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Effect the Depth of Shearhead on the Behavior of Reinforced Concrete Flat Plate Slabs

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Abstract
This research presents an experimental study of effect the depth of shearhead on the behavior of reinforced concrete flat plate slabs. Three reinforced concrete slab specimens were casted and tested under static load. The effect of different section depth of shearhead has been discovered through studying its impact on the load-deflection behavior, ultimate capacity, cracking load, failure mode, stiffness, ductility and energy absorption of tested specimens. The result appeared that the specimen with large section height of collar shearhead gives an increase in ultimate capacity and first crack about 83.5% and 34.6% respectively over reference specimen So (without shearhead).Also, the reduction in stiffness at failure of specimen CS8 is 82.7% ,its clear more than that of specimen CS7, in comparison with it's stiffness at 25% . The increasing in energy absorption was about (127.7%) of specimen with large section height in comparison with reference specimen. It is concluded that the loading capacity, stiffness, ductility and energy absorption increased with increasing section depth of shearhead .

Introduction

When beams, column capitals or drop panels are not used, uniform width solid concrete slabs are usually called flat plate slabs; in this case, slabs carry their own weights and external loadings directly to the supporting columns. This construction method is typically utilized in multistory buildings occupied as offices or as car parking .The main reason of adopting flat plate slab construction method is to gain the space typically occupied by beams and girders in other slab systems [1].

Flat plates experience non-traditional stresses that should be considered even when the applied loads within the normal range. Unlike traditional slabs, flat plate slabs encounter remarkably high shear and bending stresses at slab-column joint locations. These stresses could lead to structural failure if not taken into account adequately. Such stresses become even higher at edge and corner columns .The ultimate concern regarding the higher values of shear and bending moments developed at flat plate slab-column joints is that they could lead to punching failure which in turn could impose sudden collapse[1].

Punching shear strength capacity can be maximized by using the conventional amount of shear reinforcement as shearhead reinforcement; however, the required reinforcement amount can be impractically increased when thinner concrete slabs are considered [2]. shearhead can be defined as an element that is added to slab-column joint for structural purposes. The loads transferred from the slab to column through the joints can develop high shear stresses at the joint and thus lead to punching shear failure . Shearheads can effectively aid in reducing the concentration of vertical loads applied on the column by distributing them around it in order for shifting the critical shear section far from the column face and hence increasing the perimeter that will resist the applied punching shear [3].

Experimental Work

1. Specimens details

All the slabs have same dimensions (1000x1000x80) mm for (length x width x thickness) respectively, and have same flexural reinforcement is deformed mesh bars (ϕ6@150mm) and simply supported along all edges and the distance from c/c of support was (900mm). Two specimens with circular shearhead as shear reinforcement of diameter (550)mm and one is without shear reinforcement as a reference specimen . The variable which adopted in this study is the section depth of collar shearhead (30 and 40) mm with one stiffener in each direction. The steel column dimensions are (100X100) mm loaded at the center of slab. See Figure (1), (2) and plate (1). The specifications and details of these slabs are listed below:

1-Slab S_O: It is cast without punching shear reinforcement.

2-Slab CS7: It is cast with (550) mm diameter of circular shearheads, one stiffener of (520 x 30 x 3)mm of (length x height x thickness) in each direction .

3- Slab CS8: It is cast with (550) mm diameter of circular shearheads, one stiffener of (520 x 40 x 3)mm of (length x height x thickness) in each direction .

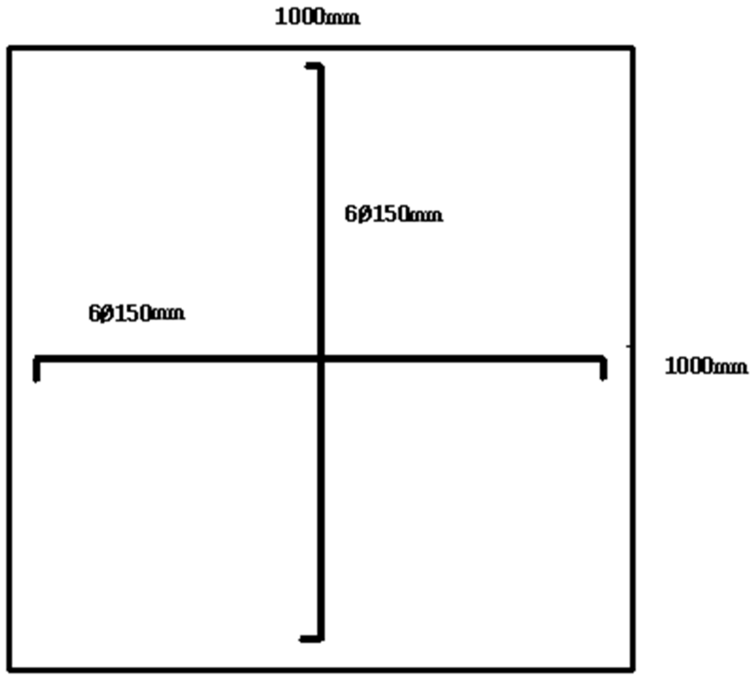


Figure (1) Specimens Reinforcement

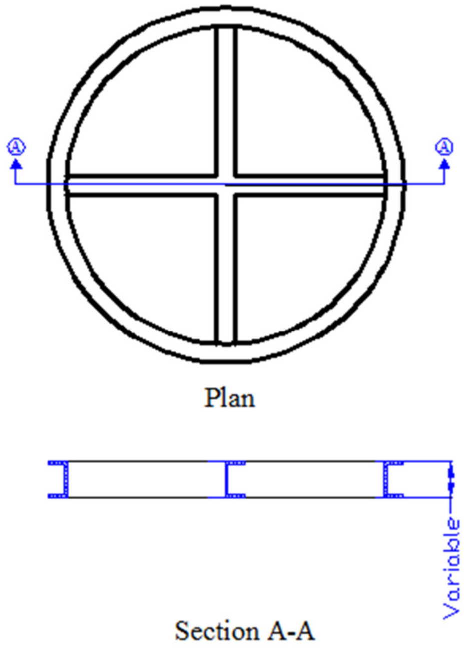


Figure (2) Circular Shearhead

plate(1) Position of Shearhead

2. Materials

a. Cement

The type of cement used in this study is ordinary Portland cement (Type I), the Tables (1) and Table (2) contains the chemical and physical properties of cement.

Table (1) Chemical Composition of Cement

Compound Composition	Chemical Composition	Percentage By Weight	Limit of IOS:5/ 1984[4]
Lime	CaO	63.11	------
Silica	SiO_2	20.37	------
Alumina	Al_2O_3	5.15	------
Iron Oxide	Fe_2O_3	4.39	------
Magnesia	MgO	1. 68	<5
Sulfate	SO_3	2.57	<2.8
Loss on Ignition	L.O.I	2.72	<4
Total	-	99.99	Total
Lime Saturation Factor	L.S.F	0.92	0.66-1.02
Tricalcium aluminates	C_3A	6.22	------
Tricalcium silicate	C_3S	49.23	------
Dicalcium silicate	C_2S	21.50	------
Tricalcium alumona ferrite	C_4AF	13.34	------
Insoluble residue	I.R	0.69	<1.5

Table (2) Physical Properties of Cement

Physical Properties	Test result	Limit of IOS 5/1984[4]
Finess using Blaine air permeability apparatus (cm^2/g)	4426	> 2300
Setting time using Vicat's instrument		
Initial (min)	190	> 45 min
Final(hrs)	5:00	< 10 hr
Compressive strength for cement paste at		
3 days (MPa)	24	>15
7 days (MPa)	32	> 23

b. Coarse Aggregate

The maximum size of coarse aggregate used in this study is (12) mm. The sieve analysis of coarse aggregate is listed in Table (3).

Table (3) Grading of Coarse Aggregate

No.	Sieve Size (mm)	Present Work of Coarse Aggregate (% Passing)	Limits of Iraqi specification No.45/1984[5]
1	20	100	100
2	14	100	90-100
3	10	74.5	50-85
4	5	3.5	0-10
5	2.36	---	---

c. Fine Aggregate

The maximum size of fine aggregate used in this study is (5) mm. The sieve analysis of fine aggregate is listed in Table (4).

Table (4) Grading of Fine Aggregate

No.	Sieve size(mm)	Cumulative passing (%)	Limits of Iraqi specification No.45/1984[5] zone 2
1	10	100	100
2	4.75	90.55	90-100
3	2.36	87.31	75-100
4	1.18	63.1	55-90
5	0.6	43.51	35-59
6	0.3	14.64	8-30
7	0.15	0.02	0-10

3. Concrete Mix, Casting and Curing

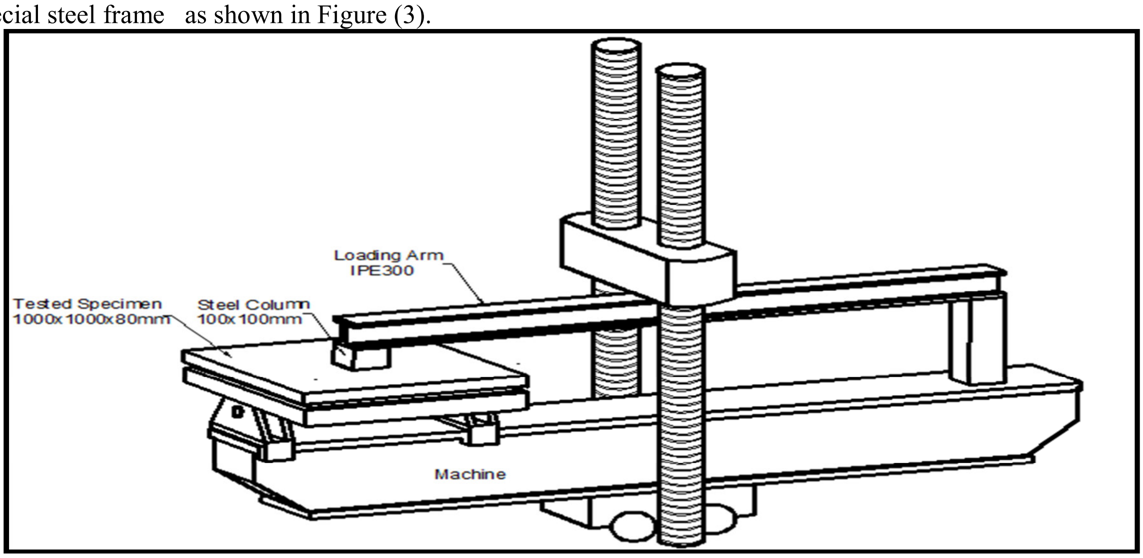
1. To get rid from the clay particles, the sand was bathed and dried .
2. To remove large particles, the gravel was sieved through (14)mm sieve size.
3. To remove the dust and clay particles from the gravel ,the gravel was washed carefully.
4. Weight preparation by using electronic balance with 40 kg capacity.

To achieve good workability and homogeneity ,it is necessary to follow the appropriate method to mix the concrete as provided by the ACI committee 211.1-9 [6].According to this specifications, the required mixing time ranging from 6 mints to 8 mints by using 0.19m^3 drum mixer .

After (24) hours, the specimens were stripped from the molds and cured (kept) in water bath for (28) days with almost constant laboratory temperature. Before (24) hours from test date, they were taken out of the water bath and then tested in accordance with the standard specifications after painted by using white washer.

4. Testing Machine

A universal test hydraulic machine have 3000 kN maximum capacity was used to apply the load through a special steel frame as shown in Figure (3).



Figure(3) Testing Set up

5. Discussion and Results

5.1 Load-deflection Relationships:

The mid –span deflection of the control and strengthened slabs where recorded at a constant load steps (each 2.5 kN) and the deflection also recorded under the point load at the center of the slabs.

The initial linear stage named as un-cracked stage; its elastic state of the member, the member restore to its original state when releasing. After cracking stage, the slop of the curve starts to decrease with loading. This decrease in slop is attributed to losses in stiffness accompanied with cracking of concrete and increases the deformations. It was observed that the deflection at the center of the reference slab (S_o) was larger than that of strengthen specimen CS7 and CS8. The effect of cracking of the concrete is more noticeable in slab CS8 than CS7, cracks tend to form completely across the slab section. So, there is large reduction in stiffness accompanied with large increase in deflections. Almost, the first crack could be detected by observing the point of slop decreasing. A yield lines are significantly appeared at the tension face of the slab, which might be giving an indication on the yielding of reinforcing steel bars.

In post-yielding stage, the large deflections increments were clearly occurred, in addition to increase in crack width until failure of the specimen by flexure.

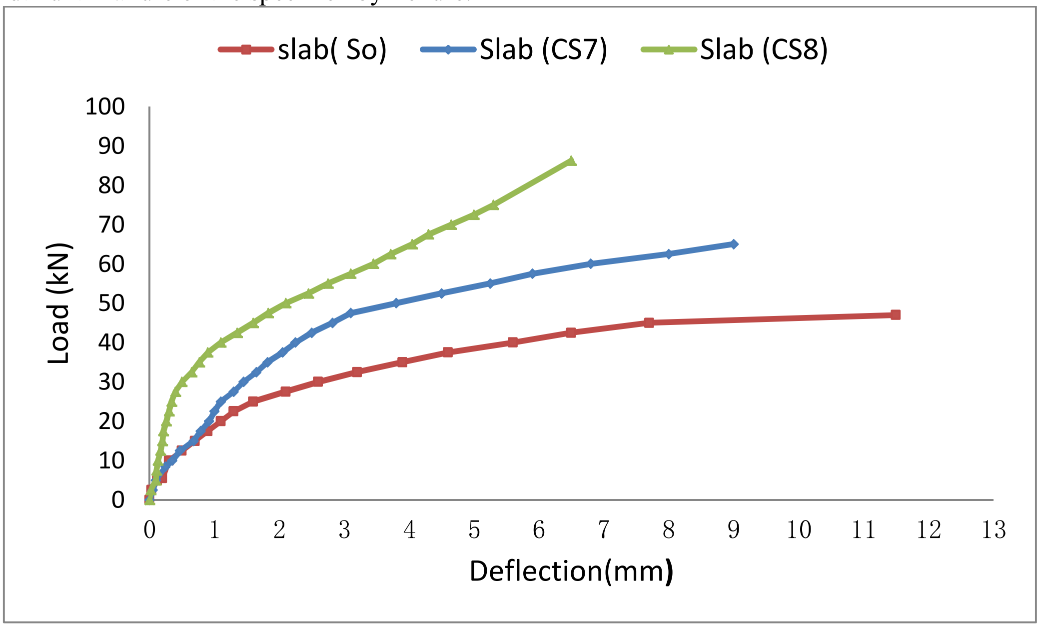


Figure (4) Load –Deflection Curve

5.2 Ultimate Capacity :

Two sections height of shearhead were used; 30mm and 40mm for specimens CS7 and CS8 respectively, the 40mm section height embedded in specimen CS8 gives an increase in ultimate capacity about 83.5% over reference specimen So (without shearhead). Also, the specimen CS7 gives an increase about 38.2% over reference specimen So.

Table (5) The Load Capacity and First Crack of The Tested Slab

specimen	First Crack	% Improvement of P_{cr}	Ultimate Load (Pu)	% Improvement of P_u	P_{cr}/P_u %	Mode of failure
So	13	R	47	R	27.6	flexure
CS7	8.5	*34.6	65	38.2	13	flexure
CS8	17.5	34.6	86.25	83.5	20.5	flexure

Where: * is decrease of improvement and R is the reference specimen

5.3Cracking Load:

The first crack was occurred under the loaded area in the tension face of the slab at 8.5 kN for slab CS7 and 17.5 kN for specimen CS8, the first crack was increase about 34.6% in specimen CS8 that have larger height (40)mm of circular shearhead than the reference specimen So (without shearhead), the large section contribute to reduce the depth of neutral axis inside the section. So, the punching stresses increased at the connection in comparison with specimen that have small height of shearhead.

5.4 Mechanical Behavior of Slabs

Three specimens were tested under static load; the failure mode of all specimens was interpreted as a flexural failure in which the flexural cracks were observed to form simultaneously at failure. At the compression surface a few longitudinal flexural crack formed near mid span. Although, the tension surface crack could be formed at a specific stage of loading, it's proposed that the longitudinal crack at the tension face initiate firstly than extended to the full depth of the slab.

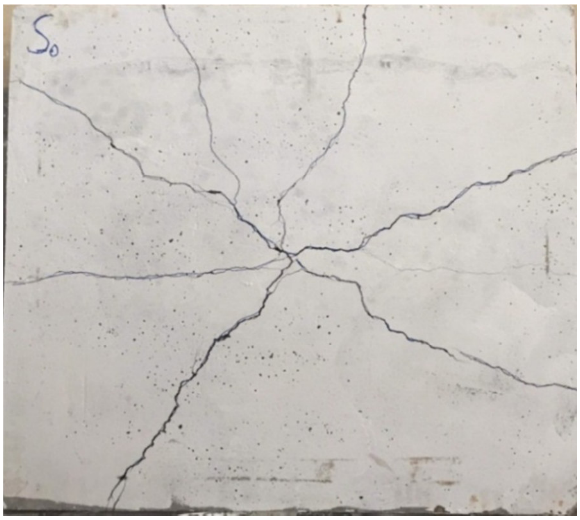


Plate (2) The Reference Specimen(So)

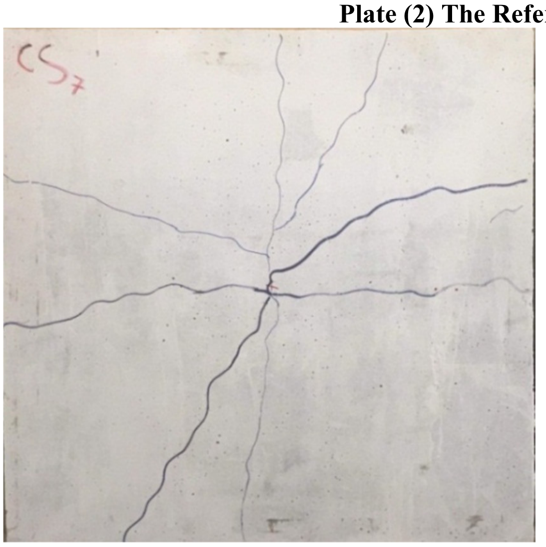


Plate (3) The specimen (CS7)

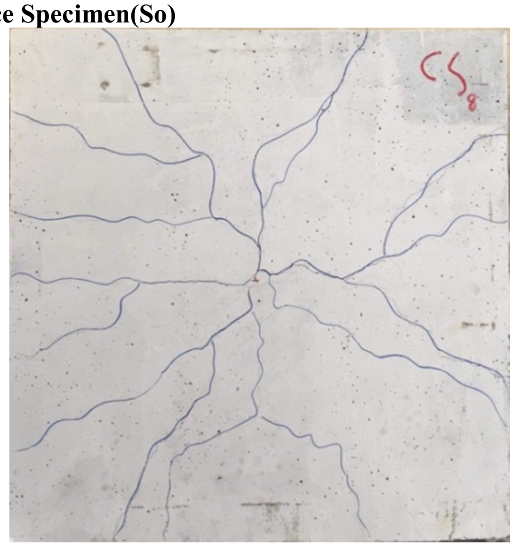


Plate (4) The Specimen (CS8)

5.5Crack Pattern and Failure Modes

In general, slabs with shearhead reinforcement have first cracks load about 13% and 20.2% of ultimate load for specimen CS7 and CS8 respectively. While, the reference specimen have first crack load about 27.6% of ultimate load. All specimens failed by flexural mode and appeared ductile behavior. In post-yielding stage the crack width increased significantly and the cracks divided the slab into four pieces due to create an internal hinge at crack.

5.6 Stiffness :

Stiffness can be defined as the resistance of an elastic body to deformation by an applied force and can be expressed as:

$k = F / \delta$ ---(1)

where:-

k = stiffness (N/m, lb/in), F = applied force (N, lb), δ = deflection (m, in)

It is important to measure the effect of shearhead reinforcement on the flat plate stiffness. The rate of degradation in stiffness is an indication of their damage through loading life [7].

Randomly, a specific points in load – deflection curve has been selected to follow the decrease in stiffness;

25%, 50%, 75% and 100% of ultimate load were selected to determine the stiffness and make a comparison between them.

The depth of the shearhead section effect on the amount of degradation of stiffness through loading life. At 50% of ultimate load, there is a 12.8% reduction in stiffness of specimen CS7, and 59.2% a reduction in stiffness of specimen CS8 in comparison with it's stiffness at 25%. At 75% of ultimate load, there is a reduction in stiffness about 40% and 78.4% for specimen CS7 and CS8 in comparison with it's stiffness at 25% respectively. At the failure, the reduction in stiffness of specimen CS7 is 68%, while ,the reduction in stiffness specimen CS8 is 82.7% . i.e , the reduction in stiffness at failure of specimen CS8 is clear more than that of specimen CS7, in comparison with it's stiffness at 25% . It was observed that the stiffness of reference specimen is less than specimens with shearhead in 50%,75%and100% of ultimate load; at 50% of ultimate load, there is a 38% reduction in stiffness, and 66.2% a reduction in stiffness at 75% of ultimate load, and about 83.9% reduction in its stiffness at 100% load level in comparison with it's stiffness at 25%.

Table (6) The Stiffness of Tested Slabs

Specimen	Stiffness at 25% (1)	Stiffness at 50% (2)	% decreasebet.(1) and(2)	Stiffness at 75% (3)	% decrease bet.(1) and(3)	Stiffness at 100% (4)	% decrease bet.(1) and(4)
So	26.11	16.2	38%	8.81	66.2%	4.2	83.9%
CS7	22.5	19.6	12.8%	13.5	40%	7.2	68%
CS8	76.7	31.25	59.2%	16.5	78.4%	13.2	82.7%

5.7 Energy Absorption

The energy absorption can be defined as the energy of a material can absorbed before failure. The brittle material absorbed a little energy before failure; the failure is sudden and uncontrolled. While, ductile material has ability to absorb a great amount of energy before failure, it can be determined from the area under load-deflection curve [8].

The using of shearhead with large height improved the energy absorption of specimen such as slabs CS7 and CS8 with shearhead depth 30 mm and 40 mm respectively, the increasing in energy absorption was about (127.7%) of specimen CS8 in comparison with reference specimen and about 2.18% over reference specimen for specimen CS7.

Table (7)The Energy Observation of Tested Slab

Specimen	Energy absorption (kN.mm)	Percentage(%) Improvement of energy absorption
So	415.9	R
CS7	425	2.18
CS8	947.25	127.7

R is the reference specimen.

5.8 Ductility

Ductility may be defined as the ratio of the maximum deflection at ultimate load to the deflection at yielding. There are two types of failure; ductile failure with a prior notice before fracture and the brittle failure which characterized by suddenness and the failure is un-controlled [9] .Table (8) shows the deflection reading at ultimate carrying capacity, deflection reading at yield load and the ductility index for each specimen. Using shearhead section height effect positively on ductility index of tested slabs; 16% and 60% increasing in ductility when using 30mm and 40mm embedded shearheads in comparison with reference specimen So.

Table (8) the Ductility of Tested Slab

specimen	Δu (deflection at failure)(mm)	Δy (deflection at yield)(mm)	Ductility index	% increase in ductility index
So	11.5	4.6	2.5	R
CS7	9	3.1	2.9	16
CS8	6.5	1.6	4	60

***R is the reference specimen of each group.**

5.9 Load –strain Relation of Concrete

Strain was measured for each slab on the concrete at compression face at distances (d) and (d/2) from the column edge of reference specimen and (d) and (d/2) from shearhead edge in other specimens in diagonal direction. To allow a comparison of concrete strains in different specimens, the concrete strains for each specimen at maximum and yield load are shown in Table (9) and(10).

In Table (9), the specimen with large section depth 40 mm (CS8) achieved maximum strain at failure about (0.815 $x10^{-3}$), while , the specimen of small section depth 30 mm (CS7) achieved maximum strain at failure about (0.788 $x10^{-3}$), the reference specimen recorded a maximum strain at failure about 0.989 $x10^{-3}$. All specimens failed in flexural mode accompanied with yielding strain 0.345$x10^{-3}$, 0.575 $x10^{-3}$ and 0.399 $x10^{-3}$ for specimens So, CS7 and CS8 respectively.

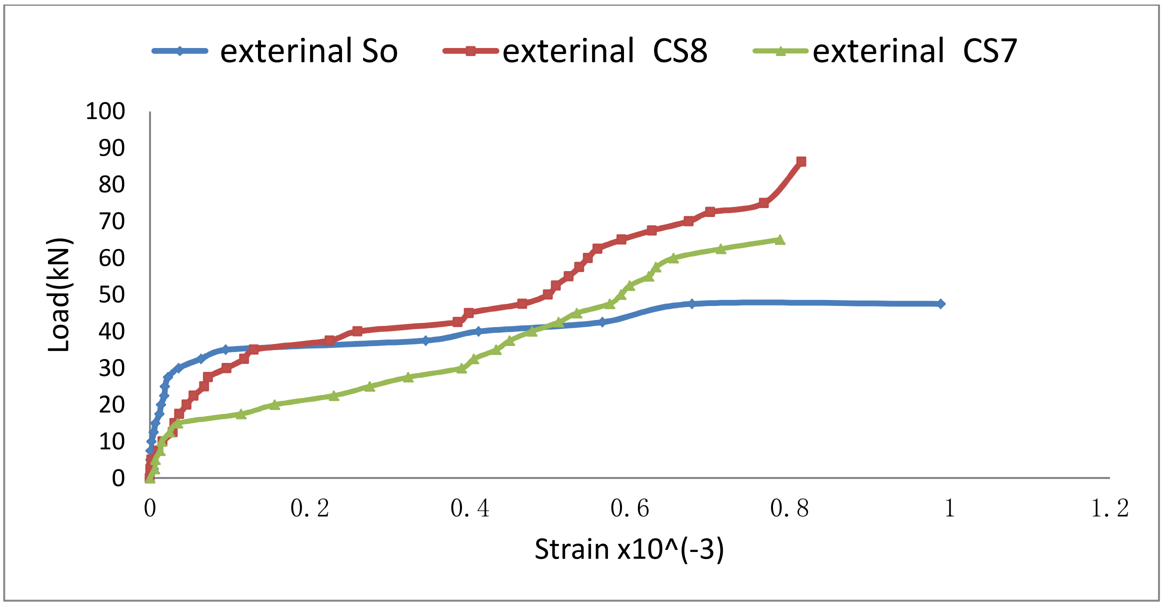
When strain was measured at a distance (d/2), it give the same indication as in distance (d) in terms of increase strain due to change section height of shearhead .

Table(9) The Strain of Concrete at Distance (d)

specimen	Yield load kN	Yield strain$x10^{-3}$	maximum strain$x10^{-3}$
So	37.5	0.345	0.989
CS7	47.5	0.575	0.788
CS8	45	0.399	0.815

Table (10) The Strain of Concrete at Distance (d/2)

Specimen	Yield load kN	Yield strain $x10^{-3}$	maximum strain $x10^{-3}$
So	37.5	0.236	0.654
CS7	47.5	0.385	0.655
CS8	45	0.306	0.772



Figure(5) The Strain of Concrete at Distance (d)

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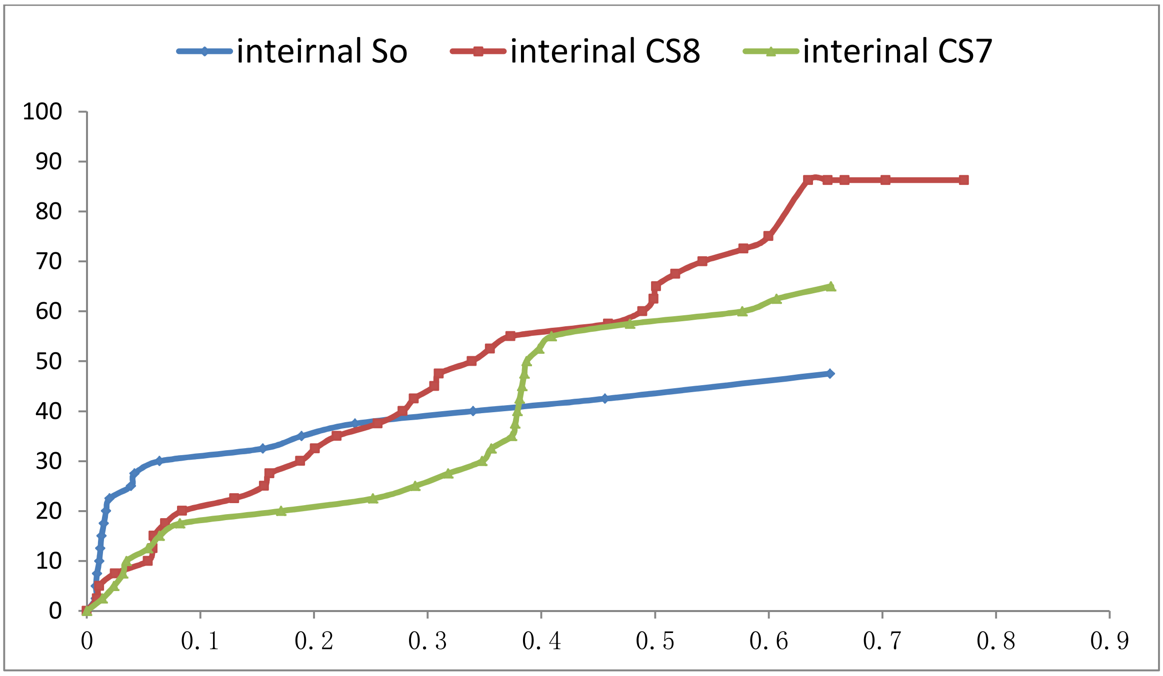


Figure(6) The Strain of Concrete at Distance (d/2)

5.10 Load –strain Relation of Collar Shearhead

For each slab, strain was measured in the collar shearhead at two places; at edge and center of collar shearhead. When strain measured at central of shearhead there is slightly increase in strain about (3.1%) when the height of collar shearhead increase with respect the specimen CS7.

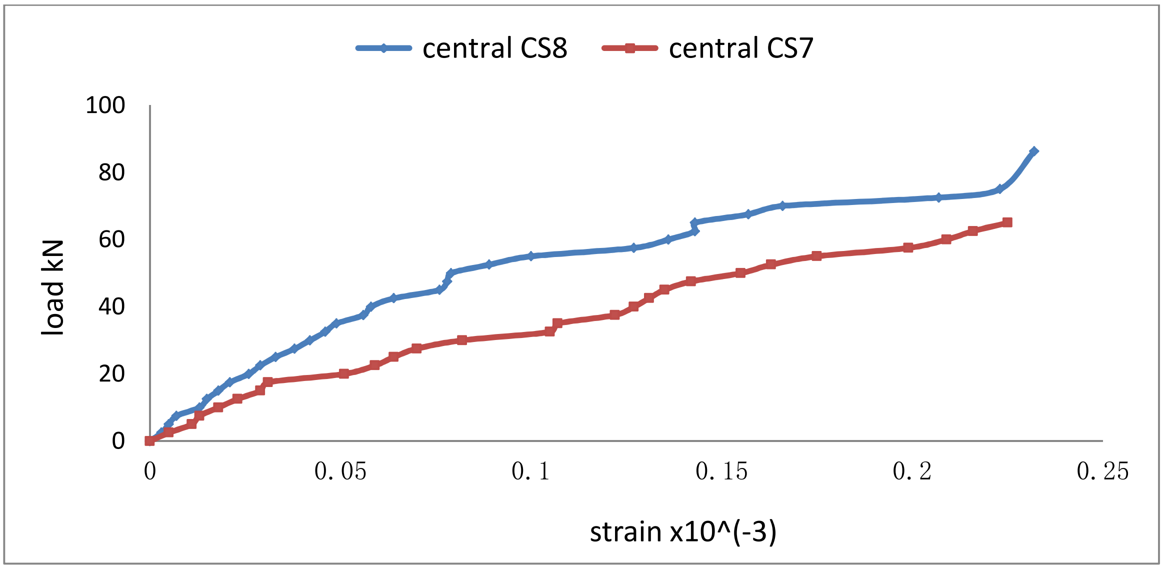
Also for each specimen, the strains were measured at edges of collar shearhead. The maximum strain is (0.945×10^{-3}), it was observed in specimen (CS8) that have the large height shearhead reinforcement (40)mm , the yield strain in specimen (CS7) and (CS8) is 0.35 $\times10^{-3}$ and 0.114 $\times10^{-3}$ respectively .

Table (11) The Strain of Collar Shearhead at Central

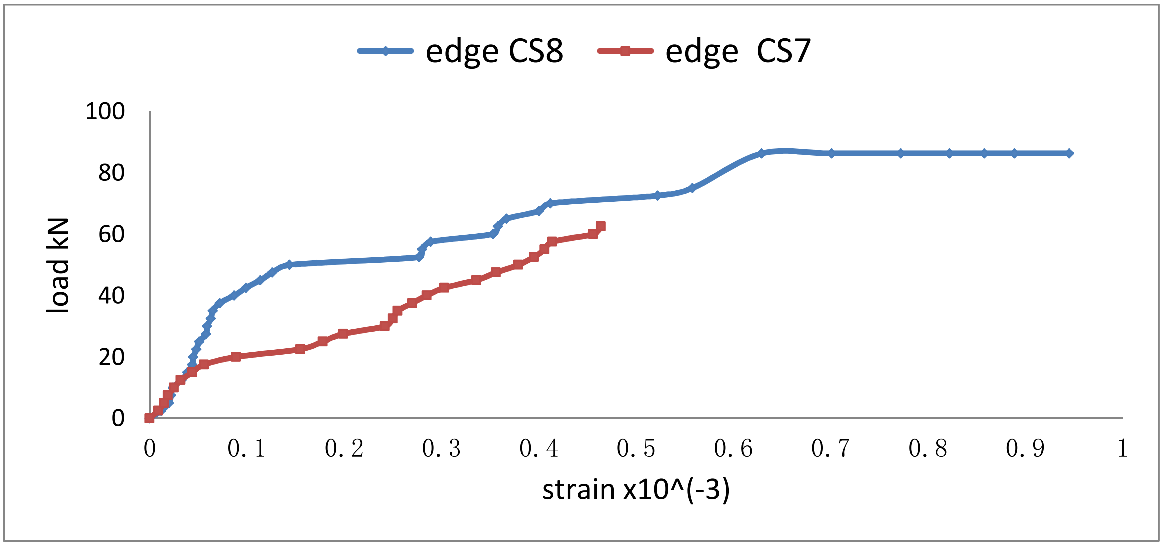
Specimen	Yield load kN	Yield strain $x10^{-3}$	maximum strain $x10^{-3}$
CS7	47.5	0.175	0.225
CS8	45	0.076	0.232

Table (12) The Strain of Collar Shearhead at Edge

Specimen	Yield load kN	Yield strain $x10^{-3}$	maximum strain $x10^{-3}$
CS7	47.5	0.350	0.482
CS8	45	0.114	0.945



Figure(7) The Strain of Collar shearhead at Central



Figure(8) The Strain of Collar shearhead at Edge

5.11comparisons with common codes

The experimental result s of punching shear strength of tested panels were compared with common international codes of reinforce concrete ;ACI-318M-14 ,BS-8110-97,Euro code-04 and AS3600 code-94 are more commonly used of different countries .

ACI-318M-14[10] provides the following equation for punching shear strength V_c is the smallest of the following:

$$0.33\sqrt{f_c'}\ .\lambda. \qquad \text{---(2)}$$

$$0.17\left(1+\frac{2}{\beta}\right)\ \lambda\sqrt{f_c'} \qquad \text{---(3)}$$

$$0.083\left(2+\frac{\alpha_s\, d}{b_o}\right)\ \lambda\sqrt{f_c'} \qquad \text{---(4)}$$

where:

f_c' = specified compressive strength of concrete ,MPa

β =the ratio of long side to short side of the column

λ= modification factor to reflect the reduced mechanical properties of

Light weight concrete relative to normal weight concrete.
b_0 = perimeter of critical section located at d/2 from the face of the column or loaded area ,mm
d= distance from extreme compressive fiber to centroid of longitudinal tension reinforcement ,mm
α_s = 40 for interior columns, 30 for edge columns, and 20 for corner columns.
The safety factor was not affected significantly by increasing the section depth of shearhead , the safety factor of specimen CS7(with 30mm depth) and CS8 (with 40mm depth) was 3.82 and 3.88 respectively. While, the safety factor of the reference specimen recorded less value than strengthened specimens .
BS-8110-97[11] adopted the following equation for punching shear strength V_c:

$$Vc = 0.27\sqrt[3]{(100\rho \mathbf{f_{cu}})}\ \sqrt[4]{\left(\frac{400}{d}\right)}\ \left(\frac{ud}{\gamma_m}\right) \qquad \text{--(5)}$$

Where:
f_{cu} = characteristic strength of concrete
γ_m = partial safety factor for strength of materials=1.25.
d = effective depth or average effective depth of a slab.
u = perimeter of critical section at 1.5d from the column face, mm
There was a significant decrease in the factor of safety had been recorded when increasing the height of shearhead of specimens CS7(with 30mm depth) and CS8 (with 40mm depth) was 1.58 and 1.19 respectively. While, the reference specimen recorded factor of safety about (1.27).

On the other hand , European code[12] ,proposed the following equation to product a punching shear strength of flat plate panels V_c :

$$Vc = 0.18.K\sqrt[3]{(100\rho f_c')}\ (b_0\ .d) \qquad \text{--(6)}$$

Where:
ρ = ratio of reinforcement for bending.
f_c' = specified compressive strength of concrete, MPa.
d = effective depth or average effective depth of a slab.
b_0 = perimeter of critical section is located at 2d from the face of the column or loaded area, mm

$$K= 1+\sqrt{\frac{200}{d}} \le 2$$

When increase the depth section of shearhead the factor of safety decreased from (1.87 to 1.46) for spesimensCS7 and CS8 respectively.
Australian code AS-3600[13] provides the ultimate shear strength for slabs without prestress is given by V_{uo}=ud(F_{cv}), where:
u=length of the critical perimeter, taken at a distance of d/2 from the column (mm).
F_{cv} = punching shear strength (MPa).

$$Fcv = 0.17\left(1+\frac{2}{\beta_c}\right)\ \sqrt{f_c'}\ \le 0.34\sqrt{f_c'} \qquad \text{--(7)}$$

Where:
f_c' = specified compressive strength of concrete, MPa.
β_c = the ratio of long side to short side of the column.
There was a decrease in the factor of safety when increase the section depth of specimen CS7 (with 30mm depth) and CS8 (with 40mm depth) was 5.83 and 4.39 respectively .
Table (13) shown the factor of safety of different codes uses in the comparison.

Table (13) The Factor of Safety of Different Codes Uses in The Comparison

F.C	2.7	5.83	4.39
Punching shear strength according to AS code (kN)	130.6	379.2	379.2
F.C	1.35	1.87	1.46
Punching shear strength according to Europe code(kN)	64.31	122.19	122.19
F.C	1.27	1.52	1.19
Punching shear strength according to BS code (kN)	60.6	102.9	102.9
F.C	1.78	3.82	3.88
Punching shear strength according to ACI code (kN)	85	248.5	248.5
Experimental Ultimate load (kN)	47.5	65	86.25
Specimen	So	CS7	CS8

5.12 yield Line Analysis

Yield line theory is an upper bound theory. It is therefore always necessary to look for the lowest possible yield line load, consistent with geometrical and physical constraints, which the structure can resist. If several different yield line patterns are admissible by these constraints, the one providing the lowest load resistance will be the critical one. Yield line theory only predicts a stage of slab behavior characterized by yielding of the reinforcement, formation of extensive cracks, and appreciable deflections.

A square slab, with length of side a, is simply supported along the perimeter with the corners free to lift. Reinforcement is basically isotropic, but additional reinforcement is provided ,so that two bands, of approximately the width of the loaded area, are created which contain additional reinforcement in the direction indicated. Loading is through a square column stub of side length a' at the center, and it is assumed that the concrete under the column does not crack. The magnitudes of the positive yield moments are m1 in the major portions of the slab and km1 in the bands, perpendicular to the direction of the steel. A simplified yield line pattern is employed for the analysis, for which it can easily be determined that[14]:

$$P = 8m_1\left(1 + K\,\frac{a'}{a-a'}\right) \quad \text{--(8)}$$

Where: p : is the ultimate load capacity of slab
m1: is yield moments
K : is constant
a : is length of slab
a' : is side length of column stub.

The experimental results are compared with the yield line theory prediction in table(14). When the section depth of the shearhead are adopted as a variable ,the accuracy of the yield line theory decrease the amount of difference when using shearhead with same diameter as shown in specimens (CS7and CS8) .

Table (14) The variation between experimental ultimate load and yield line ultimate load

Specimen	Experimental Ultimate load (kN)	Yield line Ultimate load (kN)	Variation
So	47	41.1	12.5%
CS7	65	82.2	26.4%*
CS8	86.25	82.2	4.6%

6. conclusions

1- Increase in section depth of shearhead shows improvement 83.5% and 34.6% in ultimate load and first crack load value over reference specimen So (without shearhead) respectively.
2- The reduction in stiffness at failure of specimen of large section depth CS8 is 82.7% ,it was clear more than that specimen of small section depth CS7 is 68%, in comparison with its stiffness at 25%.
3- Experimental result are showing that the ductility increase as the section depth of shearhead increase by about 60% over reference specimen.
4- The maximum strain of concrete at failure was increased when increasing the shearhead depth of stiffness.
5- The maximum strain of collar shearhead at failure increase when increasing the shearhead depth of stiffness.
6- This study also included theoretical analysis using yield line method and appeared good agreement with the experimental results for slabs under statically loaded.

References

1- Zhang ,.X" **Punching Shear Failure Analysis of Reinforced Concrete Flat Plates using Simplified UST Failure Criterion** ", M.Sc. Thesis, Faculty of Engineering and Information Technology ,Griffith University , December 2002.
2- Aziz, A. H. and Husain, L. F.," Punching Shear and Flexural Strengths of Self Compacted Concrete Non-Rectangular Shaped Flat Plate Slabs", Diyala Journal of Engineering sciences Vol. 04, No. 01, pp. 95-107, June 2011.
3- Abd Al-Amier,J.S. , Rasheed ,M. M. and Salman, R. K." **Effect of Steel Shearhead on Behavior of Eccentrically Loaded Reinforced Concrete FlatPlate"**Journal of Engineering and Development, Vol. 17, No.1, Mar. 2013, ISSN 1813 - 7822.
4- IQS No.5/1984," Portland Cement", Central Agency for Standardization and Quality Control, Planning Council, Baghdad, Iraq, Translated from Arabic.
5- IQS No. 45/1984, **"Aggregate from Natural Sources for Concrete"**, Central Agency for Standardization and Quality Control, Planning Council, Baghdad, Iraq, Translated from Arabic Edition.
6- ACI 211.1-91, "Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete, American Concrete Institute", ACI 211.1–91, ReaPProved 2009, 38PP
7-M.Khuntia ,and S, K. Ghosh ,"Flexural stiffness of reinforced concrete columns and beams: Experiential Verification "ACI Structural Journal ,Vol.101,pp364-374,2004.
8-Mrs.S.P.Sangeetha and Dr.P.S.Joanna, "Flexural Behavior of Reinforced Concrete Beams with GGBS ,International Journal of Civil Engineering and Technology ,5(3),2014 ,pp.124-131.
9-M.J.N,Priestly ,and M.J.Kowalsky,"Aspects of drift and ductility capacity of rectangular cantilever structural walls" , Bulletin of the New Zealand National Society for Earthquake Engineering, Vol. 31, Issue 2 ,pp.73-85,1998.
10-ACI 318, Building Code Requirements for Structural Concrete and Commentary. 2014, Reported by ACI Committe 318. American Concrete Institute, Detroit, Michigan.
11- BS 8110, Part 1, **"Code of Practice for Design and Construction"**, British Standards Institution, London, 1997.
12-European Committee for Standardization: Eurokod 2: Design of concrete structures - Part 1-1: General rules and rules for buildings, (2004) pp. 225.
13-(AS3600) Concrete Structures Standard. Standards Association of Australia, 1994.
14- GESUND H. and KAUSHIK Y.P. "**Yield Line Analysis of Punching Failures in Slabs"** The national Academies of Sciences Engineering Medicine Transportation Research Board, Register for the Automated Vehicles Symposium, July 9-12 ,2018 ,San Francisco.