Behaviour of Reinforced Concrete Flat Plate with Embedded Bearing Plate

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Abstract

This study presents an experimental investigation on the influence of embedded shearhead reinforcement (steel plate) on the punching shear strength of reinforced concrete slabs. This work includes the investigation and testing of one control slab and five scale models of slab-column connection simply supported along the four edges. A shearhead was made using a steel plate with T-section stiffeners, the stiffeners were fabricated to be with two lines welded on the tension face of the plates. The main variables studied were the dimensions and thickness of the steel plate (used as punching resistance) .The results show that ultimate load capacity at failure increases by (16.48%) over the reference slab. Also, the punching shear stress decreases about (29.24%) below the reference slab.

Keywords: punching shear, reinforced concrete flat plate, steel plate.

تصرف البلاطات الخرسانية المسلحة المستويةمع صفيحة التحمل المطمورة

الخلاصة

تقدم هذه الدراسة بحثا عمليا على البلاطات المستوية التي تحتوي على تسليح قص، هذا التسليح يتضمن استخدام صفائح حديدية مطمورة في البلاطة. يتضمن الفحص عتبة سيطرة واحدة و خمسة بلاطات ذات إسناد بسيط على حوافها الأربعة وتتكون هذه البلاطات من صفيحة حديدية مقواة بخطين مزدوجين من مقاطع حديدية ذات مقطع حرف (T) لكلا الاتجاهين، وكانت المتغيرات الأساسية هي تأثير أبعاد وسمك الصفائح الحديدية على مقاومة البلاطة للقص الثاقب. اظهرت النتائج بان خصائص المقاومة والتشوهات تتأثر نتيجة تغير سمك وأبعاد الصفيحة الحديدية، كذلك فأن قيمة الحمل الاقصى عند الفشل ازدادت بمقدار(16.48)% عن البلاطة المرجعية ونقصان باجهادات القص بمقدار(29.24)% عن البلاطة المرجعية .

INTRODUCTION

Flat plate structure is a slab and column structure consisting of horizontal and uniform depth slab that transfer loads directly to the columns without the aid of beams or capitals or drop panels. This system is an economical and widely used form especially for multistory residential buildings, also for hotels, motels, apartment houses, hospitals, and dormitories condominium, car parks and office

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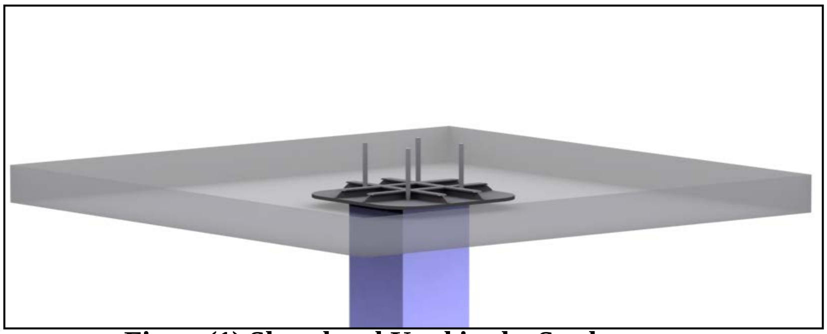
buildings. The critical problem in the design of concrete flat plate is the concentration of shear stresses around the column-slab connection which can cause abrupt punching shear failure at loads far below the slab flexural strength.

If the design of a slab is found adequate for flexure but not for punching shear, and an increase of the depth or use of higher concrete strength in the whole slab are not desired, the use of shearhead reinforcement is referred to in order to increase the punching shear strength. A shearhead is a separately definable structure embedded in the concrete at the junction, and serves to spread the load of the floor on the respective column and thereby reduces the effect of the vertical forces; i.e., reduces the stress in the slab concrete by increasing the critical punching shear perimeter around the column.

In 1961, Moe[1] tested three (150mm) thick slabs in which (19mm) thick steel plate was placed over the column and even with the compression surface of the slab, the plates were intended to increase the effective size of the column. In 1970, Hanson [2] tested three (203mm) thick lightweight concrete slabs. Two of the specimens contained shearheads, and in one of the specimens ducts were located (7.5mm) from the end of the shearhead arm. In 2005, Jawad [3] tested five specimens. The main variables are dimensions of shearhead and plane steel strip welded to the steel channel shape. Also, in 2005, Al-Kerwei [4] presented a theoretical study on one type of shear reinforcement called open wide collar. In 2006, Al-Maiaahei[5], tested fourteen specimens with special embedded shearhead. He tested four types of steel plate (stiffened plate in edge by steel angles with shear connectors distributed on the surface of the steel plate, perforated plate stiffened in edge by steel angles, stiffened plate of parallel steel strips placed vertically and steel angles in edges and finally cross shape with distributed shear connectors. In 2007, Al-Bayati's [6] experimental study included sixteen specimens. The main variables studied were the shape; dimension, thickness and shear connector of steel plate. Also, in 2007,Abd Al-Salam,[7], presented a numerical study of flat plate construction with special embedded shearhead using finite element method. She studied the effect of using steel plate as shear reinforcement with three types of steel plate (square steel plate with shear connectors distributed on the surface of the steel plate, cross shape with distributed shear connectors and a square plate which has rounded edge with distributed shear connectors).

In this paper, steel plate shearhead reinforcement with steel shear connector are used to avoid the problem of excessive punching shear stresses. The shearheads used is a plate with stiffeners.



Figure(1) Shearhead Used in the Study

Specimens Details

Six medium scale concrete flat plate slabs, were constructed for this study using normal strength reinforced concrete for a square slab (1000×1000mm) in size, with a total thickness of (70mm) and (150×150mm) square stub column with (200mm) height cast monolithically at the centre of the slab. The slab portion of these models was reinforced with deformed wires of (6mm) diameter distributed across the section (75mm c/c) as shown in Fig. (2).
Five specimens were made with square steel plate of rounded corners as shearhead reinforcement. Shearhead plate was used with (3mm, 5mm and 8mm) thickness and size were taken to represent the distance from the column face to edge of the plate (d, 1.5d and 2d) where d is the effective depth of the slab ≅60mm. The obtained length of the steel plate was as follows,

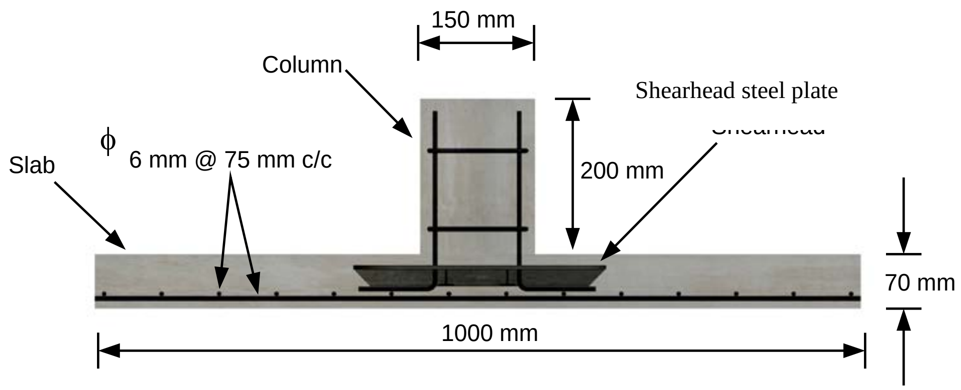
For small plate (S) : plate length =2d+150= 2(60)+150= 270 mm
medium plate (M) plate length =2(1.5d)+150=2(90)+150=330 mm
Large plate (L) plate length =2(2d)+150=2(120)+150=390 mm

Shearhead Details

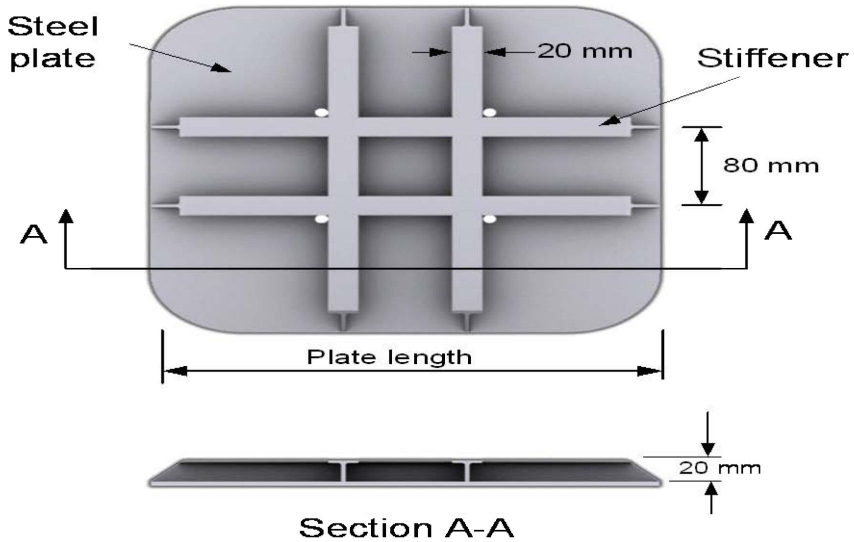
This type was made using a steel plate with T-section stiffeners (3mm thickness, flange 20 mm width and web 20 mm height), the stiffeners were fabricated to be with two lines welded on the tension face of the plates with (80mm c/c) space between the two lines for each
direction, as shown in Fig.(3).

Table (1) Characteristics of the Tested Slabs

Specimens	Dimensions of Plate (mm)
R	**_**
TS5	270 x 270 x 5
TM3	330 x 330 x 3
TM5	330 x 330 x 5
TM8	330 x 330 x 8
TL5	390 x 390 x 5



Figure(2) Specimen Dimensions Prototype Model



Figure(3) Shearhead Steel Plate Details

Compression Test

The machine which was used for compression tests of cylinders and cubes was an (MFL) (300ton) capacity hydraulic universal machine in the structural laboratory in Civil Department, College of Engineering, University of Al-Mustansiriya. Cylinders of (150×300mm) [8] and cubes of (150×150mm) [9] were used to test the compressive strength of concrete. Table (2) shows the results of cylindrical compressive strength tests.

Table (2) Compressive Strength of Tested Slabs

Specimens	Cylinder Compressive Strength, fc' (MPa)
R	31.33
TS5	29.77
TM3	29.74
TM5	30.62
TM8	28.87
TL5	29.34

Static Modulus of Elasticity

With the same machine that was used for the compression test, cylinders of (150×300mm) [10] were used to test the static modulus of elasticity, the compressmeter used has a gage length of (150mm) and dial gage of (0.002mm) accuracy. The results of static modulus of elasticity are shown in Table (3).

Table (3) Static Modulus of Elasticity Values for Tested Slabs

Specimens	Measured Static Modulus of Elasticity (MPa)	Predicted Static Modulus of Elasticity (ACI 318M-08) = $4700\sqrt{f'c}$ (MPa)
R	27.62	26.31
TS5	26.90	25.38
TM3	26.81	26.63
TM5	27.03	26.01
TM8	28.96	25.29
TL5	27.73	25.46

Modulus of Rupture

Prisms of (500×100×100mm) [11] were used to test the modulus of rupture, which a load span of (300mm) under two points loading. The results of modulus of rupture are shown in Table (4).

Table (4) Measured and Predicted Values of Modulus of Rupture

Specimens	Measured Modulus of Rupture (MPa)	Predicted Modulus of Rupture (ACI 318M-08) = $0.62\sqrt{fc'}$ (MPa)
R	4.15	3.47
TS5	3.86	3.38
TM3	3.93	3.38
TM5	3.92	3.43
TM8	4.2	3.33
TL5	4.01	3.36

Load Measurement

The beam and supporting frame in testing the 1/2-scale models were designed to be sufficiently stiff as shown in Fig.(4) which were attached to the testing machine in compressive strength, the load was measured directly the calibrated machine gage at (4 kN) interval for dial gages.

Figure(4) Preparation for Loading Test Machine.

Numerical Applications

To study more thoroughly the punching shear behaviour of reinforced concrete slabs with shearhead, a nonlinear finite element analysis has been carried out to analyze all experimentally tested slabs. The analysis is performed by using the finite element models in the finite element package ANSYS 9.0.

The elements types and material properties shown in Table (5) were used to model the experimentally tested slabs.

Table (5) Material Properties of the Model Tested Slabs

<table>
<tr><th>Element type</th><th>Representation</th><th>Material properties</th></tr>
<tr><td>SOLID65</td><td>Concrete</td><td>
<table><tr><th colspan="2">Linear isotropic</th></tr><tr><td>EX</td><td>27467</td></tr><tr><td>PRXY</td><td>0.2</td></tr></table>
<table><tr><th colspan="3">Multilinear isotropic</th></tr><tr><td></td><td>Strain</td><td>Stress</td></tr><tr><td>Point 1</td><td>0.000273</td><td>7.5</td></tr><tr><td>Point 2</td><td>0.000751</td><td>18.447</td></tr><tr><td>Point 3</td><td>0.001229</td><td>25.641</td></tr><tr><td>Point 4</td><td>0.001707</td><td>29.11</td></tr><tr><td>Point 5</td><td>0.0021845</td><td>30</td></tr><tr><td>Point 6</td><td>0.003</td><td>30</td></tr></table>
<table><tr><th colspan="2">Concrete</th></tr><tr><td>ShrCf-Op</td><td>0.2</td></tr><tr><td>ShrCf-CI</td><td>0.6</td></tr><tr><td>UnTensSt</td><td>3.9</td></tr><tr><td>UnCompSt</td><td>30</td></tr><tr><td>BiCompSt</td><td>0</td></tr><tr><td>HydroPrs</td><td>0</td></tr><tr><td>BiCompSt</td><td>0</td></tr><tr><td>UnTensSt</td><td>0</td></tr><tr><td>TenCrFac</td><td>0.6</td></tr></table>
</td></tr>
<tr><td>LINK8</td><td>Longitudinal steel reinforcement and Stirrups ($\phi 6\ mm$)</td><td>
<table><tr><th colspan="2">Linear isotropic</th></tr><tr><td>EX</td><td>200000</td></tr><tr><td>PRXY</td><td>0.3</td></tr></table>
<table><tr><th colspan="2">Bilinear isotropic</th></tr><tr><td>Yield Stss</td><td>483</td></tr><tr><td>Tang Mod</td><td>10</td></tr></table>
</td></tr>
<tr><td>SOLID45</td><td>Loading steel pad</td><td>
<table><tr><th colspan="2">Linear isotropic</th></tr><tr><td>EX</td><td>200000</td></tr><tr><td>PRXY</td><td>0.3</td></tr></table>
</td></tr>
<tr><td>SHELL63</td><td>Shearhead steel plates and Stiffeners</td><td>
<table><tr><th colspan="2">Linear isotropic</th></tr><tr><td>EX</td><td>200000</td></tr><tr><td>PRXY</td><td>0.3</td></tr></table>
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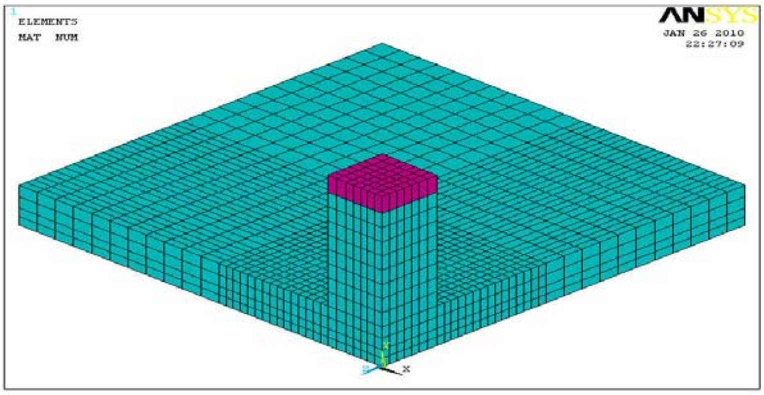
Modeling and Meshing of the Tested Slabs

Modeling and meshing were used of a quarter of the tested slabs (double symmetry). The model and the shearhead are divided into a number of small elements as shown in Fig. (5) and Fig.(6).



Figure(5) Mesh of the Model

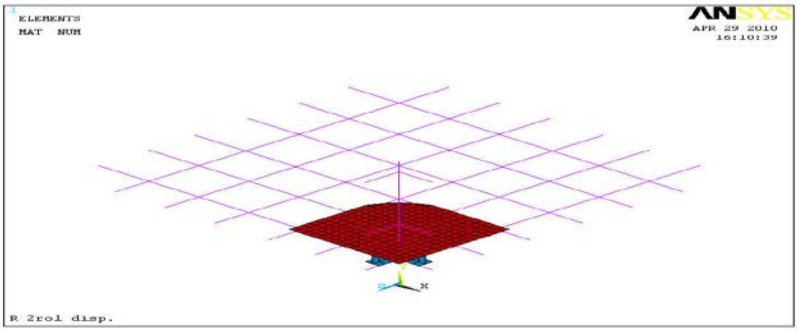


Figure (6) Mesh of the shearhead

Experimental Results and Discussion
First Crack

In reference specimen (without shear reinforcement), the first crack was observed in the corners of the column sides along the line of the tension reinforcement on the tension surface in the form of flexural cracks about (15.93%) of the ultimate load.
The first cracking of all the tested slabs with shear reinforcement was first observed in the tension zone of the slab near one or more of the corners and edges of the steel plate at (16.33-17.37) % of the ultimate load, as shown in Table (5). At this stage of loading, the tensile stress in concrete reached the modulus of rupture value and cracking started in the zone of maximum tensile stress. With further loading, new cracks appeared parallel to the diagonal axis and extended towards the slab edge. At the end of loading stages, all the slabs failed in punching shear as shown in Figures (7) through (12).

In general, slabs with punching shear reinforcement (steel plate) had first cracking load greater than the reference specimen.

Test results show that, when thickness of the steel plate increases from (3mm to 5mm) for slabs TM3 and TM5 the first cracking load increases from (16.5 kN to 17 kN) respectively. Also, increasing the thickness from (5mm to 8mm) in TM5 and TM8 increases first cracking load from (17 kN to 18 kN) respectively.

Also, the test results show that the increase in the dimensions of the steel plate increases first cracking load from (15 kN to 17 kN) in slabs TS5 (with dimensions 270mm x 270mm) and TM5 (with dimensions 330mm x 330mm) . While, the increase in the dimensions in slabs TM5 (with dimensions 330mm x 330mm) and TL5 (with dimensions 390mm x 390mm) decreases first cracking load from (17 kN to 16 kN). This result because the applied load is distributed on area with relatively large rigidity in slabs TM5. Therefore, the stresses in concrete are small with respect to TL5 and as a result, the tensile stresses in concrete reaches the modulus of rupture value with large loads.

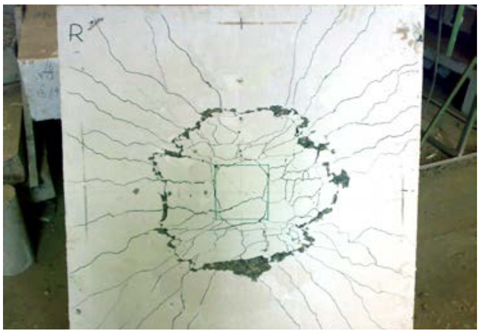
Generally, slabs with embedded steel plate have crack width smaller than the reference specimen. Crack widths were measured with special crack measuring instrument having a least width of 0.05mm. At the first stages of loading, the increase in crack width is small with the increase in load until yielding of the steel reinforcement after which the increase in crack width becomes large with small increment of load, and the crack width continues to increase without any appreciable increment in load, as shown in Figures (13) and (14).

In general, the test results show that the increase in thickness of steel plate from (3mm) to (5mm), with the same dimensions, in slabs (TM3 and TM5) respectively, decreases the maximum crack width. Also, the increase in thickness of steel plate from (5mm) to (8mm) in slabs (TM5 and TM8 respectively decreases the maximum crack width.

It is found that increasing the dimensions of steel plate from (270mm x 270mm) to (330mm x 330mm) for slabs (TS5 and TM5) respectively, increases the maximum crack width. Also, increasing the dimensions of steel plate from (330mm x 330mm) to (390mm x 390mm) for slabs (TM5 and TL5) respectively, increases the maximum crack width.

Table (6) First Cracking and Ultimate Loads

Specimens	**First Cracking load (kN)**	**% Increase in cracking load**	**Ultimate load (kN)**	**% Increase in ultimate load**
R	14.5	-	91	-
TS5	15	3.45	89	-2.20
TM3	16.5	13.79	95	4.40
TM5	17	17.24	104	14.29
TM8	18	24.14	106	16.48
TL5	16	10.35	98	7.69



Figure(7) Crack Patterns at Tension Side of Slab R

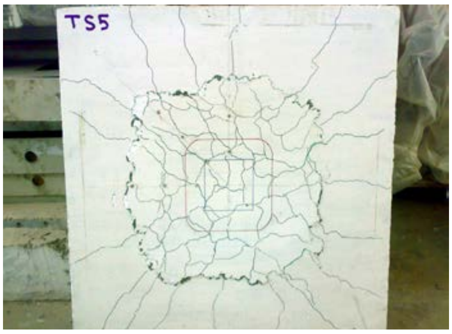
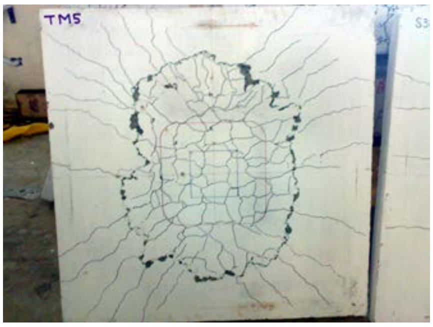


Figure (8) Crack Patterns at Tension Side of Slab TS5

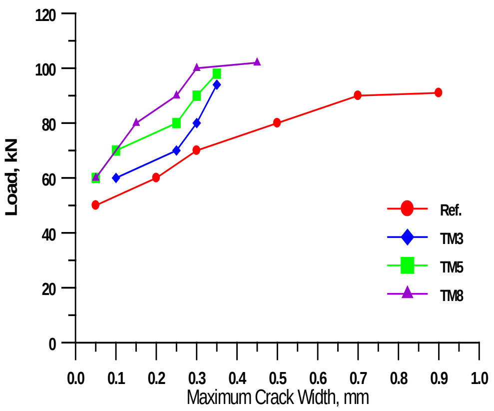
Figure (9) Crack Patterns at Tension Side of Slab TM3

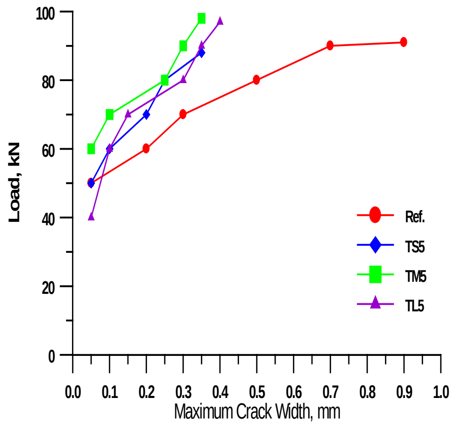
Figure (10) Crack Patterns at Tension Side of Slab TM5

Figure (11) Crack Patterns at Tension Side of Slab TM8



Figure(12) Crack Patterns at Tension Side of Slab TL5





oad-Maximum Crack abs R,TM3, TM5, TM8

Figure (14) Load-Maximum Crack Width for Slabs R,TS5, TM5, TL8

Ultimate Load Capacity

Determining the ultimate load capacity of slab specimens with suggested punching shear reinforcement is the main aim of this study and to compare the results with the reference specimen (without punching shear reinforcement). The observed failure loads of the tested slabs are shown in Table (5).

Generally, the effect of steel plate used (in most cases) is to increase the ultimate load capacity and the percentage of increase reaches (16.48%) over the reference slab (R). The results show that a slab gives a decrease in strength over that of the reference specimen (R) by about (2.20) % in (TS5), shear connectors used in this specimen are not sufficient to give a good interaction between concrete and steel plate.

It is found that the increase in thickness of steel plate from (3mm) to (5mm), with the same dimensions, in slabs (TM3) and (TM5) respectively increases the ultimate load capacity from (95 kN to 104 kN). Also, the increase in thickness of steel plate from (5mm) to (8mm), with the same dimensions, in slabs (TM5) and (TM8) respectively increases the ultimate load capacity from (104 kN to 106 kN).

The results show that the increase in the dimensions of the steel plate increases the ultimate load capacity from (89 kN to 104 kN) in slabs TS5 (with dimensions 270mm x 270mm) and TM5 (with dimensions 330mm x 330mm). The increase in the dimensions in slabs TM5 (with dimensions 330mm x 330mm) and TL5 (with dimensions 390mm x 390mm) decreases the ultimate load capacity from (104 kN to 98 kN).

Load-Deflection Behaviour

The deflection profile is shown in Figures (15) through (20) where each curve represents a state of slab in each 10 kN increment. Deflection profile was measured along the length of tested slabs (at the centre of slabs, 150 mm from the centre of the slab along X-axis, 150 mm from the centre of the slab along Y-axis and at a distance 500 mm from the centre of the slab out of support) by means of (0.001 mm) dial gauge, and readings from this gauge were recorded for each load increment. These figures show that the increase in deflections at first stages of loading is small with the increase in load (in an elastic manner). When the cracks start developing, deflections in the slabs increase at a faster rate, and continues to increase without an appreciable increment in load (finally the deflection increases without any additional load and the dial gauge starts to move very rapidly). At the same load level, the deflection in the slab with embedded steel plate is smaller than the deflection in the slab without steel plate because the steel plate increases flexural rigidity of the slab. As a result, the deflection decreases. Figures (21) and (22) represent the load-deflection curves for tested slabs.

It is found , when the thickness of the steel plate increases from 3mm in TM3 to 5mm in TM5 the ultimate deflection increases by about (1.21%). Also, increasing the thickness from 5mm in TM5 to 8mm in TM8 increases the ultimate deflection by about (6.93 %).

The test results show that the increase in the dimensions of the steel plate increases the ultimate deflection by about (13.11 %) in slabs TS5 (with dimensions 270mm x 270mm) and TM5 (with dimensions 330mm x 330mm). While, the increase in the dimensions of slabs TM5 (with dimensions 330mm x 330mm) and TL5 (with dimensions 390mm x 390mm) decreases the ultimate deflection by about (3.27%).

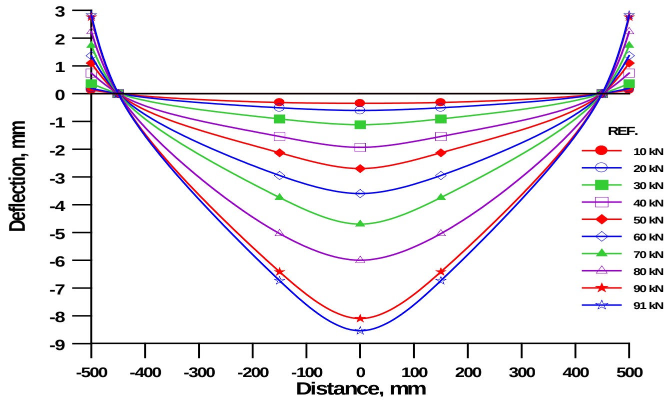


Figure (15) Deflection Profile of Slab R at Different Stages of Loading

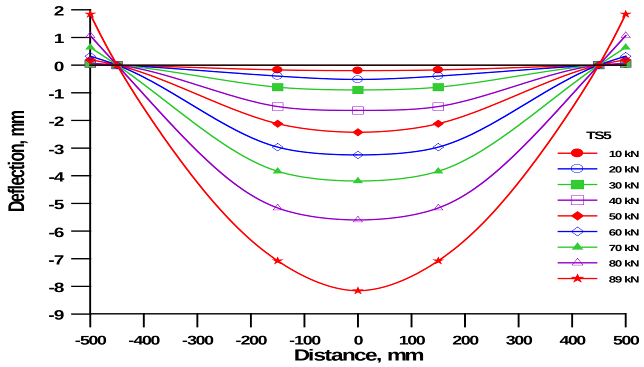


Figure (16) Deflection Profile of Slab TS5 at Different Stages of Loading

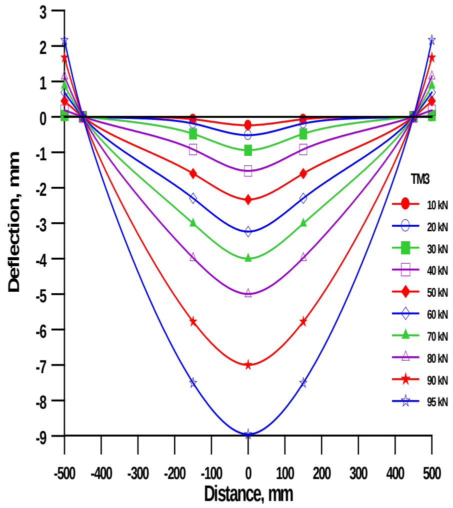


Figure (17) Deflection Profile of Slab TM3 at Different Stages of Loading

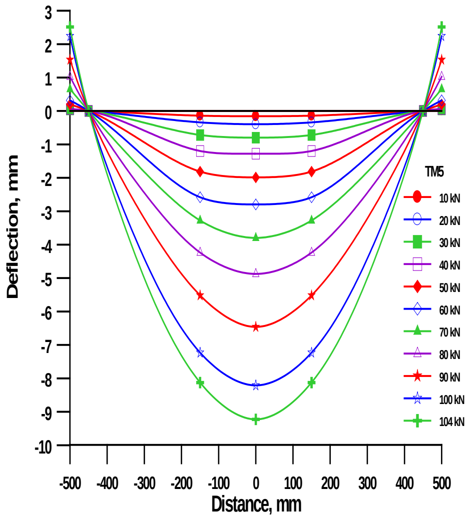


Figure (18) Deflection Profile of Slab TM5 at Different Stages of Loading

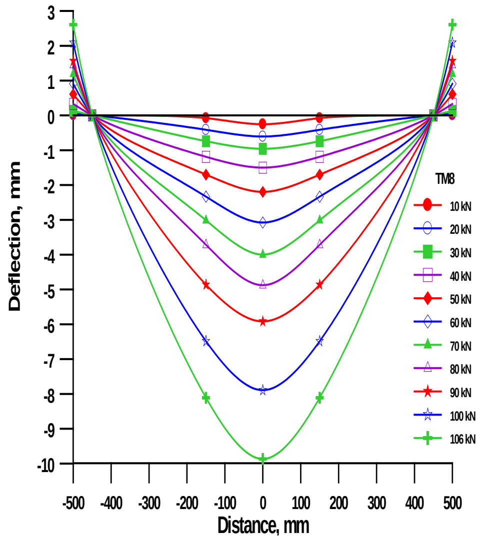


Figure (19) Deflection Profile of Slab TM8 at Different Stages of Loading

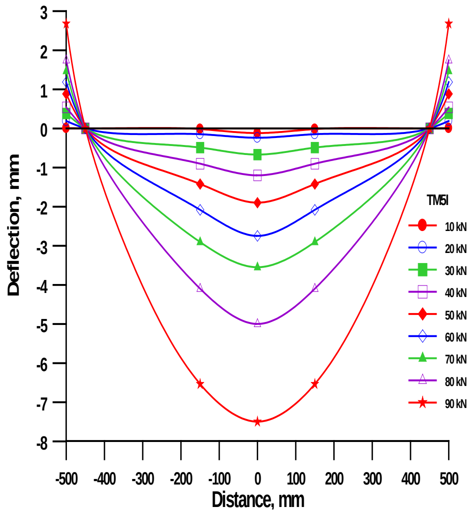
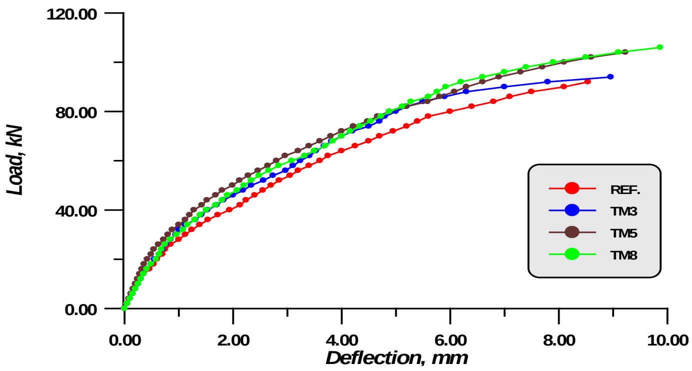
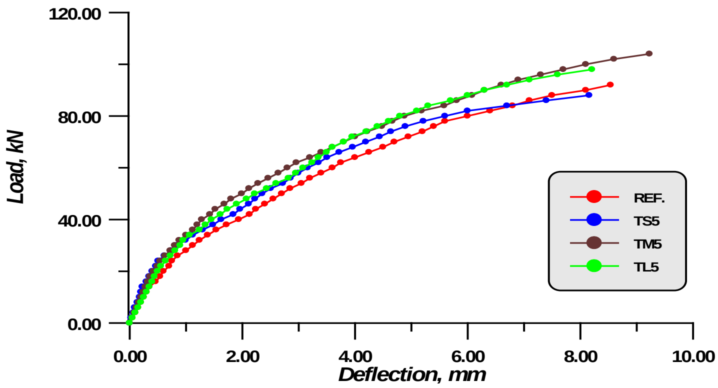


Figure (20) Deflection Profile of Slab HS5 at Different Stages of Loading



Figure(21)Load-Central Deflection Curve for Slabs R,TM3, TM5, TM8



Figure(22)Load-Central Deflection Curve for Slabs R,TS5, TM5, TL5

Critical Section Perimeter Measurements

According to ACI (318-08) [12] and BS (8110-97) [13] codes, the critical section perimeter is assumed to be at (d/2) and (1.5d) from the column face, respectively.

For the slabs without steel plate, the critical section perimeter is considered as half the distance (x) between the column face and the end of the actual punching failure surface on the tension side of the slab. While, it is considered as half the distance(x) between the steel plate and the end of the actual punching failure surface for the slabs with steel plate. The calculated distance is based on the measured area.

The test results show that, when the thickness of the steel plate increases from (3mm to 5mm) for slabs TM3 and TM5, the critical section perimeter increases by about (0.42%). Also, the test results show that the increase in the dimensions of the steel plate increases the critical section perimeter by about (19.60 %) in slabs TS5 (with dimensions 270mm x 270mm) and TM5 (with dimensions 330mm x 330mm).The increase in the dimensions in slabs TM5 (with dimensions 330mm x 330mm) and TL5 (with dimensions 390mm x 390mm) increases the critical section perimeter by about (9.75 %). In general, it can be noted that the calculated critical section perimeter according BS (8110-97) is better than the ACI (318M-08), based on the comparison with the measured values from the present study.

Table (7) Measured and Calculated Critical Section Perimeters

Specimens	Measured distance of failure surface x (mm)	Measured Critical Section Perimeters * (mm)	% increase critical section perimeter	Calculated critical section perimeter# (mm)	Calculated critical section perimeter " (mm)
R	198	1392	-	828	1284
TS5	133	1612	15.80	1308	1764
TM3	150	1920	37.93	1548	2004
TM5	152	1928	38.50	1548	2004
TM8	146	1902	36.64	1548	2004
TL5	139	2116	52.01	1788	2244

* At x/2 from the face of column or steel plate
#At d/2 from the face of column or steel plate
"At 1.5d from the face of column or steel plate

Shear Stress Characteristics in Tested Slabs:

In general, slabs with punching shear reinforcement with respect to the reference specimen (without punching shear reinforcement) can relatively decrease the maximum shear stresses due to increased perimeter of the critical section as shown in Table (8) .

It is found , that when the thickness of the steel plate increases from 3mm in TM3 to 5mm in TM5 the ultimate shear stress increases from (0.92 MPa to 0.99 MPa). Also, increasing the thickness from (5mm to 8mm) in TM5 and TM8 increases the ultimate shear stress from (0.99 MPa to 1.03 MPa).

The test results show that the increase in the dimensions of the steel plate decreases the ultimate shear stress from (1.02 MPa to 0.99 MPa) in slabs TS5 (with dimensions 270mm x 270mm) and TM5 (with dimensions 330mm x 330mm). The increase in the dimensions in slabs TM5 (with dimensions 330mm x 330mm) and TL5 (with dimensions 390mm x 390mm) increases the ultimate shear stress from (0.99 MPa to 1.06 MPa).

Table (8) Ultimate Shear Stresses in Tested Slabs

Specimens	Ultimate load (kN)	Measured critical section perimeter at x/2 from the face of column or steel plate (mm)	Ultimate Shear Stresses (MPa)	% Decrease in Ultimate Shear Stresses
R	91	1392	1.21	-
TS5	89	1612	1.02	15.66
TM3	95	1920	0.92	23.96
TM5	104	1928	0.99	17.56
TM8	106	1904	1.03	14.88
TL5	98	2116	0.86	29.24

Numerical results

The ultimate loads of the modelled slabs were indicated by the state that the slabs no longer can support additional load as indicated by the convergence failure of ANSYS program in failing to find a solution.

Table (9) shows the ultimate load and ultimate deflection of all tested slabs obtained from the numerical study (ANSYS 9.0) and experimental tests.

Fig. (23) shows the nodal displacements in Y-direction at failure load of Reference slab.

Table (9) Experimental and Numerical (ANSYS) Ultimate Load

Beam No.	Experimental values		Numerical values (ANSYS)	
	Ultimate load (kN)	Ultimate Deflection (mm)	Ultimate load (kN)	Ultimate Deflection (mm)
R	91	8.54	86	8.19
TS5	89	8.16	86	10.1
TM3	95	9.12	98	8.74
TM5	104	9.23	95	8.9
TM8	106	9.87	103	8.76
TL5	98	8.21	101	9.67

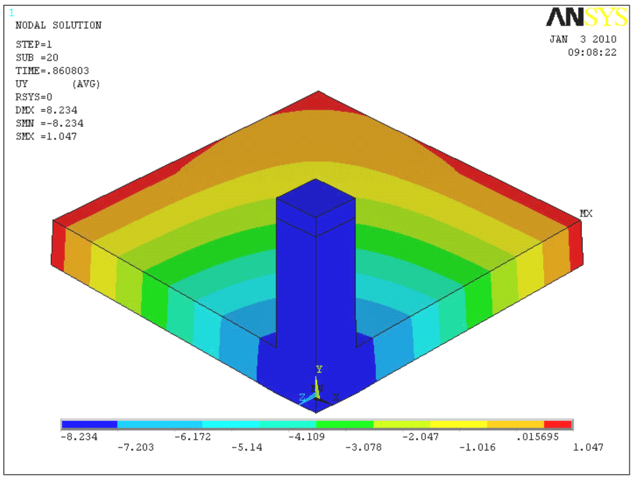


Figure (23) Nodal Displacement at Failure Load of Reference Slab R

Load-Deflection Behaviour

Figures (24) to (29) show the experimental and numerical (ANSYS) Load-Central deflection Behaviour of all tested slabs.

In general, it can be noted from the Load-Deflection plots that the finite element analysis agrees with the experimental results throughout the entire range of Behaviour.

Conclusions

The results show that the increase in thickness of steel plate with the same dimension increased the first cracking load, the ultimate deflection, the ultimate load at failure, the critical section perimeter and the ultimate shear stress and decreased the maximum crack width.

The results show that the increase in dimension of steel plate with the same thickness increased the maximum crack width, the critical section perimeter and decreased the ultimate shear stress. Also, increased the first cracking load, the ultimate load at failure and the ultimate deflection when dimension increases from (270 X270mm) to (330 X330 mm) and decreases the first cracking load, the ultimate load at failure and the ultimate deflection when dimension increases from (330 X330mm) to (390X390 mm). Based on the comparison with the measured values from the present study, the calculated critical section perimeter according BS(8110-97) is better than the ACI (318M-08).

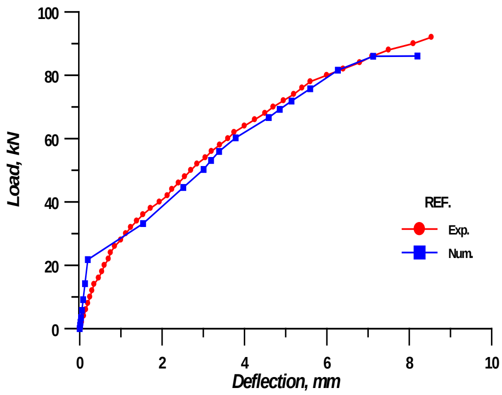


Figure (24) Numerical (ANSYS 9) and Experimental Load-Deflection Behavior for Slab R

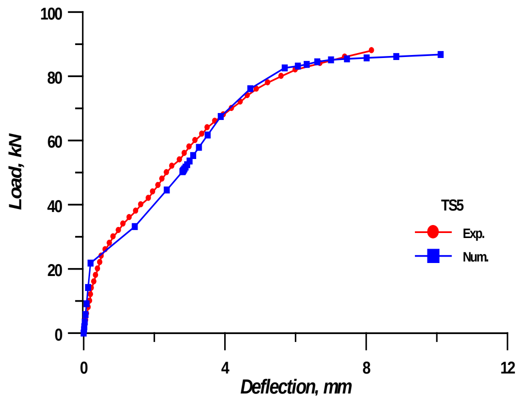


Figure (25) Numerical (ANSYS 9) and Experimental Load-Deflection Behavior

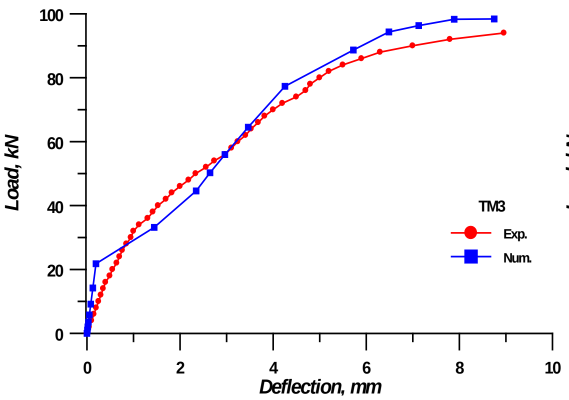


Figure. (26) Numerical (ANSYS 9) and Experimental Load-Deflection Behavior for Slab TM3

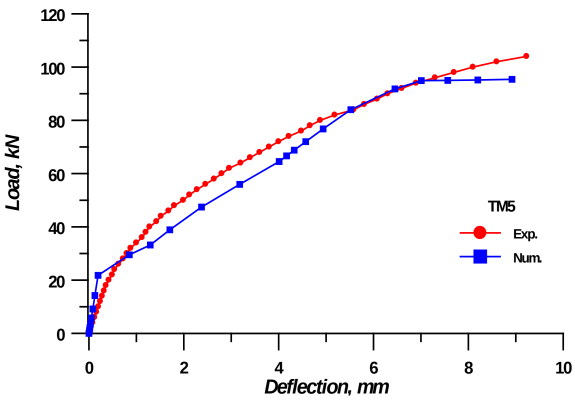
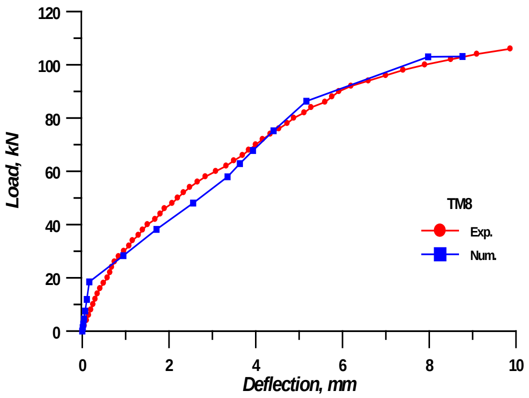


Figure. (27) Numerical (ANSYS 9) and Experimental Load-Deflection Behavior for Slab TM5



Figure(28) Numerical (ANSYS 9) and Experimental Load-Deflection Behavior for Slab TM8

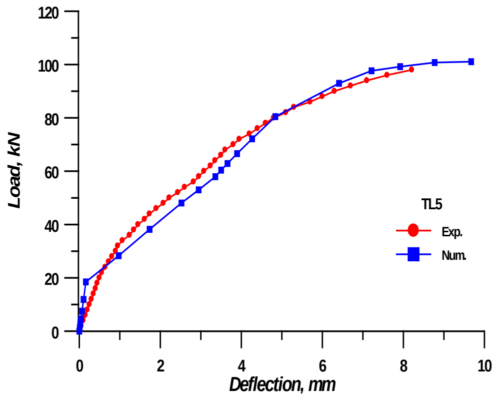


Figure (29) Numerical (ANSYS 9) and Experimental Load-Deflection Behavior for Slab TL5

References

[1] Moe, J., "Shearing Strength of Reinforced Concrete Slabs and Footing under Concentrated Load" Portland Cement Association Research and Development Laboratories Bulletin D47, April 1961, PP. 130.

[2] Hanson, J. M., "Influence of Embedded Service Ducts on the Strength of Flat Plate Structure", Portland Cement Association Research and Development Bulletin, RD 005.01D, 1970.

[3] Jawad, M. K., "Experimental Study on Shearheads in Reinforced Concrete Flat Plates", Ph.D. Thesis, Al-Mustansiriya University, September 2005, PP.1-175

[4] Al-Kerwei, R., H., "Theoretical Study of Open Wide Collar Shearhead Reinforcement Embedded in Flat Plate Construction", M.Sc. Thesis, Civil Engineering Department, Al-Mustansiriya University, July 2005, PP.1-98.

[5] Al-Maiaahei, A. N., "Experimental Study of Flat Plate Construction with Special Embedded Shearhead", M.Sc. Thesis, Al- Mustansiriya University, March 2006, PP.1-127

[6] Al-Bayati, H.H.Y., "Experimental Study of Flat Plate Construction with Embedded Shearhead Steel Plates ", M.Sc. Thesis, Al- Mustansiriya University, 2007, PP.1-155.

[7] Abd Al-Salam,L. S., " Theoretical Study of Flat Plate Construction with Special Embedded Shearhead Using Finite Element Method ", M.Sc. Thesis, Al-Mustansiriya University, October, 2007.

[8] ASTM C39-86, "Test Method for Compressive Strength of Cylindrical Concrete Specimens", ASTM International.

[9] BS 1881: Part 116:1983, "Method for Determination of Compressive Strength of Concrete Cube".

[10] ASTM C469-87, "Test Method for Static Modulus of Elasticity and Poisson s Ratio of Concrete in Compression" ASTM International.

[11] ASTM C78-84, "Test Method for Flexural Strength of Concrete" ASTM International.

[12] ACI Code (318M-08) "Building Code Requirement for Structural Concrete and Commentary ", American Concrete Institute, Detroit, , 2008.
[13] British Standard Institution (BS 8110), (1997) "Code of Practice for Design and Construction" British Standard Institution Part 1, London.