DOI: 10.26367/DJES/VOL.12/NO.4/4 eISSN 2616-6909

Effect of Steel Tube Thickness on Flexural Behavior of Concrete Composite Beams Using Different Section Shapes

Amer M. Ibrahim, Wissam D. Salman
Fahad M. Bahlol, Humam A. Abdulhusain
Department of Civil Engineering, University of Diyala
Amereng76@yahoo.com, Dr_wissam80@yahoo.com, Fahadbahlol22@gmail.com, Humam.civil@gmail.com

Abstract

The current paper aims to investigate the effect of steel tube thickness on the structural behavior of concrete composite beams with different steel tube sections. The experimental work of this study included a series of bending tests. The loading type used to study this effect on bending behavior of steel tubes was simply supported beam tested by two points load. Six composite beam specimens were performed and tested up to failure using three shapes of steel section (hexagonal, square and rectangular), every two specimens have the same shape of steel section. The type of shear connector was the headed stud for all specimens and to investigate the effect of thickness, this study used two thicknesses of steel tube sections of (2) mm and (3) mm. The tests showed improvement in the flexural behavior by increasing thickness of different steel section shapes, (50%) increasing in steel tube thickness led to increase the ultimate load by (32% - 34%). The ultimate slip at the ultimate load, for each specimen, is decreased by increasing the thickness of steel tube, the range of decreasing is (3.55% - 30.16%).

Keywords: Composite beams, Hexagonal section, steel section thickness, Shear connector.

Paper History: (Received:14-5-2018; Accepted:9-9-2018)

Introduction

Composite term means two or more than one material interfere to combined distinctive unit mass offers several advantages over non-composite portion [1,2]. In this case, using the steel beam and the slab those act together as "Composite Beam" and their action is similar to the monolithic T-beam, concrete is stronger in compression than in tension, and steel is susceptible to buckling in compression (IS 11384-1985) [3]. The general advantages of this type of beams must get by using efficient connection between the two material, reinforced concrete and structural steel, when headed stud was used in this study.

There are several considerable advantages achieved by using composite action, they can be summarized as follow:

1. Efficient use of material.
2. Cost reduction.
3. Greater stiffness.
4. Extra usable space.
5. Saving in labor and other construction material.
6. Sustainable effort.

Indeed, this type of beams may be appreciate for the building types such as commercial, industrial buildings and stores, etc.

Experimental Work

This study includes testing of six specimens of concrete composite beams with steel tube sections instead of I-Section, details of experimental specimens is tabulated in Table (1). This study dealt with ultimate loads, central deflection, ductility, crack width and interface slip for all composite beams. Table (2) concludes the results of the tested specimens. Dimensions of experimental specimens are (2000*400*130) mm, two of specimens are composite beams with hexagonal steel tube section, length of six ribs is (57.74) mm as shown in Figure (1), other two specimens are with square steel tube section with dimensions of (100*100) mm as shown in Figure (2), last two specimens are with rectangular steel section and dimensions are (200*100) mm as shown in Figure (3). The difference between these six specimens is the thickness of steel tube, ever similar steel section have two composite beams one has (2) mm thickness of steel tube, other has (3) mm as thickness.

Dimensions of tube sections were different according to its shape but the similarity parameter in all tubes were depth of steel tube (100) mm and inserting depth in concrete slab (20) mm. The typical shape of the three steel tubes is shown as sections in three figures, length of all steel tubes is (2000) mm. The headed shear stud connecters are used in order to prevent slip between concrete slab and steel tube and to resist the longitudinal shear at the interface between steel tube and concrete slab, and to prevent the vertical separation between them, headed stud shear connectors of diameter (10) mm and overall length (75) mm with a head of diameter (19) mm and height (7) mm were welded by gas metal arc welding over top fiber of steel tube in each specimen. The shear studs are shown in Figure (5) and according to (Johnson R.P, 1994)[4], total numbers of studs was (33) with spacing between them (60) mm according to the design

DOI: 10.26367/DJES/VOL.12/NO.4/4 eISSN 2616-6909

requirements of composite construction (Euro code 4, 2004)[5], Mechanical properties of studs had been certified by the manufacturer as given in Table (3). The reinforced concrete slab consists of two layers of (4.75) mm diameter @ (60) mm spacing of the deformed bars which were used in the two directions longitudinal as well as the transverse direction of slab as shown in Figure (5). The locally material were used in producing self-compacted concrete as shown in Figure (6), which include gravel, cement, sand, lime stone and water with super plasticizer as an admixture for concrete mixing. Natural gravel was washed and left in air, and then used after drying by saturated surface dry condition with (12.5) maximum size, gravel is comply with the requirements of Iraqi standards the (Iraqi Standard Specification I.Q.S No.5, 1984)[6] as listed in Table (6) as well as the grading is tabulated in Table (7). Also for the Ordinary Portland cement (Tasloja factory), the physical and chemical tests are conducted to ensure that the cement are comply with the requirements of Iraqi standards (Iraqi Standard Specification I.Q.S No.5, 1984) [7].The chemical and physical tests results of cement are listed in Table (4). While natural silica sand was used after provided it from Aldooz region in Iraq as fine aggregate with maximum size of (4.75) mm, sand is comply with the requirements of Iraqi standards (Iraqi Standard Specification I.Q.S No.5, 1984)[6] as listed in Table (5). Lime stone material provided from market and used, the ordinary tap water was used in making concrete and curing for (28) days after casting, final equipment of material step was provided admixture (super plasticizer) for the mixture. Several mixes are prepared to get the required compressive strength of concrete. A mix with weight percentage (300 cement: 850 sand: 670 gravel: 235 lime stone : 200 water : 1.85 % S.P) are used with slump of (70) mm which was satisfied (EFNARC, 2002)[8]. The average concrete compressive strength of standard cylinder (*fc'=30N/mm2*) is determined from standard compression tests. Simply supported composite beam specimens were tested after (28) days in Diyala university/engineering college–structural libratory to get data Collection, under two concentrated loads applied at the third points with (1900) mm clear span as shown in Figure (4).They are prepared, cleaned and painted with a white color in order to reveal of possible cracks. After that, the load is applied and the readings are taken every (5) kN, and at every increment, manual measurements are recorded including the load, central deflection, slip, crack width by data crack device.

Result and Discussion

During testing of the specimens, flexural cracks are observed at the bottom of the concrete flange of all specimens, these cracks are initiated at different load stages, then extended further and corresponded to the increasing of the load applied. These flexural cracks at the pure bending moment rejoin are developed and observed. The type of failure is flexural failure by yield occurred in steel tube followed by crushing of concrete flange in compression zone. Elastic behavior from starting the static loading reaching the yield stage, as shown in Figure (7). The tested groups and test results are listed in Table (4). The initial change of specimen (CBHS-3) happened between (90) kN and(110) kN, for (CBSS-3) it was between (110) kN and(130) kN. For (CBRS-3) the first change in deflection curve was between(130) kN and (170) kN. The behavior of specimens changed directly when load reached exactly (140) kN for (CBHS-3) and (160) for (CBSS-3)and(170) kN for (CBRS-3). By increasing the load, specimens got the ultimate load and large values of deflection following flexural failure happened on pure bending moment region. the result show clear increasing in (CBHS-3) by (32%) compared with (CBHS-2) and (32%) for (CBSS-3) compared with (CBSS-2) and (34%) for (CBRS-3) compared with (CBRS-2). This growing in ultimate capacity happened because increase the gross area of steel tube section when using high thickness more than the reference beams, it leads to increase the moment of inertia resulting high ultimate capacity.

The relationships between load and deflection as shown in Figure (7) presents decreasing in deflection that appeared clearly in ($0.75\%P_u$) stage on (CBHS-3), (CBSS-3) and (CBRS-3) by (36%) and (33%) and (20%) respectively when comparing every steel tube section separately to appeared effect of increasing thickness of steel tube exactly. This decreasing in deflection happened because the effect of thickness that increases the area of section and afforded increasing in moment of inertia that decreasing the deflection of steel tube section at service stage. It is good increasing attending in ductility due to raise thickness of steel tube, percentages of that are (12%) ,(9%) and (6%) for (CBRS-3), (CBSS-3) and (CBHS-3) respectively. The cause is increasing flexural stiffness that increase the steel tube beams ductility. Tests showed increasing in slip when increasing thickness of steel tube at ultimate stage as shown in Figure (8) by (3.6%) and (15.7%) and (30.2%) for (CBHS-3), (CBSS-3) and (CBRS-3) respectively because the ultimate load is more than reference composite beams loads. The cracking width was identical from the beginning of loading until load (100) kN but after that it decreased by (6.25%), (5.26%) and (20%) for (CBRS-3) and (CBSS-3) and (CBHS-3) respectively, that is clear in Figure (9). The decreasing here appear effect of using greater thickness of tube.

Conclusion

This paper described an experimental study that focused on the behavior and strength of steel–concrete composite beams with different steel tube sections. The main conclusions taken from study are the following:

- The flexural behavior of specimens is improved by increasing thickness of different steel section shapes, (50%) increasing in steel tube thickness leads to increase the ultimate load by (32-34%).

Diyala Journal of Engineering Sciences Vol. 12, No. 04, December 2019, pages 41-49 ISSN 1999-8716
DOI: 10.26367/DJES/VOL.12/NO.4/4 eISSN 2616-6909

The ductility is defined as the ratio of the ultimate displacement at 0.85% of the peak load beyond the failure load to the yield displacement corresponding to the intersection point of the tangent line of 0.75% of the peak load with the horizontal line of the peak load, Rodrigues, H. et al. (2013)[9]. In steel tube section ductility is improved by (6%-12%) as increasing percentage when increasing thickness of steel tube by (50%).

The interface slip at the ultimate load, for each specimen, is decreased by increasing the thickness of steel tube, the range of decreasing is (3.55% - 30.16%).

The crack width is decreased by increasing the steel tube thickness, percentage of decreasing is ranged between (20% - 60%).

References:

1. Wissam D. Salman, Strength and Behavior of Composite Steel Tube Concrete Beam, Diyala Journal of Engineering Sciences, (2015), 8 (2), 163-181.
2. Amer M. Ibrahim, Nazar K. Ali and Wissam D. Salman, Flexural Capacities of Reinforced Concrete Two-Way BubbleDeck Slabs of Plastic Spherical Voids, (2013), 6 (2), 9-20.
3. IS 11384. Code of Practice for Composite construction in Structural Steel and Concrete. [CED 38: Special Structures], 1985.
4. Johnson, R. P., Composite Structure of Steel and Concrete, Second Edition, New Jersey, United States, Blackwell Scientific publication, 1994.
5. Eurocode 2: Design of Concrete Structures, Part 1 -1: General Rules and Rules for Buildings, 2004.
6. IOS No. 45. Iraqi Standard Specification for Aggregate (Icosqc), Baghdad, Iraq, 1984.
7. IOS No. 5. Iraqi Standard Specification for Portland Cements (Icosqc),Baghdad, Iraq, 1984.
8. EFNARC., Specification and Guidelines for Self-Compacting Concrete. EFNARC, United Kingdom, 2002.
9. Rodrigues, H. et al. Experimental Investigation on the Flexural Behavior of the Steel- Concrete Composite Beams, 2013

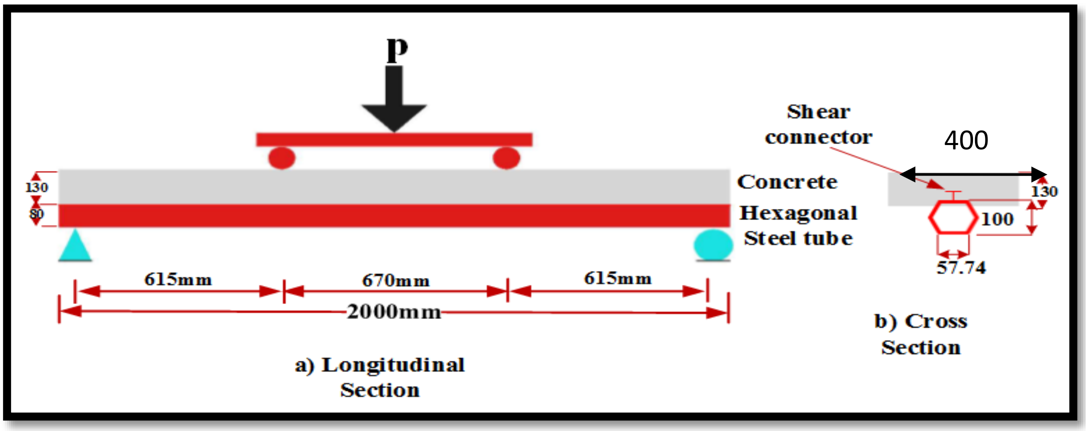


Figure 1 : Composite beam with hexagonal steel tube section

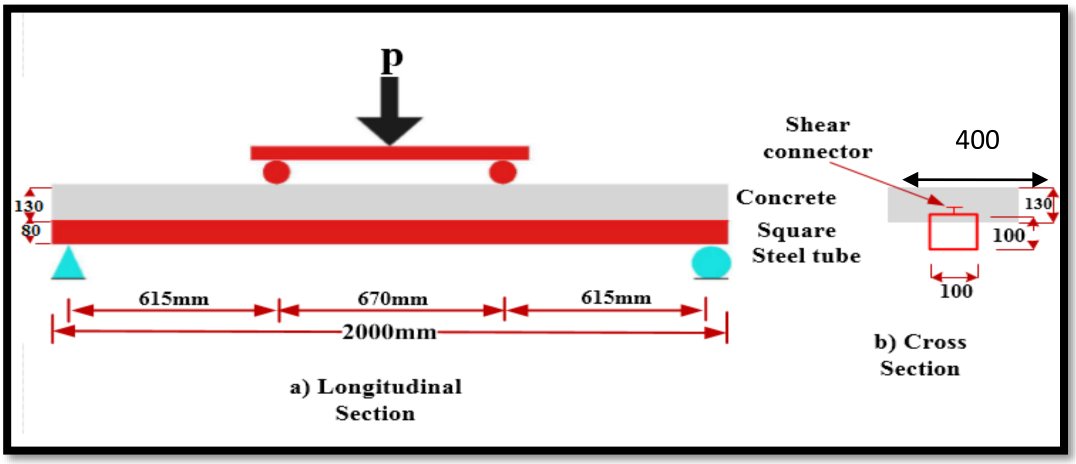


Figure 2 : Composite Beam with Square Steel Tube Section

Diyala Journal of Engineering Sciences Vol. 12, No. 04, December 2019, pages 41-49 ISSN 1999-8716
DOI: 10.26367/DJES/VOL.12/NO.4/4 eISSN 2616-6909

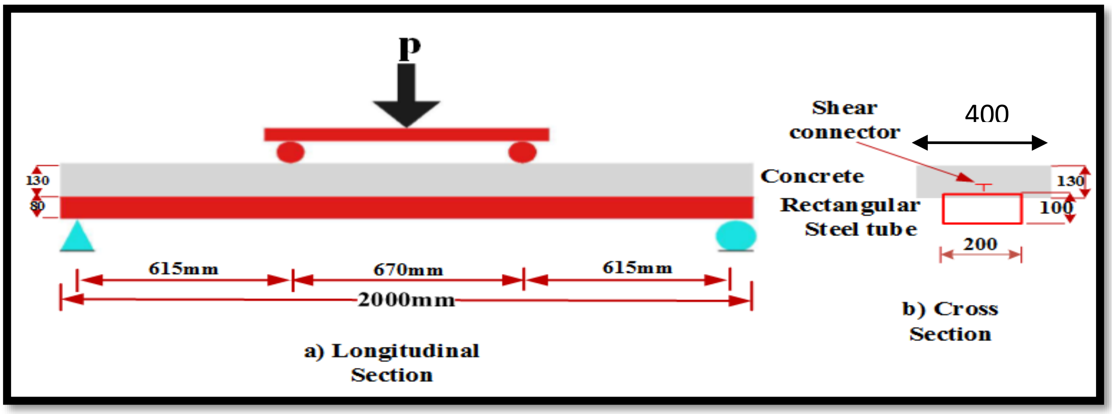


Figure 3 : Composite beam with rectangular steel tube section

Figure 4 : Testing specimen by two points loads machine

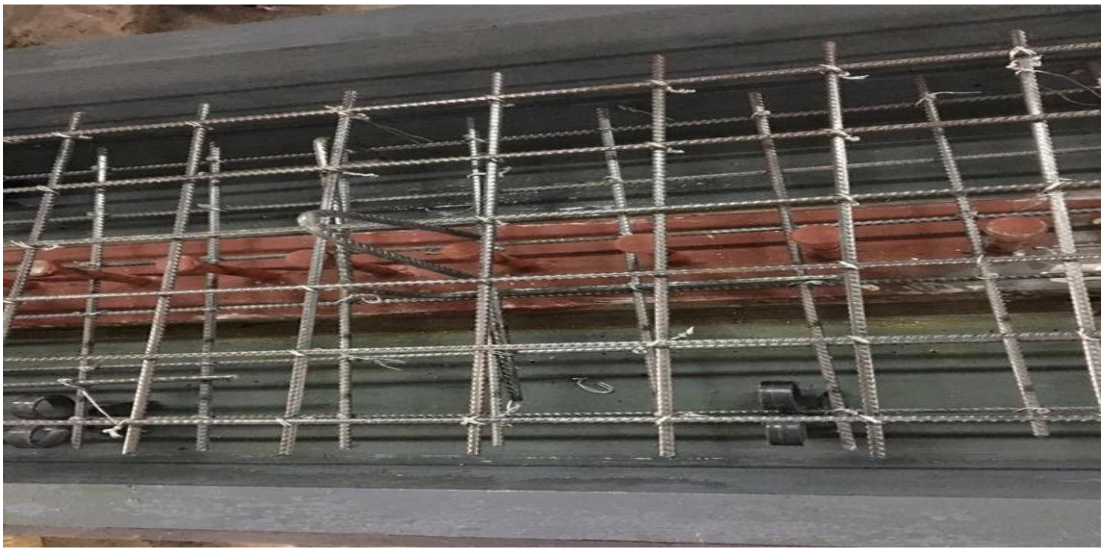
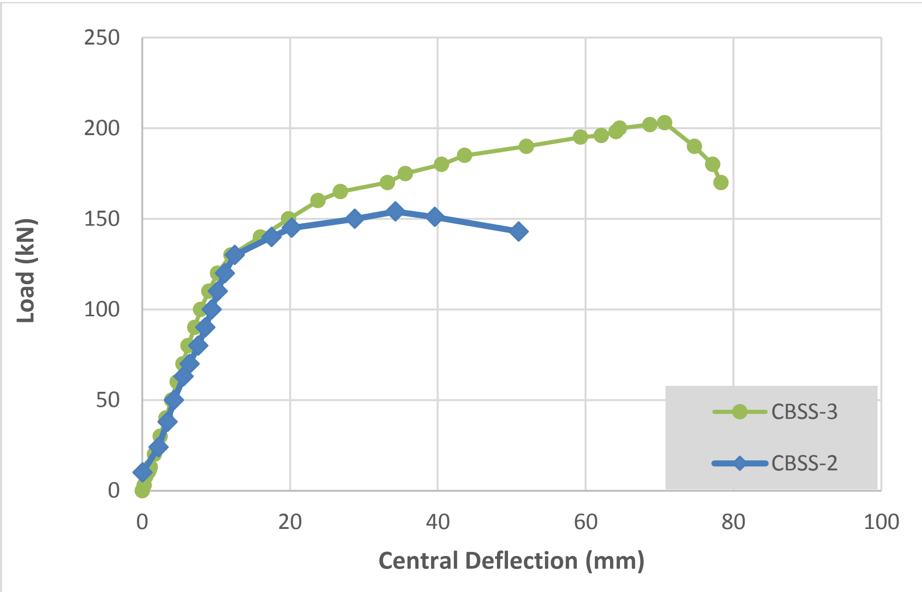
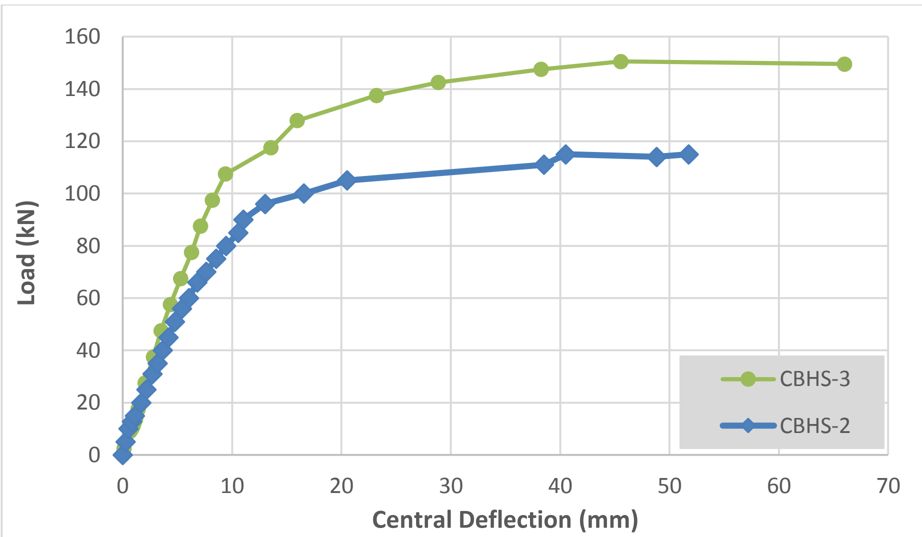


Figure 5 : Reinforcing steel bars of concrete slab in two directions

Figure 6 : Casting specimen with its cubes, cylinders and prisms

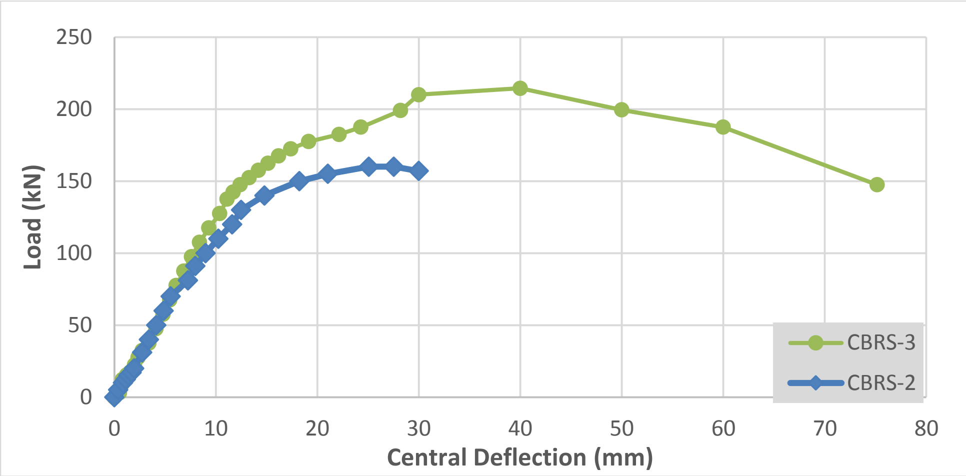


(a) Square steel tube



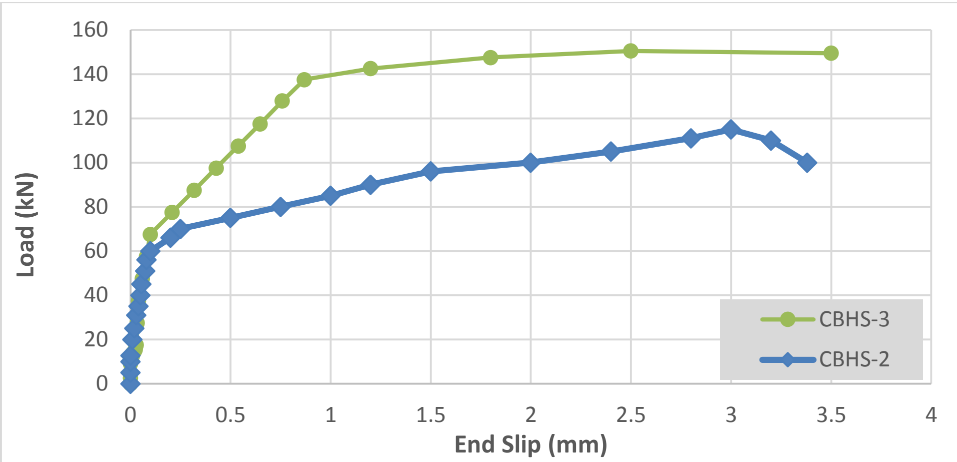
(b)Hexagonal steel tube

Diyala Journal of Engineering Sciences Vol. 12, No. 04, December 2019, pages 41-49 ISSN 1999-8716
DOI: 10.26367/DJES/VOL.12/NO.4/4 eISSN 2616-6909

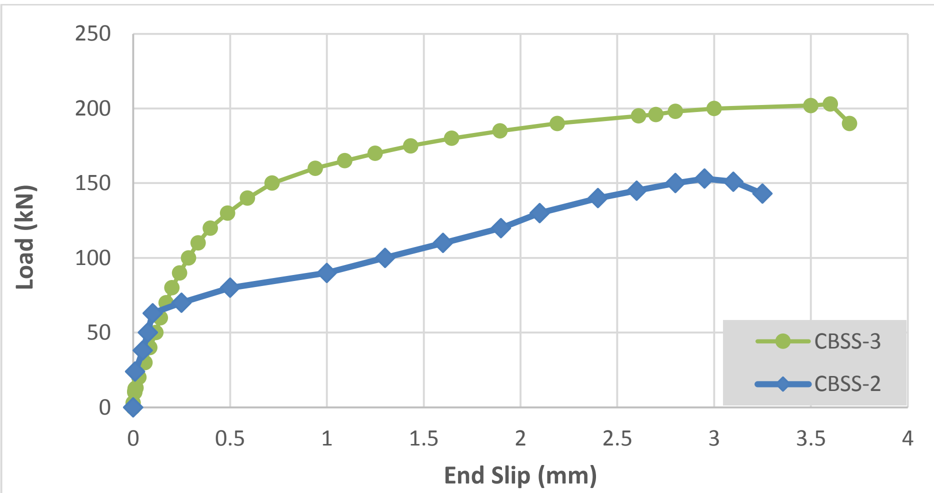


(c) Rectangular steel tube

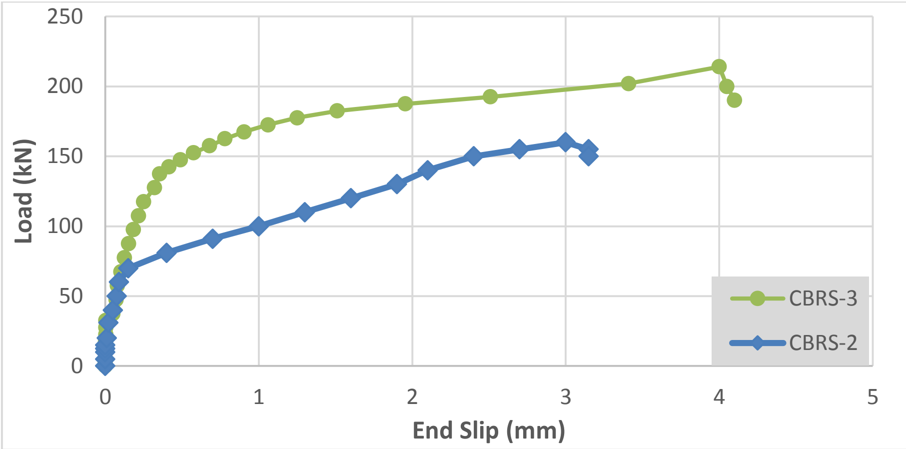
Figure 7 : Load – central deflection curves for specimens



(a) Hexagonal steel tube

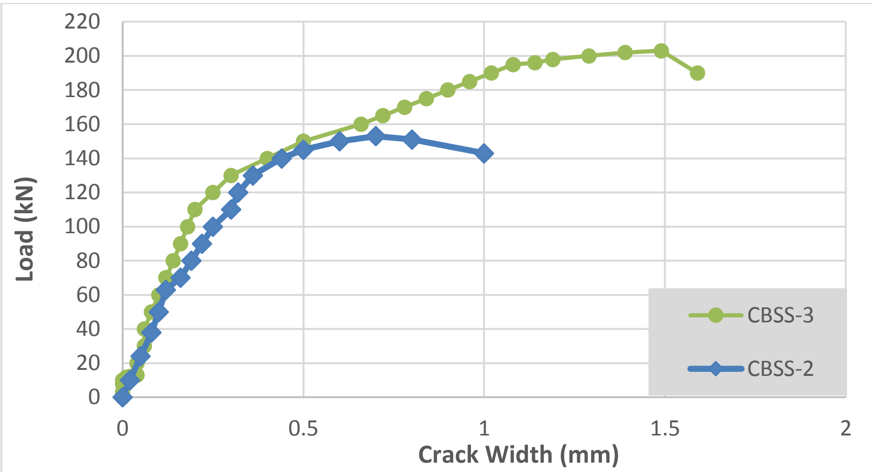


(b) Square steel tube

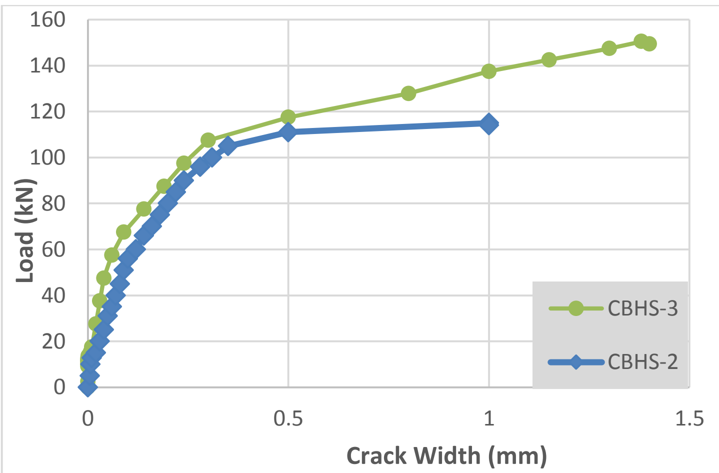


(c) Rectangular steel tube

Figure 8: Load – end slip relationship for specimens

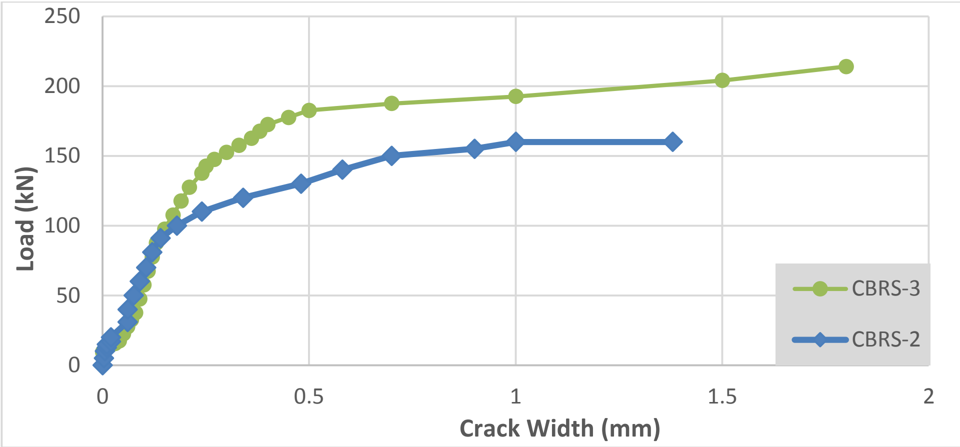


(a) Square steel tube



(b) Hexagonal steel tube

DOI: 10.26367/DJES/VOL.12/NO.4/4 eISSN 2616-6909



(c) Rectangular steel tube

Figure 9 : Load – crack width relationship

Table 1: Details of tested specimens in this study

Type of Steel Section	Specimen	Type of Shear Connector	Thickness of Steel Tube (mm)
Hexagonal	CBHS-2	Stud	2
	CBHS-3		3
Square	CBSS-2		2
	CBSS-3		3
Rectangular	CBRS-2		2
	CBRS-3		3

Table 2 : Test results of specimens

Specimen	Pu (kN)	% Inc. in Pu	Δ at 0.75Pu (mm)	Ductility	% Increasing in Ductility	Slip (mm)	%Inc in Slip	Crack Width at 0.7Pu (mm)	%Inc. in Crack Width
CBHS-2	114	-	10.18	1.20	-	3.38	-	1	-
CBHS-3	150.5	32	6. 5	1.26	6	3.5	3.6	1.2	20
CBSS-2	154	-	10.21	1.22	-	3.25	-	1	-
CBSS-3	203	32	6.8	1.33	9	3.76	15.7	1.6	60
CBRS-2	160	-	11.6	1.07	-	3.15	-	1.38	-
CBRS-3	214	34	9.3	1.2	12	4.1	30.2	1.8	30

Table 3 : Material properties of head stud connector

Yield Strength MPa	Tensile Strength MPa	Max. Elongation %
350	450	15

Table 4: Physical properties of cement

Physical Properties	Test Results	Limits of Iraqi Specification No.5/1984
Specific Surface Area (Blaine Method),cm^2/g	298.5	Not less than 230
Setting Time (VicatApparatatus) :		
Initial Setting, (min)	166	Not less than 45
final setting, (min)	255	Not greater than 600 min
Compressive strength, MPa at 3 days	18.76	$\geq$ 15.00
Compressive strength, MPa at 7 days	26.81	$\geq$ 21.00
Soundness(autoclave Method), %	0.35	$\leq$ 0.8

*The test was carried out in the laboratory of the Consulting Engineering Bureau/ Baghdad University.

Table 5 : Physical properties of fine aggregate

Physical properties	Test result*	Limits of (IQS No.45:1985)
Specific gravity	2.60	-
Sulfate content	0.11%	0.5% (max)
Absorption	0.75%	-
Clay content	2.3	5% (max)

*The test has been carried out in the laboratory of the Consulting Engineering Bureau / Baghdad University**.**

Table 6: Physical properties of coarse aggregate

Physical properties	Test result*	Limits of (IQS No.45:1985)
Specific gravity	2.60	-
Sulfate content	0.08%	0.1% (max)
Absorption	0.70%	-
Clay content	0.4	3% (max)

*The test has been carried out in the laboratory of the Consulting Engineering Bureau / Baghdad University**.**

Table 7 : Grading of coarse aggregate

Sieve size (mm)	%Passing by weight*	Limits of (IQS No.45:1985)
19	100	100
12.5	100	90-100
9.5	65.7	50-85
4.75	2.23	0-10

*The test has been carried out in the laboratory of the Consulting Engineering Bureau / Baghdad University**.**