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Study of Embedded Collar Headas Shear Reinforcement of High Strength Concrete of Flat PlateWith Opening

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Abstract
This study displays an experimental investigation on one form of embedded shearhead called(collar head reinforcement) as shear reinforcement and it displays also theefficient uses of different forms of reinforced concrete . Also it displays the efficient of existence of opening on punching shear strength of reinforced concrete flat plate. In the present research, ten specimens are tested with dimensions (1000x1000x75 mm) which are divided into two groups; the first group is a normal strength concrete with a compressive strength 30MPa; the second group is high strength concrete with a compressive strength 60MPa. Each group consists of five specimens, the first specimen is reference specimen R , and second specimen with opening adjacent to the column but without collar head No 1, and third specimen] with presence of openings adjacent to the column and with collar head reinforcement on both sides of the column towards the opening (horizontal) No 2, and fourth specimen with presence of openings adjacent to the column and with collar shear head reinforcement on both sides of the column away from the opening (vertical) No3, fifth specimen with presence of opening and with collar headreinforcement in all sides the column and extend to the opening No 4. The percentage of cracking load to ultimate load capacity was between (40 –48.5)%. By using collar shearhead around the column sides and extended to the opening, the cracking load can be increased to 100% . In flat plate with opening, the deflection and crack width can be decrease by using collar head around the column and extend to the opening and by increasing the compressive strength of concrete of the section.. The slabs which had openings adjacent to the column but strengthened with collar head, the percentage of the critical section perimeter was between (107.5 – 128.3) % that was reflected to the capability of this type of shear reinforcement(collar head) in compensation the shortfall in the critical section due to the existence of openings..
Keywords: key words, flat plate , high strength , opening
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1. Introduction

Flat plate is two-way concrete which has uniform depth and the load transfer directly to supporting columns without beams or column capitals or drop panels. Flat plates can build quickly due to their simple formwork and reinforcing bar arrangements. They need the smallest heights to provide specified height requirements and they give the most elasticity in the arrangement of columns and partitions (Al-Karkhy, H. F 2004).Punching shear failure of reinforced concrete slabs occurs when concentrated loads are applied, causing very high shear- and axial stresses. At first, the combined stress performance leads to radial cracks, starting at the edge of the load enforcement zone. Increasing the load causes tangential cracks around the load enforcement zone. The failure state is reached when an inclined crack forms around the column, the column separates from the slab. Without shear reinforcement, the punching shear failure performs in a brittle method within the discontinuity region of the highly stressed slab at the column (Karsten Winkler and FriedhelmStangenberg).Shearhead is a constructional member embedded at the slab-column junction, the major use of shearhead is that to serve to spread the load of the floor on its column and increasing the critical punching shear perimeter around the column(Nilson, A.H. ,Darwin, D. and Dolan, C. W 2004). And therefore decreases the effect of the vertical forces, decreases the stress in the slab concrete. Connections of columns with flat plates should not considered in design as part of the system resisting lateral forces (Hong, G., and Yew-Chang, L 2003). High and complex building can constructed by using High Strength Concrete .HSC is increasingly used in these buildings because we can reduce the dimensions of the structural members by use HSC and hence save space (Ho J.C.M., Lam J.Y.K, and Kwan A.K.H, 2010). In flat plate floor systems, there is often a need to install new services that required openings in the vicinity of columns. Small openings are required in the slab to accommodate the mechanical and electrical services such as heating, plumbing and ventilating risers, air conditioning and electrical ducts (Boon, K.H., Diah,A.M,and Loon, L.Y 2009).

2. Materails

Concrete compositions, reinforcing steel bars and steel shearhead consist of steel angle (L sections), which is tested in the laboratory and showed good agreement with specifications:

- Water: tap water used.
- Cement: we used type (I) of Bazian ordinary Portland cement .
- Fine Aggregate (Sand): we used Al –Ukhaidher natural sand .

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- Coarse Aggregate (Gravel): we used Crushed gravel from AL–Nibaee with maximum size of (10mm) .
- Steel Reinforcement: The steel reinforcement which is used to reinforce the concrete slab is deformed mesh bars with diameter is 6 mm and 75mm spacing. Columns reinforcement was bars 6 mm diameter for all slabs.
- Steel Shearhead: consist of steel angle(L sections).
- Admixture:For the production of HSC, we used super plasticizer (high range water reducing agent HRWRA) based on poly carboxylic ether.We used polymer based super plasticizer designed for the production of HSC Glenium 51. The normal dosage for Glenium 51 is (0.5-0.8) L/100 kg of cement mass.

3. Slabs details

This study is based on ten specimens, divided into two groups, the first group is normal strength concrete with acompressive strength 30MPa; the second group is high strength concrete with acompressive strength 60MPa. Each group consists of five specimens, the first specimen is reference speciment R , and second specimen with opening adjacent to the column but without collar head No 1, and third speciment with presence of openings adjacent to the column and with collar head reinforcement on both sides of the column towards the opening (horizontal) No 2, and fourth speciment with presence of openings adjacent to the column and with collar shear head reinforcement on both sides of the column away from the opening (vertical) No3, fifth specimen with presence of opening and with collar headreinforcement in all sides the column and extend to the opening No 4.All slabs were geometrically similar, having dimensions (1000×1000×75 mm) and loaded through a central column of dimension (150×150 mm) as shown in figures (1) , (2). The slabs have the same flexural reinforcement. The slabs are simply supported along all edges and the distance between center lines of supports was (900mm). The details of these slabs are listed in Table (1).

Table (1)The specimens of Test Slabs

Group No.	Specimens	Opening and Dimension	Collar Head Reinforcement
G1	NSCR	-----	-----
	NSC1	150*150	-----
	NSC2	150*150	On both sides of the col. towards the opening
	NSC3	150*150	On both sides of the col. away from the opening
	NSC4	150*150	Entire the col (all sides of col.) and extend to the opening
G2	HSCR	-----	-----
	HSC1	150*150	-----
	HSC2	150*150	On both sides of the col. towards the opening
	HSC3	150*150	On both sides of the col. away from the opening
	HSC4	150*150	Entire the col(all sides of col.) and extend to the opening

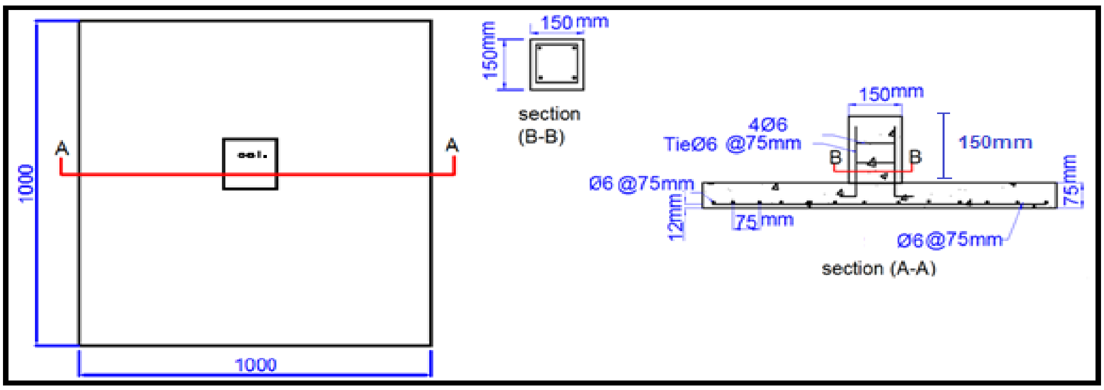

Figure (1)Dimensions and Layout of Slab without Opening.

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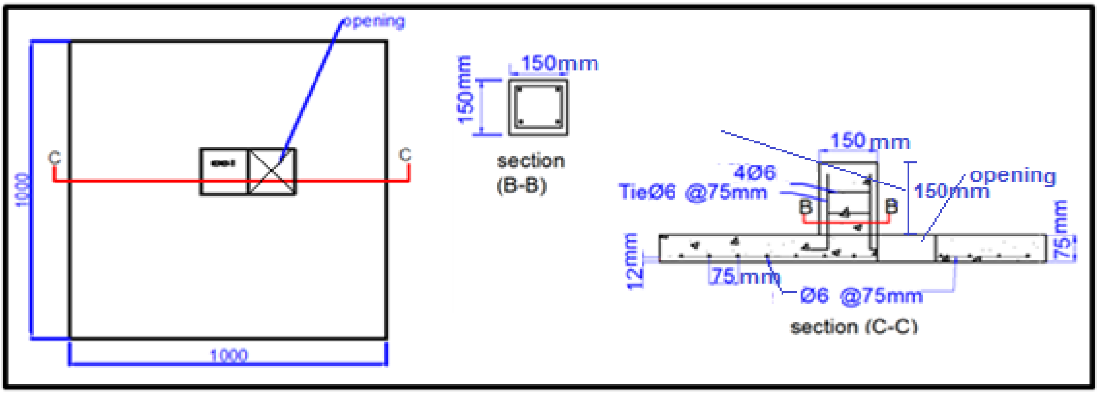

Figure (2)Dimensions and Layout of Slab with Opening

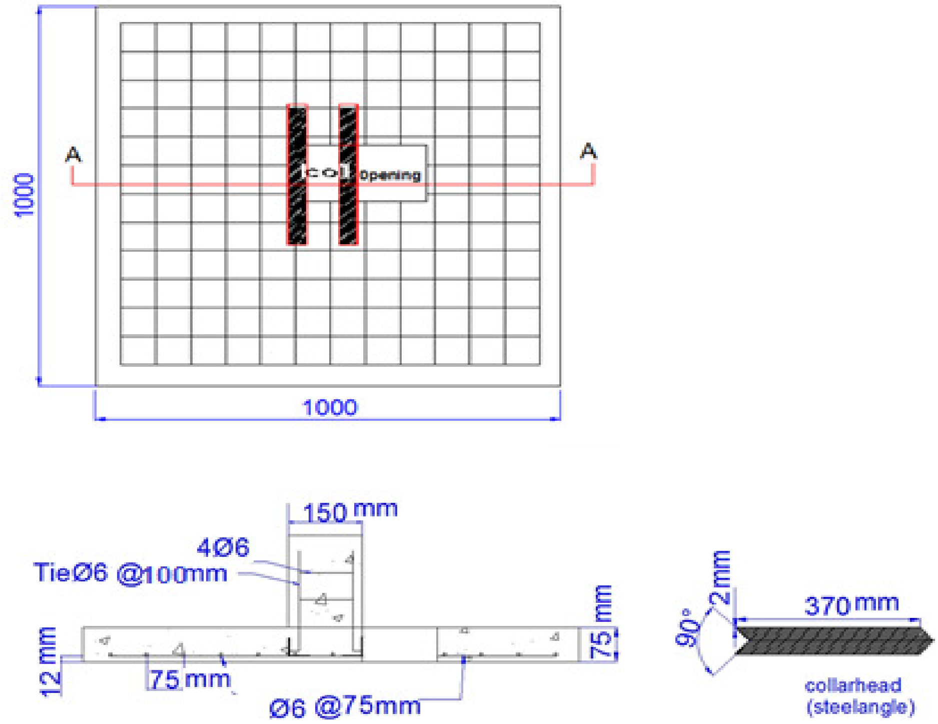

Figure (3) Dimension and Layout of Slab with Collar Head on both sides the col NO3

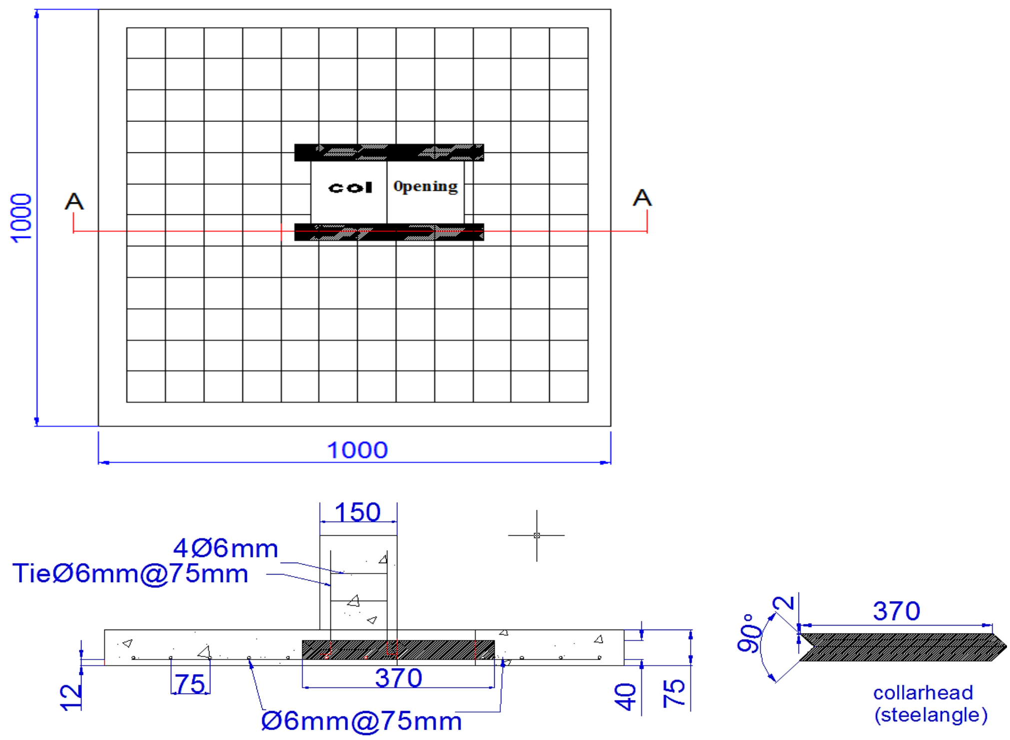

Figure (4) Dimensions and Layout of Slab with Collar Head on both sides of the col NO2

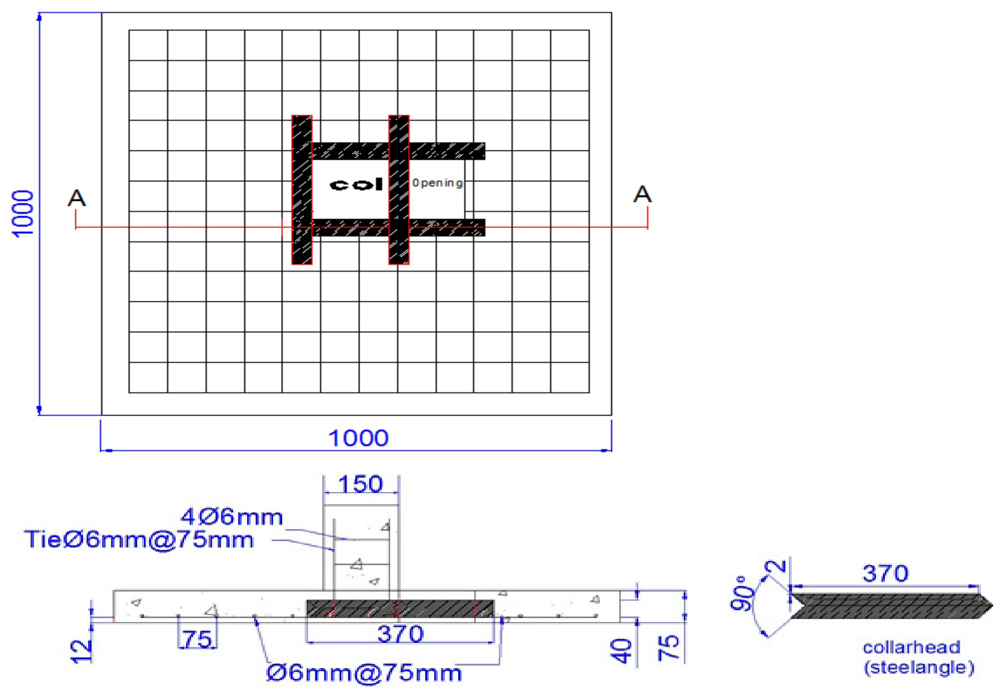

Figure (5) Dimension and Layout of Slab with Collar Head all sides of col NO4

4.Concrete Mix, Casting and Curing

The following steps are followed before mixing;

- The fine aggregate is washed and dried to remove any clay particles.
- The coarse aggregate is sieved on (10 mm) sieve size to remove the large size aggregate particles. Then, the aggregate is also washed and dried.
- Preparing the weights.

5.Testing Machine:

Testing is conducted by using MFL system of hydraulic universal testing machine type EPP300, with a maximum capacity of (3000 KN) . Before testing, a thin layer of white emulsion paint is applied onto the surface of the specimen to aid the detection of cracks, the rate of loading was 10 KN.

6.Discussion and Results

6.1 Cracking Load and Crack Pattern:

The test results of cracking and ultimate loads of slab in group G1 are illustrated in table (2) , the first crack is formed at about (40-48.27) % of the ultimate load for each slab. In group two which contains Glenium-51 as a superplasticizer, with (w/c %=0.32), and the test results of cracking ultimate loads of slab of this group are illustrated in table (2). The first crack forms roughly circular in shape and occurs under the loaded area in the tension face of the slab by about (43.33-48.5) % of the ultimate load for each slabs.

6.2. Crack Width

In general, crack widths are measured using special crack measuring instrument having a minimum thickness of 0.05 mm. At early stages of loading cracks widen slowly when loading continues until yield at reinforcement cracks become wider with excessive widening at small increments of loads. The test results show the maximum crack width decreases when compressive strength of reinforced concrete slabs increases and for specimens which have openings, one found the crack width in the larger value relative to reference, and in the specimen which have openings that reinforced by collar head the maximum crack width decreases relative to specimens which have opening only. Figures (8) to (9) show the load-crack width curve for each group of specimens.

In general :

In the reference slab NSCR, the first crack occurs at 40KN and this value decreases in the specimens which have openings adjacent to the column NSC1 to be (75)% of its reference. When we used collar head in the sides of column toward the opening NSC2, this percentage increases at(87.5) to its reference and also it is the same percentage in NSC3, and reach to 100% at NSC4 which was the collar head in the entire column and extend to opening. In the reference slabs NSCR, the maximum crack width is 2.6mm and increases in specimen which had opening NSC1 to (2.85) mm and in NSC2,NSC3 the value decreased until became (2.2mm) in NSC4and it was less than from that reference because of presence of collar head . The additive (Glenium-51) increases the compressive strength and hence results in an increase in the shear resistance at slabs of this group . In the reference slab HSCR the first crack load is the higher value than other slabs in the group, and this value decreases in the specimen which have openings adjacent to the column . When used collar head in the sides of column toward the opening HSC2, this percentage was increased at(64.28%) from reference slab and increased for HSC3 and reached to 92.86% at HSC4 which was the collar head in the entire the column and extends to opening. In the reference slabs HSCR, the maximum crack width was 2.3mm it was less than from that in group one (NSCR), that belong to increase in compressive strength of RC slabs. The crack width increased for specimen which has opening HSC1 to (2.45) mm and in HSC2,HSC3 the value decrease until to(1.8) in HSC4 and this value was less than the reference that belong to presence of collar head.

Table (2) Cracking Load of Tested Slabs

Group No.	Specimens	First Crack Load (Pcr)KN	Ultimate Load (Pu)KN	$\frac{Pcr}{Pu}$%	Maximum Crack Width (w)mm	$\frac{Pcr}{PcrR}$%	Mode of Failure
G1	NSCR	40	90	44.4	2.60	-	Punching
	NSC1	30	70	42.85	2.85	75.0	Punching
	NSC2	35	72.5	48.27	2.45	87.5	Punching
	NSC3	35	82.5	42.42	2.35	87.5	Punching
	NSC4	40	87.5	40	2.20	100.0	Punching
G2	HSCR	70	*155*	*45*	2.30	-	Punching
	HSC1	40	*82.5*	*48.5*	2.45	57.14	Punching
	HSC2	45	*95*	*47.5*	2.25	64.28	Punching
	HSC3	*60*	*132.5*	*45.3*	2.15	*85.71*	Punching
	HSC4	*65*	*150*	*43.33*	1.80	*92.86*	Punching

Plate (1) Tension Facefor Slab NSCR

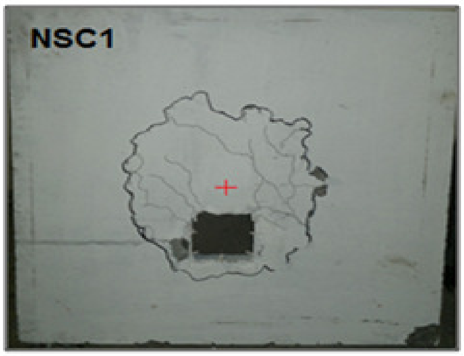

Plate (2) Tension Facefor Slab NSC1

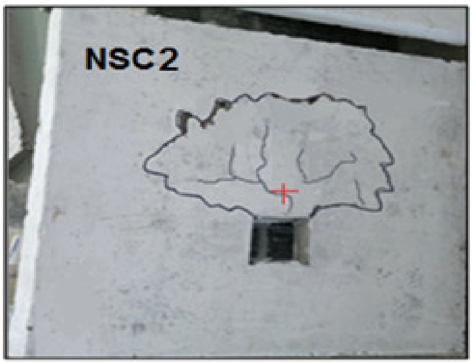

Plate (3) Tension Facefor Slab NSC2

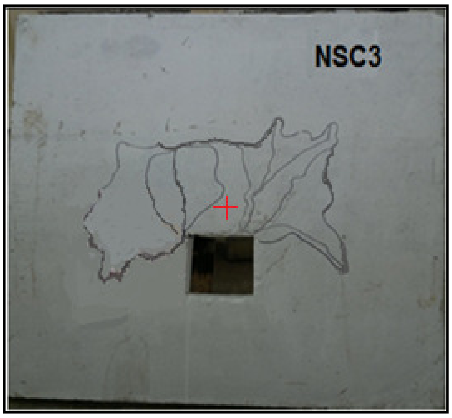

Plate (4) Tension Facefor Slab NSC3

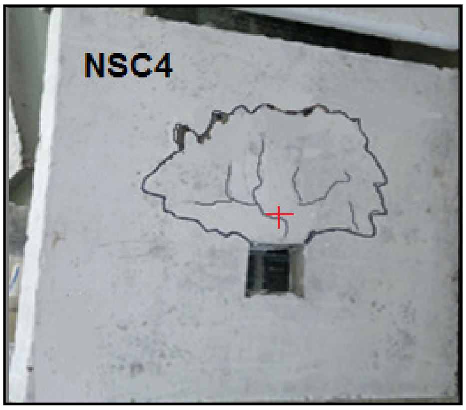

Plate (5) Tension Facefor Slab NSC4

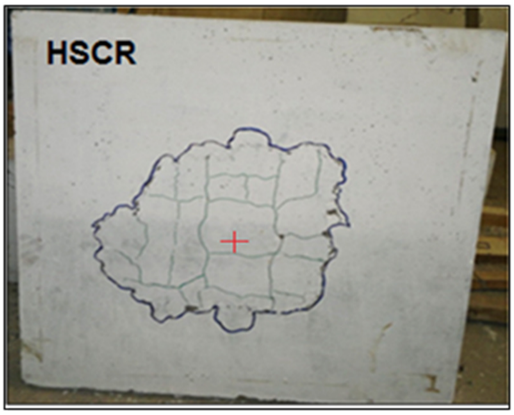

Plate (6) Tension Face for Slab HSC1

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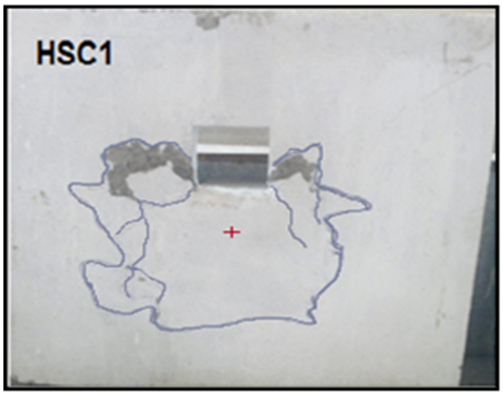

Plate (7) Tension Face for Slab HSC1

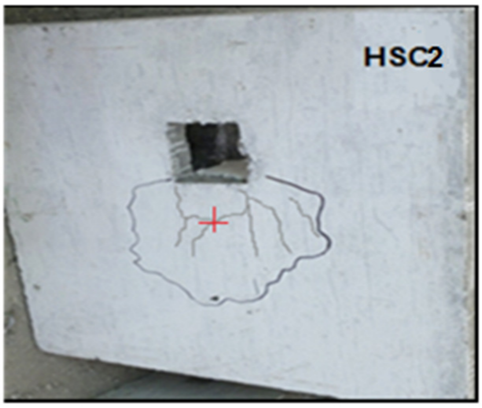

Plate (8) Tension Face for Slab HSC2

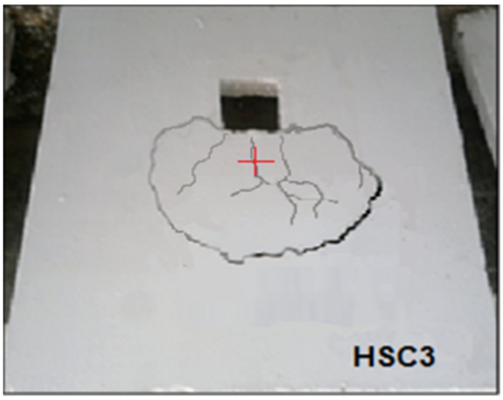

Plate (9) Tension Face for Slab HSC3

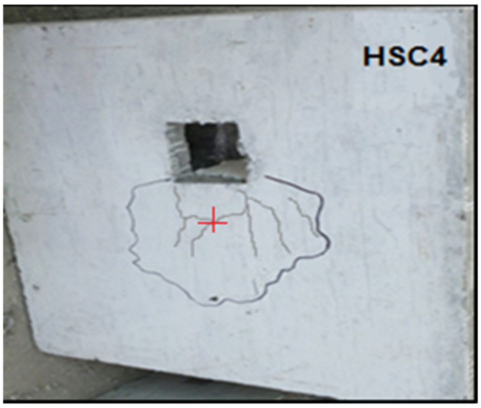

Plate (10) Tension Face for Slab HSC4

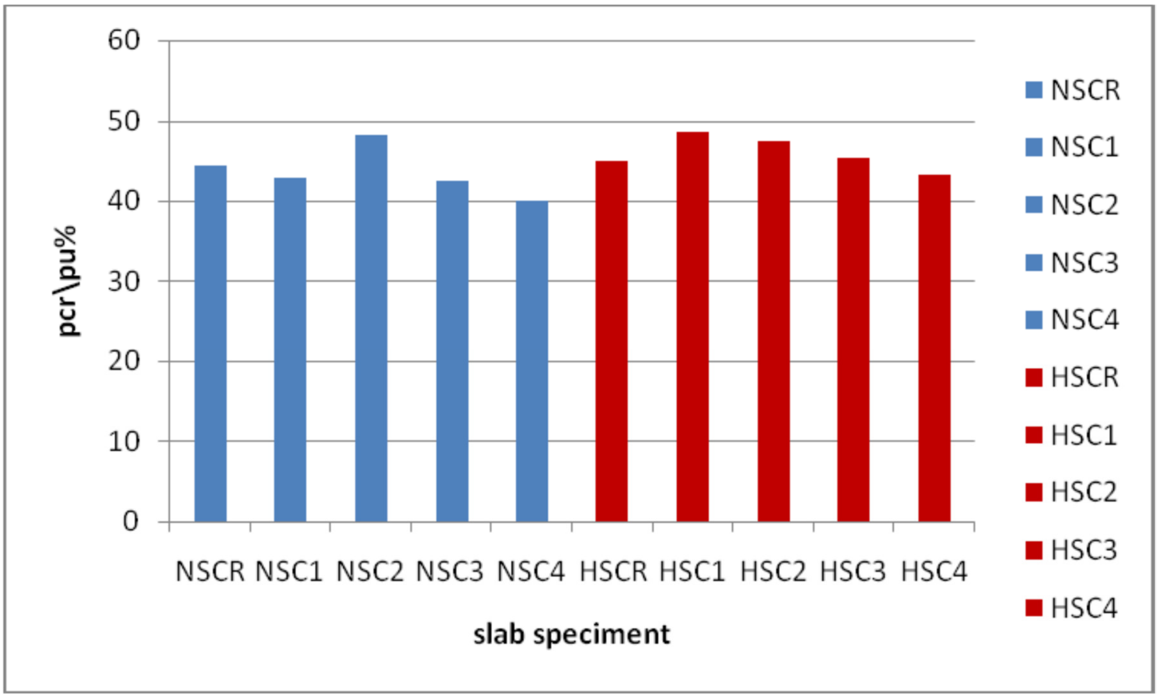

Figure (6) Cracking Load for all tested specimens

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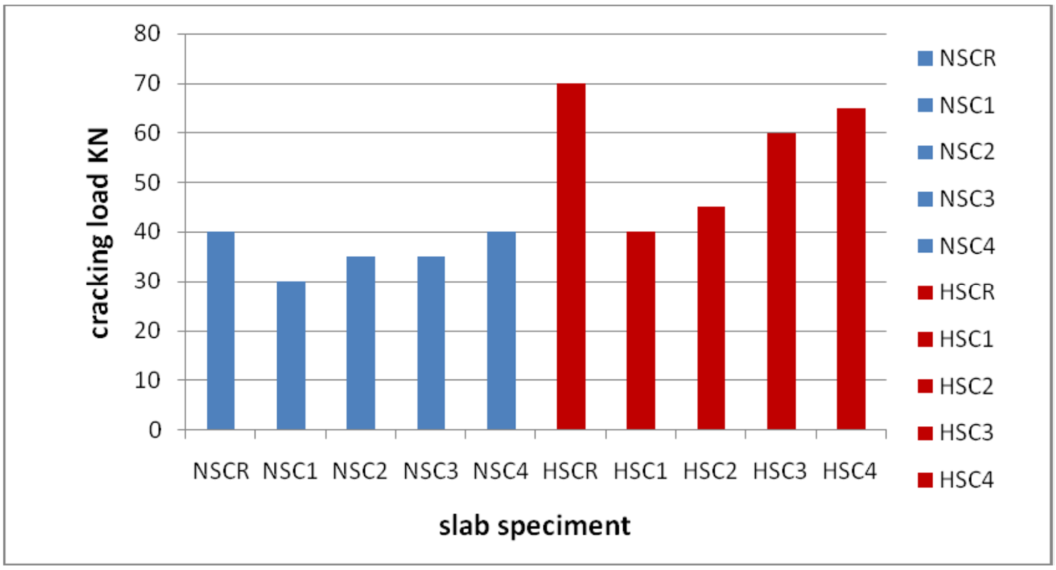

Figure (7) percentage of cracking load to ultimate load for all tested specimens

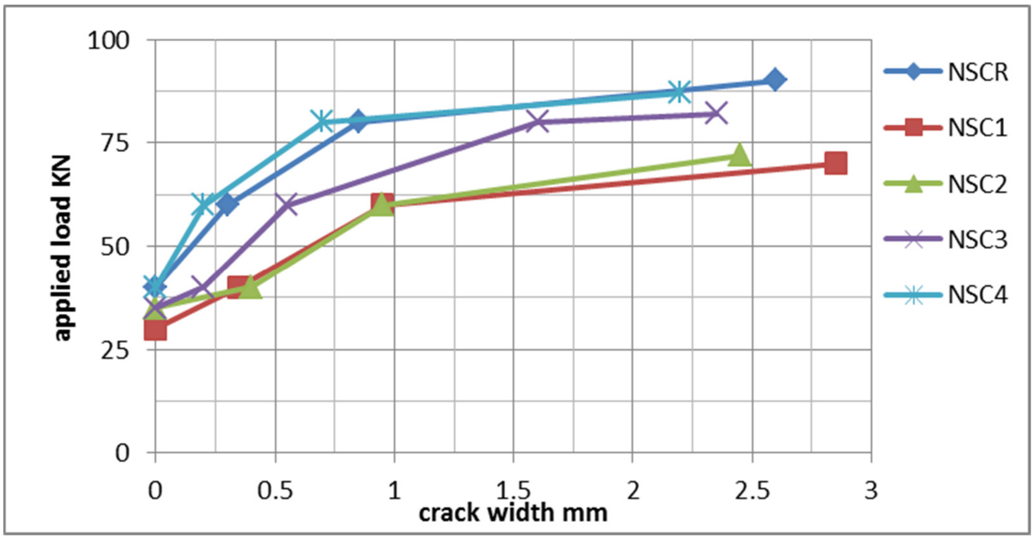

Figure (8) Maximum Crack Width for Group one

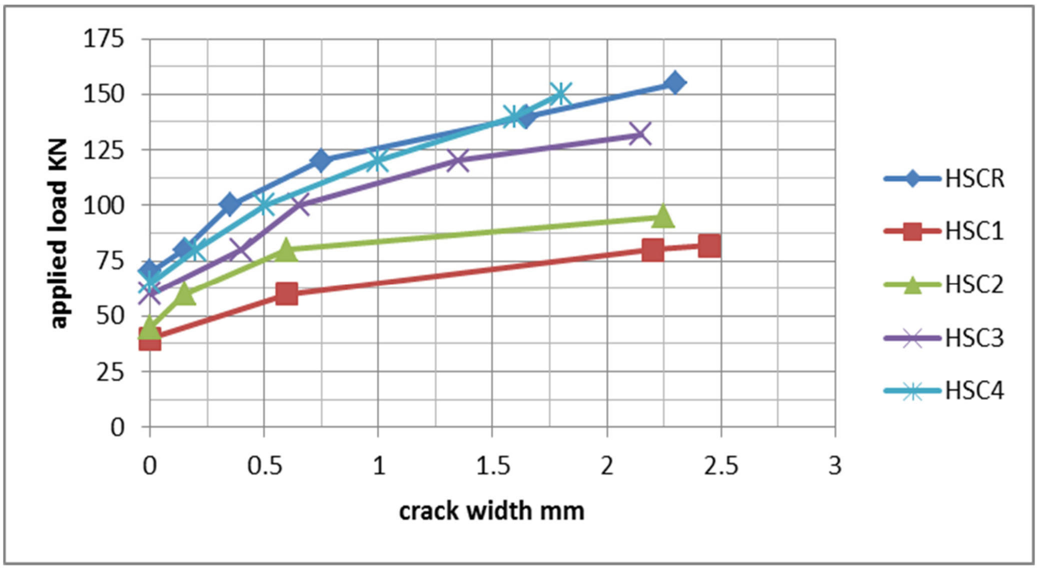

Figure (9) Maximum Crack Width for Group two

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6.3 Ultimate Load Capacity

In this study the primary aim is to determine the ultimate load capacity of specimens reinforced for punching shear by using different type of compressive strength, and reinforced the opening which presence adjacent to the column and by using collar head as shear reinforcement.

- In G1, the reference slabs NSCR, the ultimate load capacity is the highest value 90KN, relative to other slabs in that group and this value decreases in NSC1 because of openings to be (77.78%)of its reference of this group. When used collar head, the ultimate load increases to be (97.22%) of its reference in NSC4.
- In G2, the reference slabs HSCR the ultimate load capacity is the highest value 155KN relative to other slabs and this value decreases in HSC1 because of openings at (53.22%) of its reference When used collar head the ultimate load increases at (96.77%) of its reference in HSC4.

Table (3) Ultimate Load and Deflection of Tested Slabs

Group No.	Specimens	Experimental Ultimate Load (Pu)KN	$\frac{Pu}{PuR}$ %	Deflection at Ultimate Load (mm)
G1	NSCR	90	-	6.14
	NSC1	70	77.78	7.05
	NSC2	72.5	80.56	5.88
	NSC3	82.5	*91.67*	5.12
	NSC4	87.5	*97.22*	6.52
G2	HSCR	*155*	-	*7.79*
	HSC1	*82.5*	53.22	*8.00*
	HSC2	*95*	61.29	*6.90*
	HSC3	*132.5*	*85.49*	*6.17*
	HSC4	*150*	*96.77*	*8.20*

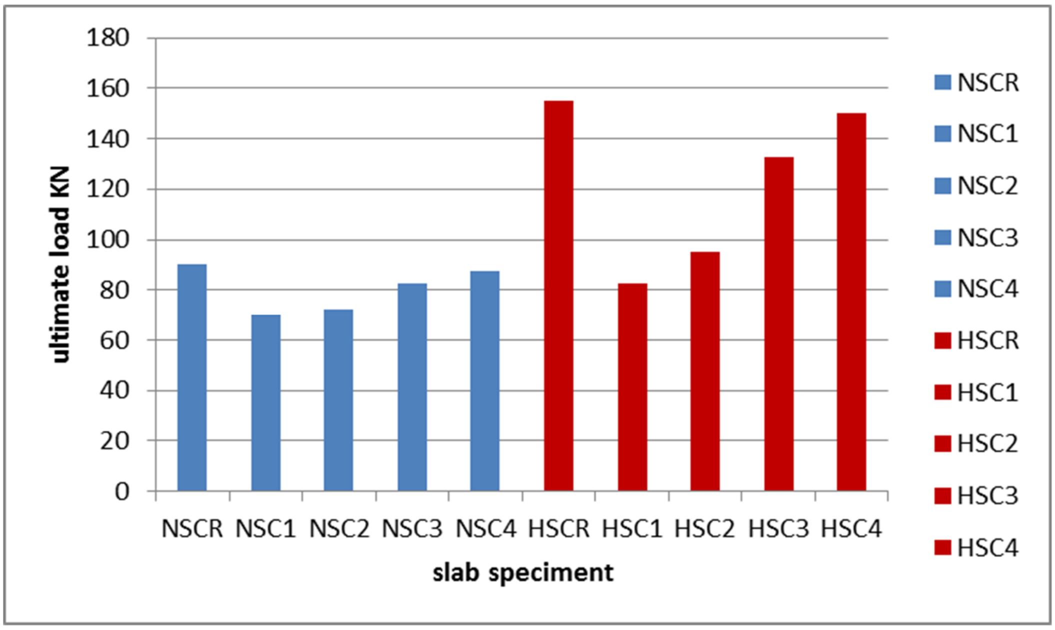


Figure (10) ultimate load capacity for all tested specimens

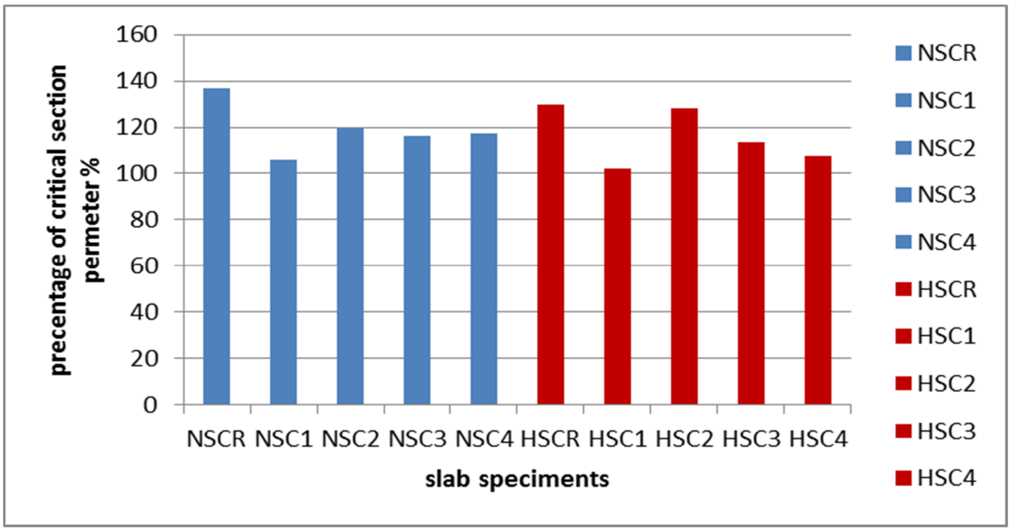


Figure (11) percentage of critical section for all tested specimens

6.4 Load-deflection Relationship

Figures (6) to (8) show the central load-deflection curve for all tested slabs in each group to illustrate the general behavior of the study specimens. The figures reflect the structural behavior of the specimens. Also, the figure illustrates the different in the stiffness value among the tested specimens through the observed values of the deflection.

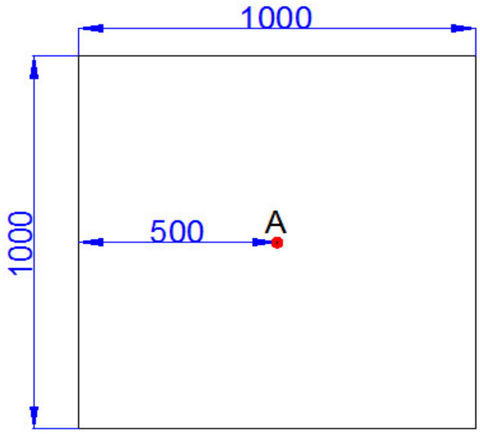


Figure (12) The Deflection Measurement

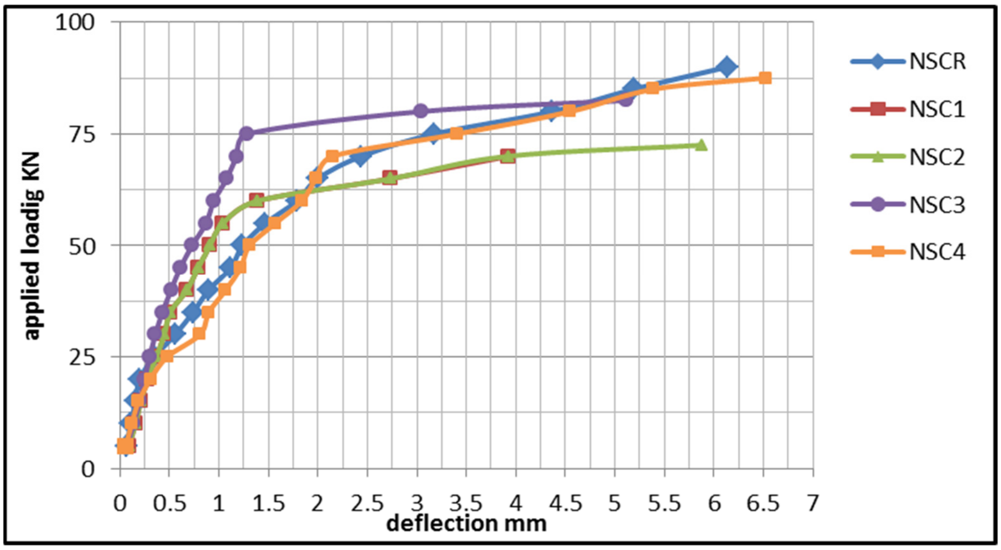


Figure (13) Central Deflection for Group One

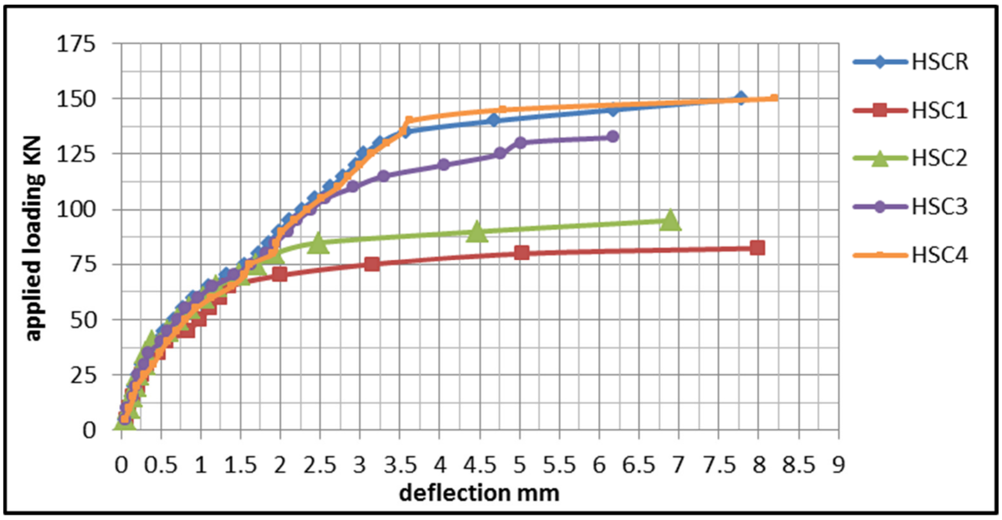


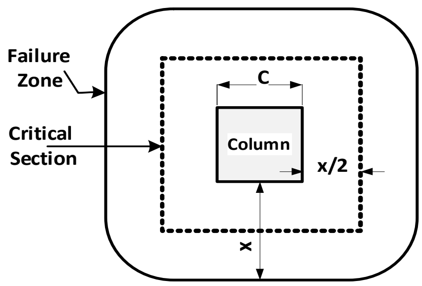
Figure (14) Central Deflection for Group two

6.5 Critical Section Perimeters

According to ACI (318-11) (ACI Committee 318, 2011), the critical section perimeter is assumed to be at (d/2) from the column face. The calculated value of the critical section perimeter in the present work equals (840 mm) according to the ACI specification and this value will be compared with all the specimens to investigate the effect of the concrete type and collar head configuration on this structural property. For the references slabs without openings, the critical section perimeter is considered as the distance (x/2) between the column side face and the end of the experimentally measured actual punching failure surface (area) on the tension face of the slab. For the rest slabs with openings, the same approach is adopted for determining thecritical section perimeter but with considering the effect of opening in decreasing the value of the critical section perimeter.

Table (4) Critical Section Perimeter of tested slab

Group No.	Specimens	Calculated Failure Area (A) mm^2	Calculated Distance of Failure Face (x) mm	Calculated Critical Section Perimeter mm	Percentage of Critical Section Perimeter (840 mm) %
G1	NSCR	164675	138	1152	137.0
	NSC1	152910	110	890	105.9
	NSC2	211125	184	1002	119.3
	NSC3	187990	169	975	116
	NSC4	202445	178	984	117.14
G2	HSCR	143575	123	1091	129.9
	HSC1	138380	101.6	856.4	101.95
	HSC2	187335	157	1078	128.3
	HSC3	171270	168	954	113.57
	HSC4	162205	151	903	107.5



Method used to Calculate Critical Sections for Solid Slab[7]

For solid slabs:

$$A = C^2 + 4Cx + \pi x^2$$

$$\pi x^2 + 4Cx + (C^2 - A) = 0$$

$$x = \frac{-4C + \sqrt{(4C)^2 - 4\pi(C^2 - A)}}{2\pi}$$

Critical section is assumed at a distance (x/2) from face of column lies in solid side of tested specimen

7.Conclusions

According to the test program carried out in the present study, the following conclusions can be drawn :-

- The configuration of the collar head is considerably effective in enhancing the structural behavior of the flat plate slab with opening.
- In general, specimens with collar head is strengthening the entire column sides and extending to the opening achieve the better results
- The concrete type has also a considerable activity on the behavior of the flat plate with opening, that increases the compressive strength of the section means improvement in structural behavior of the flat plate with opening.

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