, 0.5 Pu, and 0.75 Pu), each one include five cycles of loading and unloading. Finally, the beams were loaded to their ultimate loads. During these individual steps, deflections recorded.

The results showed that beams subjected to repeated load with 15 incremental increasing cycles load always caused some increased in the deflection in consecutive cycles, the consecutive increase of deflection with repeated loads was found to decrease [at the same applied of load level]. Also, the results explained that repeated load has insignificant effect on the ultimate load capacity and failure mode of the tested beams.

The repeated loading results showed some reduce in ultimate shear capacity of dapped end. The beams DBNCR1.5, DBCBR1.5, and DBCIR1.5 will failure at the shear force (reaction in dapped end) (96.3, 121.5, and 128.8) kN respectively. So the ultimate shear capacity of dapped end beams under repeated load decrease from static load by 4.84%, 11.95%, 8.71% for DBNCR1.5, DBCBR1.5, and DBCIR1.5 specimens respectively. This difference in reduce of the ultimate capacity for the composite section under the impact of repeated loads is due to use 3Ø10mm in the nib region for flexural with yield stress equal to 540 Mpa for DBNCR1.5. While for all composite beams used 2Ø8mm with yield stress 513 Mpa, addition to steel section of box, and I sections, with yield stress equal to 262.2 and 189.6, Mpa respectively. The crack pattern for specimens shown in Figures 22, 23, and 24.

The deflection of beams DBNCR1.5, DBCBR1.5, and DBCIR1.5 at the ultimate load in the 15th incremental increased cycles were 3.91 mm, 5.77 mm, and 5.99 mm respectively. So the reduce in deflection about 16.8 %, 17.45 %, and 12.04% respectively, as compared with static load at the failure load as shown in Figures 19, 20, and 21, the summary test results of this group shown in Table 7.

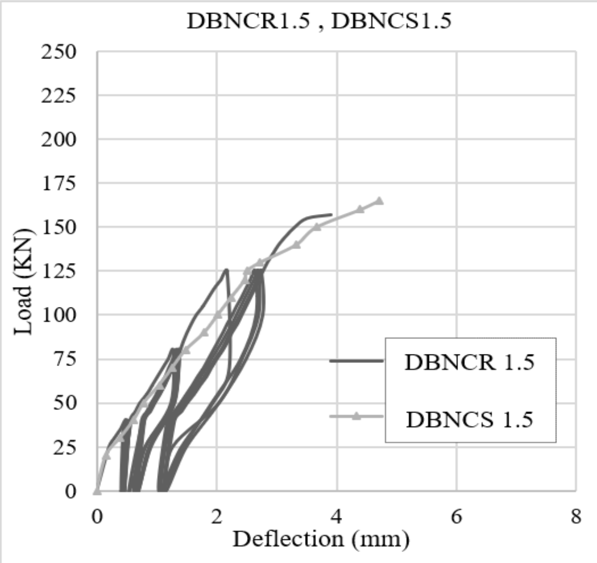

Figure 19. Load-Deflection Curve for DBNCR1.5, DBNCS1.5

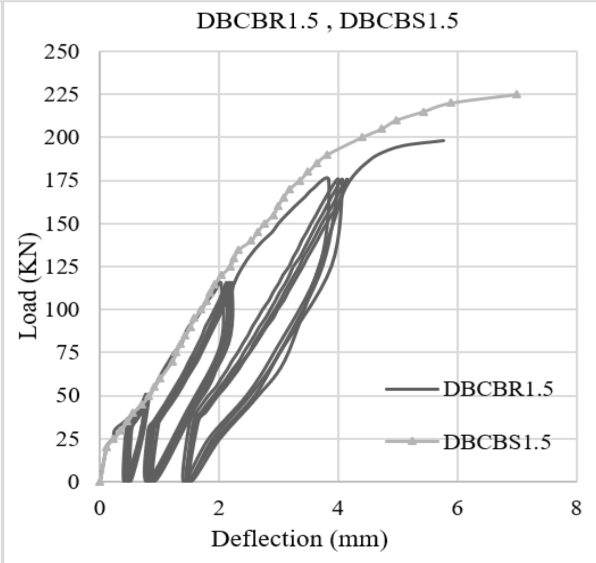

Figure 20. Load-Deflection Curve for DBCBR1.5, DBCBS1.5

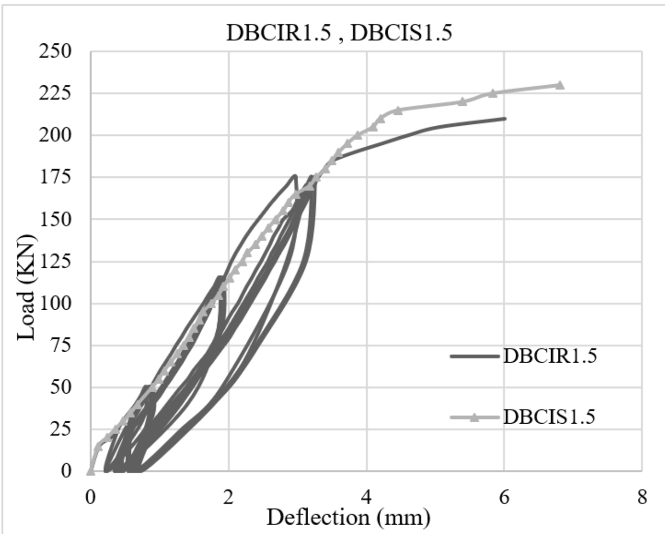

Figure 21. Load-Deflection Curve for DBCIR1.5, DBCIS1.5

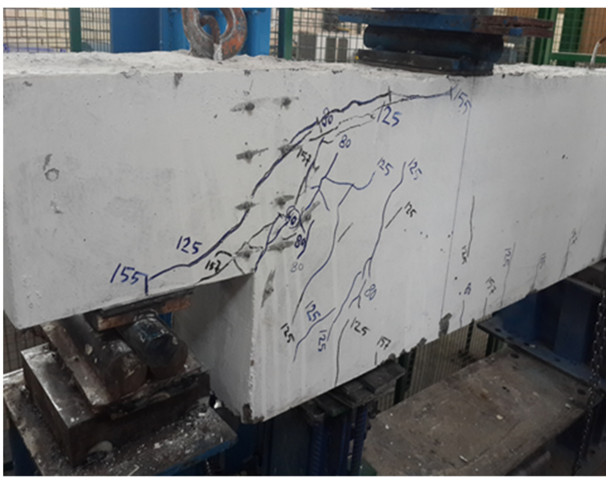

Figure 22. Cracks Modality for specimen DBNCR1.5

Figure 23. Cracks Modality for specimen DBCBR1.5

Figure 24. Cracks Modality for specimen DBCIR1.5

Table 7. Summary of results for repeated loads effect

Specimen	Reaction Force (KN)	Reduce in Shear capacity %	Reduce in Deflection %	Residual deformation ratio of total deformation %
DBNCS1.5	101.2	control	control	-
DBNCR1.5	96.3	4.84	16.8	0.291
DBCBS1.5	138	control	control	-
DBCBR1.5	121.5	11.95	17.45	0.261
DBCIS1.5	141.1	control	control	-
DBCIR1.5	128.8	8.71	12.04	0.118

4. Conclusion

Based on this study and the evaluation of the recorded data, the following conclusions were drawn:

1. Composite dapped end section constituted a viable solution to increase strength and ductility of dapped end region; it made the section stiffer, in addition to propagation of cracks on the large area of beam body before failure, and decreased the width of crack.
2. The first crack appearances for composite dapped end beam with I-section enhanced by 21.6%, and 12.5% for shear-span to depth ratio (a/d) equal 1.0, and 1.5 respectively as compared with non-composite section. So the ultimate load capacity increased by 33.33%, and 39.42% respectively
3. According to the results, the deflection decreased about 42.13 %, and 36.80% respectively for composite dapped end beam with I-section. In addition, the ductility increased by 38.6%, and 16.28% as compared with non-composite section for (a/d) equal 1.0, and 1.5 respectively.
4. The repeated loading results showed some reduce in ultimate shear capacity of dapped end from static load by 4.84%, 11.95%, and 8.71% for DBNCR1.5, DBCBR1.5, and DBCIS1.5 specimens respectively. Also the reduced of deflection about 16.8 %, 17.45 %, and 12.04% respectively as compared with static load.
5. The influence of shear-span to depth ratio (a/d) on the performance of composite dapped end beams with I-section, shown that the shear capacity decreased by 18.12%, and 37.67% for (a/d) equal to 1.5, and 1.75 respectively.

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