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EFFECT OF USING CORNER REINFORCEMENT ON THE STRUCTURAL BEHAVIOUR OF R.C SOLID SLABS

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This research introduces the real behaviour of R.C two-way slab with additional top and bottom corner reinforcement. Such reinforcement contributes in stiffening slabs corner to resist torsional and shear stresses.
For this purpose a numerical studies have been performed to illustrate the effect of such reinforcement on the structural behaviour of R.C slabs .the 3D-FEM model through (ANSYS) software package has been used to accomplish this study, the eight node solid element is used to model the concrete, this element is capable of having plastic deformation, cracking in three orthogonal directions, and crushing which were all taken into consideration. The reinforcement was modelled as a three–dimensional bar element. In this research several parameters have been taken into consideration :(a)percentage of slab main reinforcement;(b) percentage of corner reinforcement as a ratio from the main reinforcement ;(c) corner reinforcement spacing;(d)margin beam stiffness ;(e)slab rectangularity.
The results show that the existence of corner reinforcement in R.C two-way slabs improves considerably the structural behaviour of such slabs leading to higher ultimate load and lower values for deflection.
In this research the maximum midspan deflection and the ultimate load carrying capacity were recorded. It has been found for the studied cases that the increase of load carrying capacity is up to (28%) and the decrease in central deflection of slab is up to (30%).
From this study it can be found that the distribution of corner reinforcement (S=7, 14,21cm) and its percentage from the main steel (43%, 72%, 100%) has a significant effect on increasing ultimate load and decreasing the central deflection.

KEYWORDS: *Load carrying capacity, central deflection, corner reinforcement, bar intervals.*

I - INTRODUCTION

Using solid slab system for large spans is fraught with difficulties mostly due to increasing the straining actions, deflections which tend to decrease the ultimate load carrying capacity.

NOTATION

E_c	the elastic modulus	β_t	shear transfer coefficient for an open crack
f	stress at any strain	β_e	shear transfer coefficient for a close crack
f_c'	ultimate compressive strength of concrete	δ_{max}	the maximum central deflection
f_r	modulus of rapture	δ_o	the maximum central deflection at A2 failure load
f_y	steel yield stress	γ	density
k	the corner holding-down force	ε	strain at stress
M_δ	torsional moment	ε_o	strain at the ultimate compressive strength
Pcr	first cracking load	μ	percentage of corner reinforcement from the main steel
Py	first yielding load	μs	percentage of main reinforcement =As/Ac
R	corner reaction	ν	Poisson's ratio
S	corner reinforcement spacing		

It is Evident from the Elastic Theory for Slabs Analysis that

High values of torsional moment occurs at the corner regions and that if the corner of simply supported slab is not held down; it will tend to lift off the support (developing -ve corner reactions) for which reinforcement must be provided at such regions.

Therefore the *British Standard Code OF Practice* (BSI) [1] states that at corners contained by edges over neither of which the slab is continuous, top and bottom reinforcement should be provided for torsion at the corners of such slabs. Both top and bottom reinforcement should consist of two layers of bars placed parallel to the sides of the slab and extending in these directions for a distance of one-fifth of the shorter span. The area of the bars in each of the four layers, per unit width of the slab, should be three-quarter of the area required for the maximum positive moment in the slab Fig. (1-a).

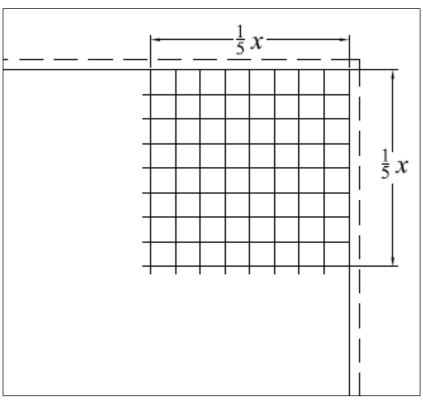


Fig. (1-a): Corner reinforcement according to BSI

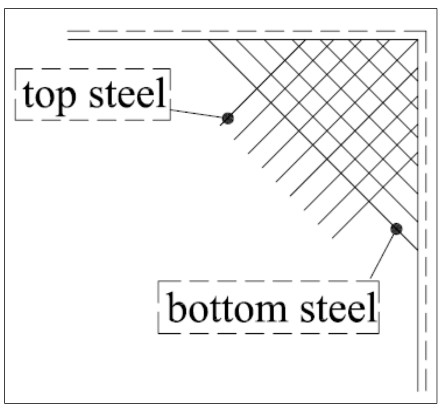


Fig. (1-b): Corner reinforcement according to ACI

However according to *the American concrete institute* (ACI-318-02) [2] this reinforcement is to be provided for a distance in each direction from the corner equal to one-fifth the longer span. This reinforcement in both top and bottom of the slab must be sufficient to resist a moment equal to the maximum bending moment per unit length of width in the slab, and it may be placed in a single band parallel to the diagonal in the top of the slab and perpendicular to the diagonal in the bottom of the slab Fig. (1-b), or in two bands parallel to the sides of the slab.

Torsion in simply supported slab**:* as mentioned before that when loading is applied to a simply supported slab the corners are lifted off their supports. The holding-down force, can be determined in terms of the load ***k by means of the elastic theory of slabs [3]. This force is expressed by "R" where:

$$R = \rho k \qquad (1)$$

Where the coefficient ρ dependent upon $\eta = ly/lx$

For slabs simply supported on four sides the values of ρ have been given by Marcus and are indicated in the following table.

Table (1)

η	1.0	1.2	1.4	1.6	1.8	2.0	2.5	3.0	3.5	4.0
ρ	0.083	0.080	0.076	0.071	0.066	0.060	0.049	0.041	0.035	0.031

Consider Fig. (2-a) in a diagonal plane $\alpha - \alpha$ at a distance *a* from the corner the force R produces a moment *Ra* "*torsional moment*" this moment is distributed over the length *2a* where:

$$M_\delta = {Ra}/{2a} = \rho \mathrm{K} / 2 \qquad (2)$$

And this" *torsional moment*"(M_δ) acts across the plane $\beta - \beta$ Fig (2-b) and produces a tensile stresses at the underside of the slab. *Hence it is necessary to provide bottom reinforcement as shown in* Fig. (2-b).

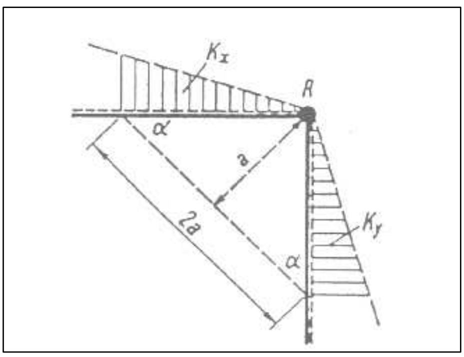


Fig. (2-a): Corner force R acts at corner

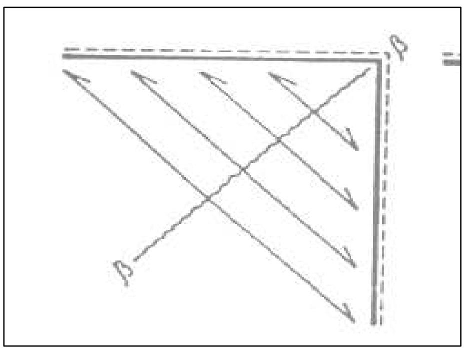


Fig. (2-b): Induced *torsional moment* (M_δ) acts across the plane $\beta - \beta$

II- VERIFICATION OF ANSYS COMPUTER PROGRAM

The used computer program has been applied on a well known example *Slab (5x5x0.12 m)* and the optioned results were in complete agreement with the exact solution obtained by Czernys [4].

II-1-Concrete Constitutive Model

Solid 65 element:

Solid65, an eight node solid element, is used to model the concrete with or without reinforcing bars (smeared or discrete reinforcement). The solid element has eight nodes with three degrees of freedom at each node–translation in the nodal X, Y, and Z directions. The element is capable of having plastic deformation, cracking in three orthogonal directions, and crushing. The geometry and node locations for this element type are shown in Fig. (3).

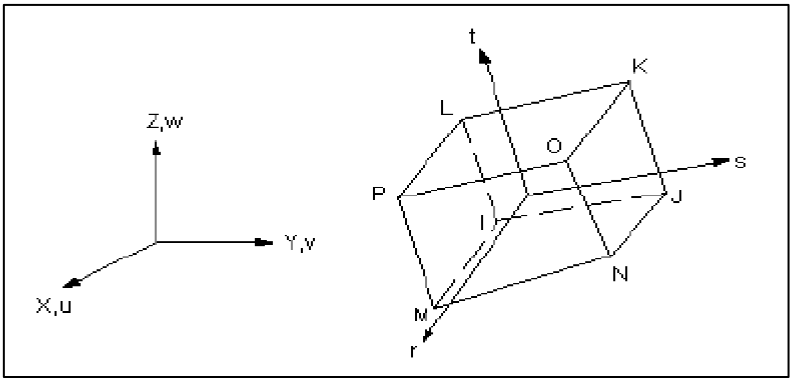


Fig. (3): Solid65-3D reinforced concrete element

The Consideration of Solid65 Element Input Data:

ANSYS requires input data for material properties of solid65 element as elastic modulus [E_r],Ultimate uniaxial compressive strength [f_c'], ultimate uniaxial tensile strength [modulus of rapture, f_r] Poisson's ratio (v), density (γ), shear transfer coefficient for an open crack (β_t), shear transfer coefficient for a close crack (β_c) [5], [6], compressive uniaxial stress-strain relationship for concrete.

The elastic modulus of elasticity: is obtained by the pulse velocity method and can be calculated by means of its ultimate concrete compressive strength for each slab model by using Equation (3) ACI_318 [2]

$$f_c' = \left[\frac{E_c}{4730} \right]^2 \qquad (3)$$

Where:

Ec elastic modulus of concrete in MPa (MPa=10.2kg/cm^2).

f_c' Ultimate compressive strength of concrete in MPa.

The tensile strength of concrete: is typically 8-15% of the compressive strength Shah *et al.* 1995 [7].

Stress- strain relation for concrete

Atypical stress-strain curve for concrete as an example is shown in Fig. (4), Bangash 1989[8]. In compression the stress strain curve for concrete is linearly elastic up to about 30% of the maximum compressive strength. Above this point the stress increases gradually up to the maximum compressive strength. After it reaches the maximum compressive strength f_{cu} the curve descends into a softening region and eventually crushing failure occurs at an ultimate strain ε_{cu}.

In tension the stress-strain curve for concrete is approximately linearly elastic up to the maximum tensile strength. After this point the concrete cracks and the strength decreases gradually to zero Bangash [8].

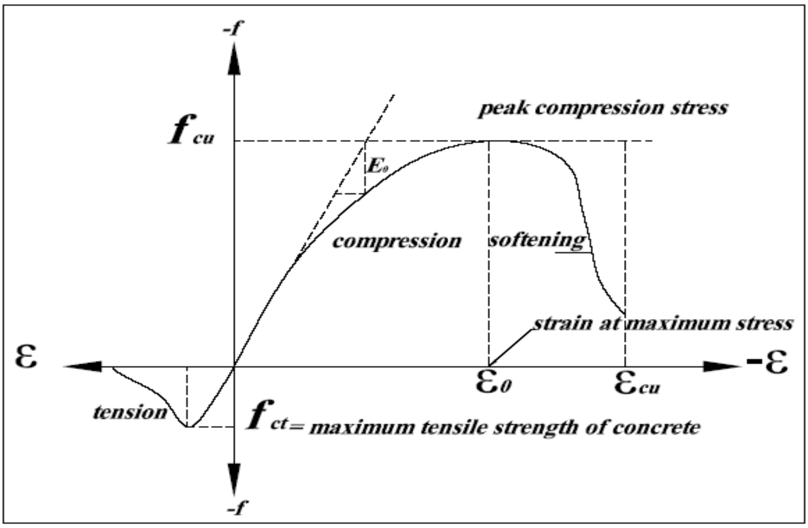


Fig. (4): Typical uniaxial compressive and tensile stress-strain curve for concrete (Bangash 1989).

Ansys program requires the uniaxial stress-strain relation for concrete in compression. Numerical expressions of Desayi and Krishnan 1964 [9] Equation (4) and (5) were used along with Equation (6) Gere and Timoshenko 1997[10] to construct the uniaxial compressive stress-strain curve for concrete in this study.

$$f = \frac{E_C \ x \ \varepsilon}{1 + \left(\frac{\varepsilon}{\varepsilon_0} \right)} \tag{4}$$

$$\varepsilon_0 = \frac{2 \ f_c'}{E_c} \tag{5}$$

$$E_c = \frac{f}{\varepsilon} \tag{6}$$

Where:

f = stress at any strain ε, in MPa (MPa=10.2kg/cm^2).

ε = strain at stress f

ε_o = strain at the ultimate compressive strength f_c' in MPa
The density (γ) and the Poisson's ratio (ν), of concrete are considered as 2200 kg/m^3 and 0.20 respectively.

Table (2)

(E_c) kg/cm^2	(υ)	(β_t)	(β_c)	(f_{rc}) kg/cm^2	($f_c^{\backslash}$) kg/cm^2
2.617E+5	0.2	0.2	0.5	33	350

*II-2-*Reinforcement Constitutive Model

Reinforcement Consideration:

In this research reinforcement has been modeled as a discrete reinforcement *(Link8)* throughout the element *(solid65).*

Link8 element, the three–dimensional spar element is a uni-axial tension-compression element with three degrees of freedom at each node: translations in the nodal X, Y and Z directions. As in a pin-jointed structure, no bending of the element is considered. The element is also capable of having plastic deformation, stress stiffening, and large deflection. The geometry, node locations, and the coordinate system for this element are shown in Fig. (5).

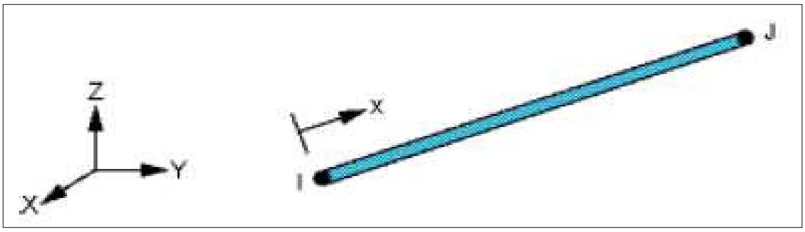


Fig. (5): Link8-3D Spar element.

Material properties for steel reinforcement:

Steel reinforcement in considered models was constructed with typical grade 36/52. The steel was assumed elastic-perfectly plastic material(Bilinear Isotropic Hardening) and identical in tension and compression.

These options use the von Mises yield criterion with the associated flow rule and isotropic work hardening. Fig. (6) shows stress-strain relationship used in this study.

taking into consideration the following data:

- Poisson’s ratio of 0.3 was used for steel reinforcement in this study Gere and Timoshinko (1997) [8].
- Yield stress f_y= 3600 kg /m^2.

III- GEOMETRICAL MODELING

In all studied cases:-

- Only one quarter of the model was solved due to symmetry, Fig. (9).

- The uniform load applied on slabs is taken as a concentrated load at the intermediate point of each element.
- All nodes on slab corners are prevented from translation in X, Y, Z directions for slab beam models.

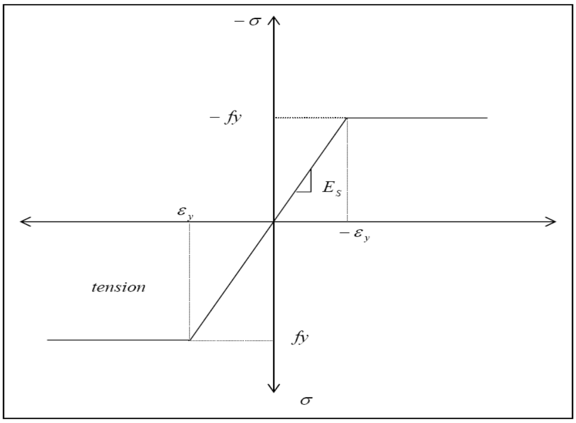


Fig. (6): Steel stress-strain relationship used in this study.

Loads and Boundary Conditions:

- The supports at the corner nodes were prevented from translation in X, Y, Z (Uz=Ux=Uy=0) support condition is shown in Fig. (7), Fig. (8) for slab models.
- The pressure applied on slabs is taken as a concentrated load at the intermediate point of each element. Fig. (7) illustrates the applied loading.
- The symmetry boundary conditions were set first. The model being used is Symmetric about two planes. The boundary conditions for both planes of symmetry are shown in Fig. (8).

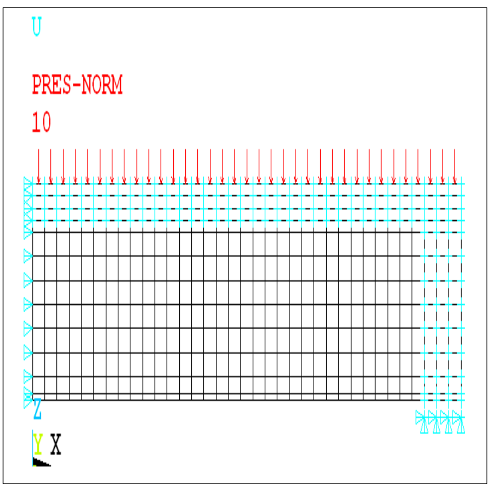


Fig. (7): Pressure on concrete element

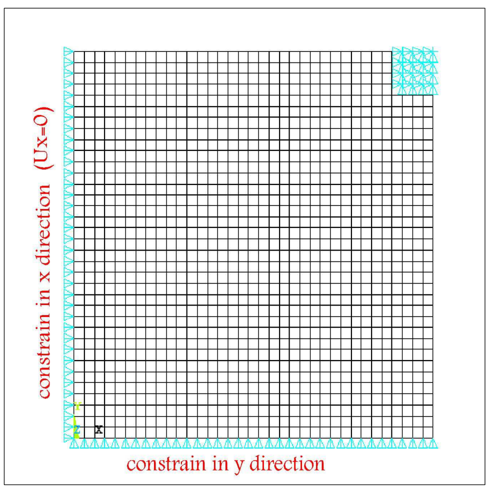


Fig. (8): Boundary Condition for Support (slab beam models)

Reinforcement Modeling:

- ***Slab reinforcement:***
  Slab has an orthogonal reinforcement in x and y direction
- ***Beam reinforcement:***
  - Main reinforcement *8#22mm,* stirrups hunger *4#16mm, side* bars *4#12mm and* stirrups *#8mm@10cm Fig. (9).*

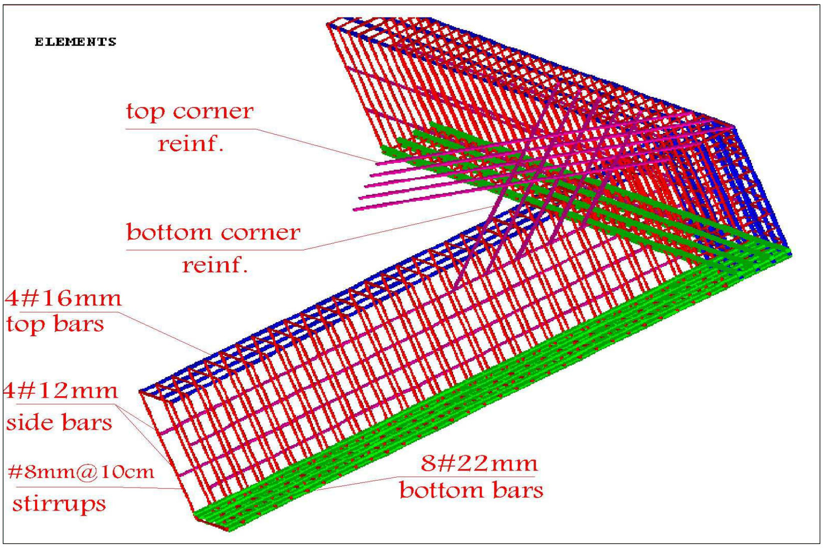


Fig. (9): Beam Reinforcement.

IV- NUMERICAL STUDY

Parametric study.

A total of 16 cases for study have been done in this analysis. In order to fulfill the above objective, the effects of the following parameters on the structural behavior of simply supported two-way slab were studied theoretically as shown in table (3).

- ***All square slabs are*** (7x7x0.15m) and supported on margin beams (30x90) with top reinforcement 4 bars (16mm), bottom reinforcement 8bars (22mm), Stirrups 8mm diameter with 10cm spacing and 4bars (12 mm)as side bars.
  - ***Group A***: The main objective of this group is to illustrate the behavior of slab (shape of failure, stress distribution, the ultimate load carrying capacity & max displacement)with different percentage and distribution of main reinforcement (μs=0.38, 0.52%, 0.67%) A1, A2, A3 respectively.
  - ***Group B***: The main objective of this group is to illustrate the effect of beam depth on slab behavior.
  - ***Group C***: The main objective of this group is to illustrate the effect of beam width on slab behavior.
  - ***Group D***: this group studies the effect of using additional top & bottom corner reinforcement and spacing between bars on shape of failure, stress distribution, the ultimate load capacity & max displacement. These slabs have

a bottom and top corner reinforcement (perpendicular to the diagonal) reinforcement with 3bars 12mm diameter (μ=43% of the main reinforcement) and has spacing between bars (S=7,14,21cm)

- **Group E**: The main objective of studying group E2 is to illustrate the effect of percent of corner reinforcement which has been taken (72%, 100% 0f the main steel with 5,7 bars 12 mm diameter respectively and spacing between bars S=14cm) on shape of failure, stress distribution, the ultimate load capacity & max displacement.
- **Group F**: this group studies the effect of top & bottom corner reinforcement in case of rectangular slabs [R=1.25(7X8.8X0.15), R=1.5(7X10.6X0.15)].

Table (3): The general plan of the parametric study.

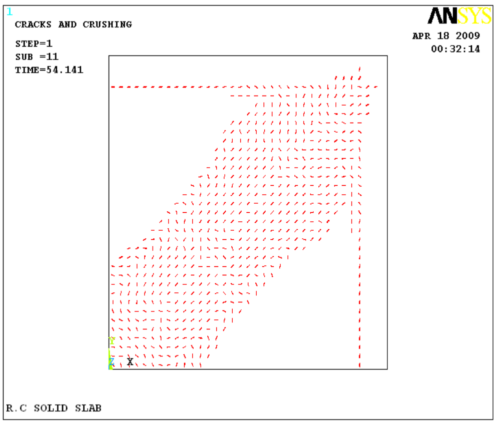
GROUP NO.	SLAB NO.	SLAB DIMENSION (m)	MAIN REINF.	BEAM		% OF.C.R (μ)	SPACING BET.BARS S(cm)	REC. (R)
				WIDTH (cm)	DEPTH (cm)			
A	A1	7X7X0.15	#12@20cm	30cm	90cm	_	_	1
	A2	7X7X0.15	#10@10cm	30cm	90cm	_	_	1
	A3	7X7X0.15	#16@20cm	30cm	90cm	_	_	1
B	B1	7X7X0.15	#10@10cm	30cm	70cm	_	_	1
	B2	7X7X0.15	#10@10cm	30cm	110cm	_	_	1
C	C1	7X7X0.15	#10@10cm	40cm	90cm	_	_	1
	C2	7X7X0.15	#10@10cm	20cm	90cm	_	_	1
D	D1	7X7X0.15	#10@10cm	30cm	90cm	43%	7cm	1
	D2	7X7X0.15	#10@10cm	30cm	90cm	43%	14cm	1
	D3	7X7X0.15	#10@10cm	30cm	90cm	43%	21cm	1
E	E1	7X7X0.15	#10@10cm	30cm	90cm	72%	14cm	1
	E2	7X7X0.15	#10@10cm	30cm	90cm	100%	14cm	1
F	F1	7X8.8X0.15	#10@10cm	30cm	110cm	_	_	1.25
	F2	7X8.8X0.16	#10@10cm	30cm	110cm	_	_	1.5
	F3	7X10.6X0.14	#10@10cm	30cm	110cm	100%	14cm	1.25
	F4	7X10.6X0.15	#10@10cm	30cm	110cm	100%	14cm	1.5

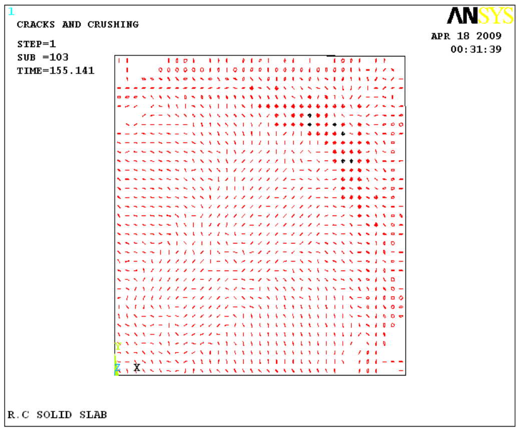
Numerical results

Slab-A2 (reference slab):

- Slab start to crack at load (1.083 t/m^2) at the bottom(parallel to the diagonal) and top (perpendicular to the diagonal)corner fiber, then it propagate gradually towards slab center with increase loading up to failure load (3.103 t/m^2) Figs. (10) and (11).
- Steel reinforcement reached the yield stress at load (2.373t/m^2) at the slab center due to tension stresses Fig. (12).
- From the above it can be deduce that slab failure caused by:

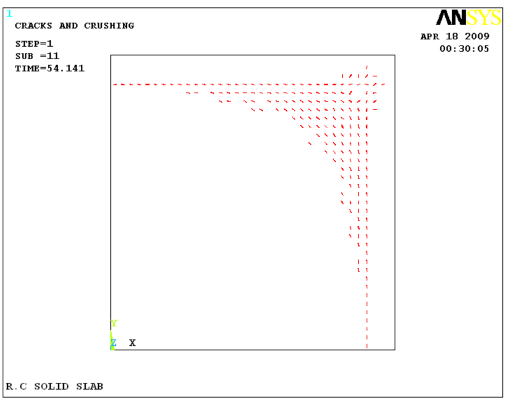
  After the Steel reinforcement reached the yield stress the slab corner subjected to strong stresses (sxy shear stress) leading to concrete crushing at the bottom corner. And consequently the collapse of slab occurred due to the increase of these stresses.

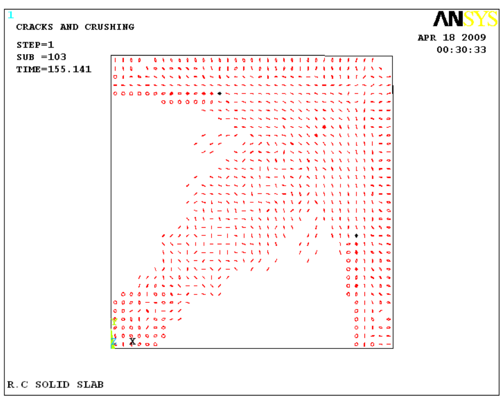




(a) (b)

Fig. (10): Cracking shape for slab (A2) ;(a) at load=1.083 t/m^2. (b) At failure load=3.10282 t/m^2 for bottom surface





(a) (b)

Fig. (11): Cracking shape for slab (A2) ;(a) at load=1.083 t/m^2. (b) At failure load=3.10282 t/m^2 for top surface.

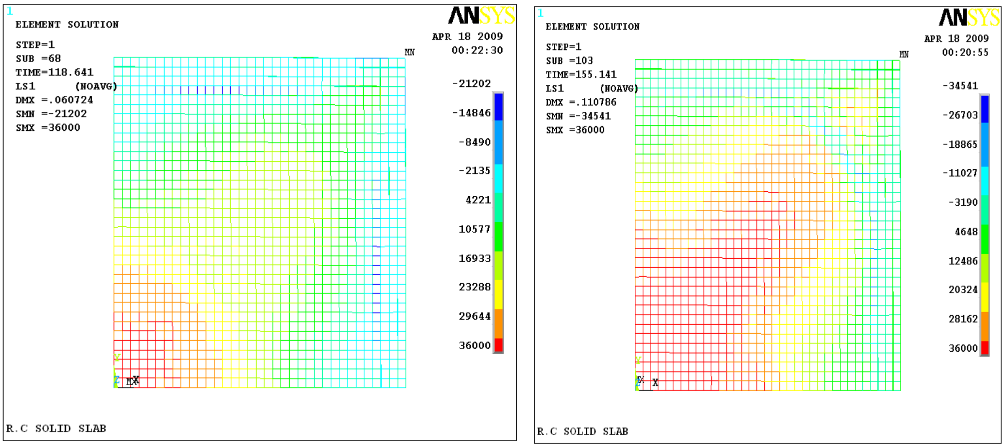


Fig. (12): Yield stress for steel element ;(a) First yield stress for steel element. (b) Yield stress at failure load for slab (A2).

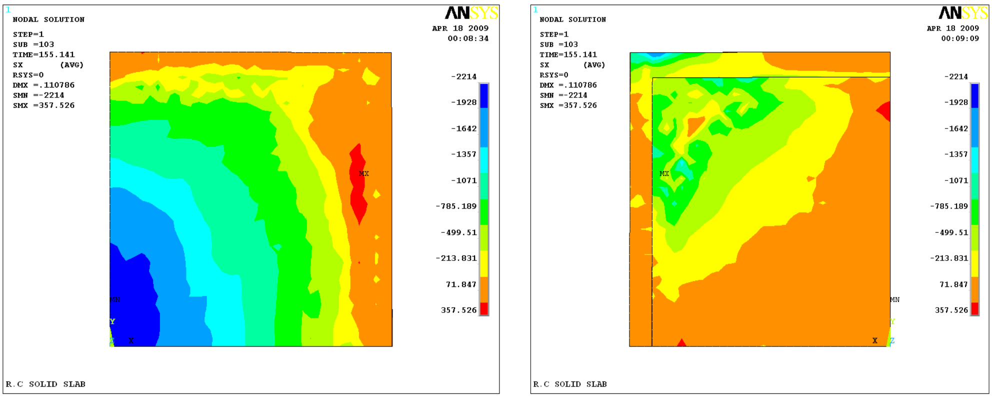


Fig. (13): Component of Stress distribution shape in X direction ;(a) Sx at top surface;(b) Sx at bottom surface)

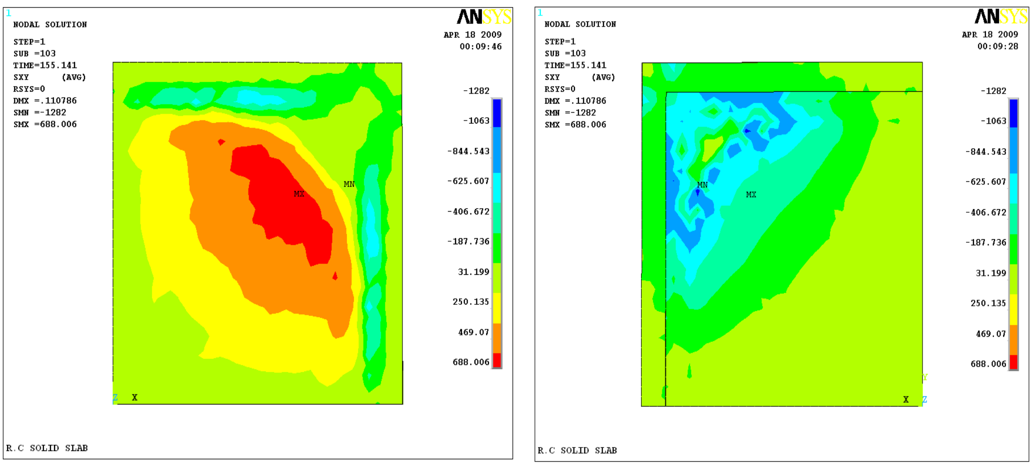


Fig. (14): Shear Stress distribution shape for slab (A2) in XY direction ;(a) Sxy at top surface;(b) Sxy at bottom surface.

Group A:

- When load is applied to the slab the first cracks to form is a roughly circular tangential crack around the parameter of loaded area due to negative bending moment in the radial direction.
- Increasing percent of main steel reinforcement from μ=0.38% (A1) to μ=0.67% (A3) improves the ultimate load carrying capacity from (2.363 t/m^2 to 3.338 t/m^2) by about 41%, and decrease the max displacement from (8.66cm at failure load =2.363 t/m^2 for slab A1) to (5.57cm at the same load =2.363 t/m^2 for slab A3) by about 55%.

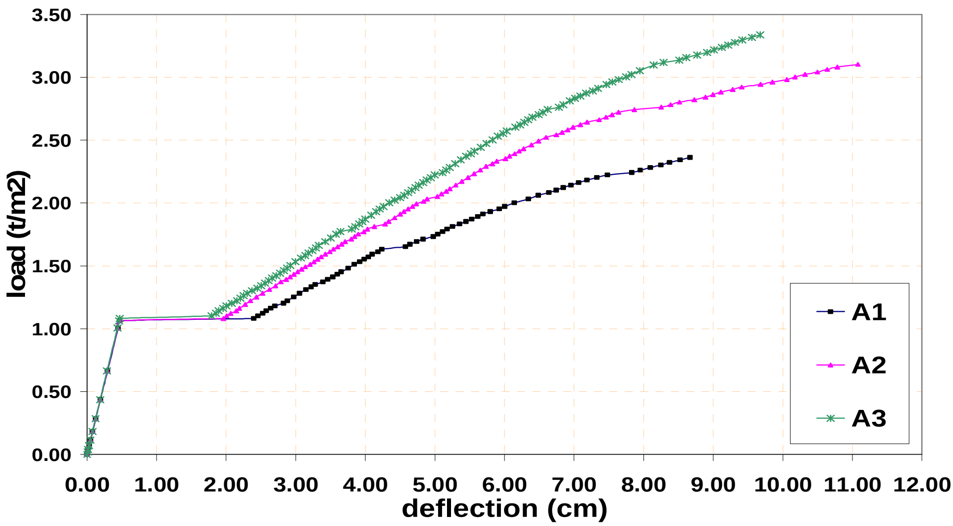


Fig. (15): Load deflection curve for group (A).

(GROUP B):

- From studying this group it can be deduced that increasing beam depth from (70cm to 90cm) B1, A2 respectively have a small effect on improving slab load carrying capacity which was (6.04%).Increasing beam depth from (90cm to 110cm) A2, B2 respectively have also a small effect on improving slab load carrying capacity which was (1.69%), at the same time it decrease central deflection by (1.0%).

(GROUP C):

Results of this group can be summarized as follows:

- Increasing beam width from *B*=20 (C2) to *B*=30 (A2) improves the ultimate load carrying capacity from (2.469 t/m^2 to 3.103 t/m^2) by about 20% and decrease max displacement from (8.143 cm to 6.408 cm at load 2.469) by about 21%.
- Increasing beam width from *B*=30 (A2) to *B*=40 (C1) improves the ultimate load carrying capacity from (3.103 t/m^2 to 3.390 t/m^2) by about 9% and decrease max displacement from (11.078 cm to 7.089 cm at load 3.103) by about 36%

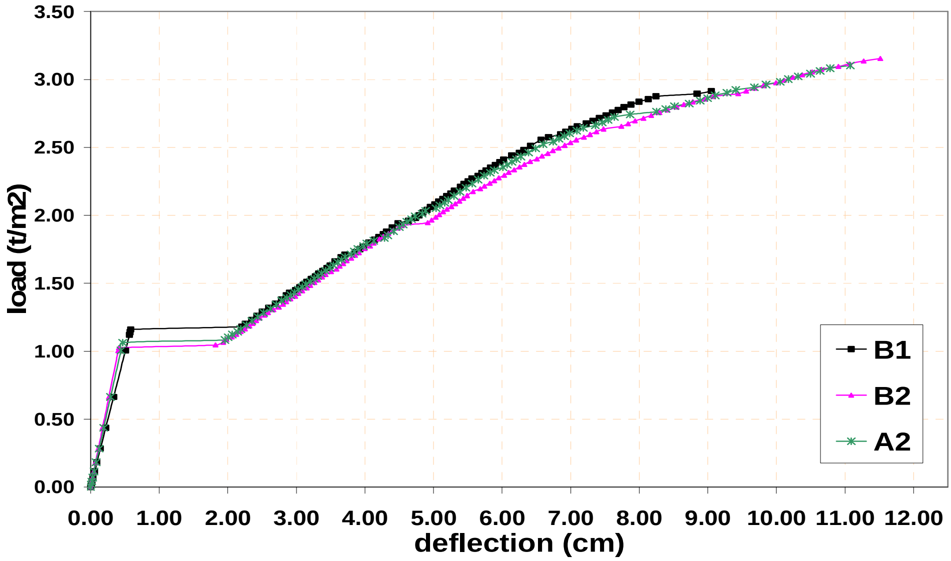


Fig. (16): Load deflection curve for group (B).

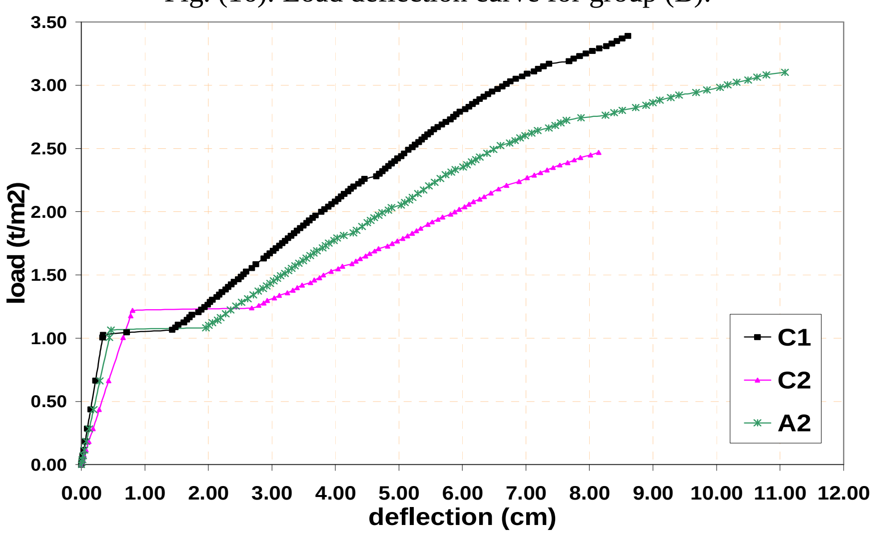


Fig. (17): Load deflection curve for group (C).

(GROUP D):

- Slabs D1, D2, D3 start to crack at the same loading value (1.103, t/m^2) in direction of parallel to the diagonal (at the bottom) and perpendicular to the diagonal (at the top) corner fiber, then it propagate gradually towards slab center with increase loading up to failure load.
- By comparing Pcr for A2 and group D it can be seen that; Corner reinforcement has a considerable effect on Pcr for such slabs, spacing between corner reinforcement do not effect on Pcr.
- Steel reinforcement reached the yield stress at load (2.323, 2.483, 2.303t/m^2) for D1, D2, D3 respectively at the slab center and the additional corner reinforcement due to tension stresses Fig. (19).

- From the above it can be deduce that After the Steel reinforcement reached the yield stress the slab corner subjected to strong stresses (sxy shear stress) leading to concrete cracking and crushing at the slab corner.
- Testing slab D2 (S=14cm) with changing the spacing between corner reinforcement to illustrate the effect of using different spacing between corner reinforcement S=7cm (D1), 21cm (D3) it can be seen that the best spacing for corner reinforcement is 14cm see Table (4), Fig. (20).
- Using this top and bottom corner reinforcement with a percent 43% from the main reinforcement improve the ultimate load capacity by (2% to 5%) and decrease the max. Displacement by (13% to16%) depends on spacing between corner reinforcement.

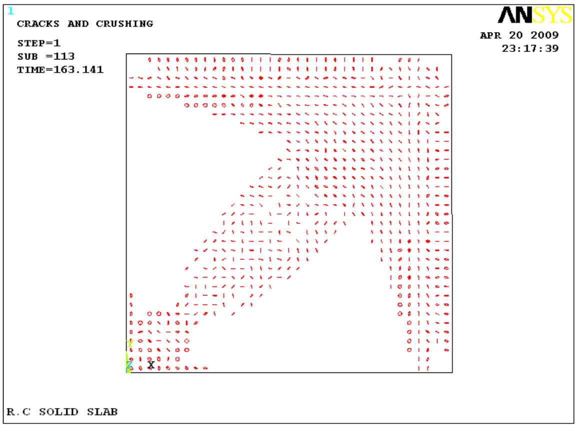
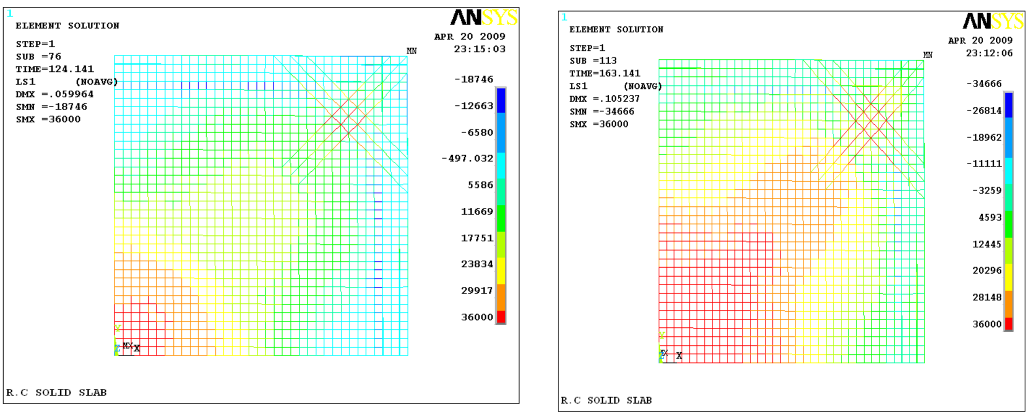


Fig. (18): Cracking shape for slab (D2) at failure load=3.263 t/m^2 for top surface.



(a) (b)

Fig. (19): yield stress for steel element ;(a) First yield stress for steel element. (b) Yield stress at failure load for slab (D2).

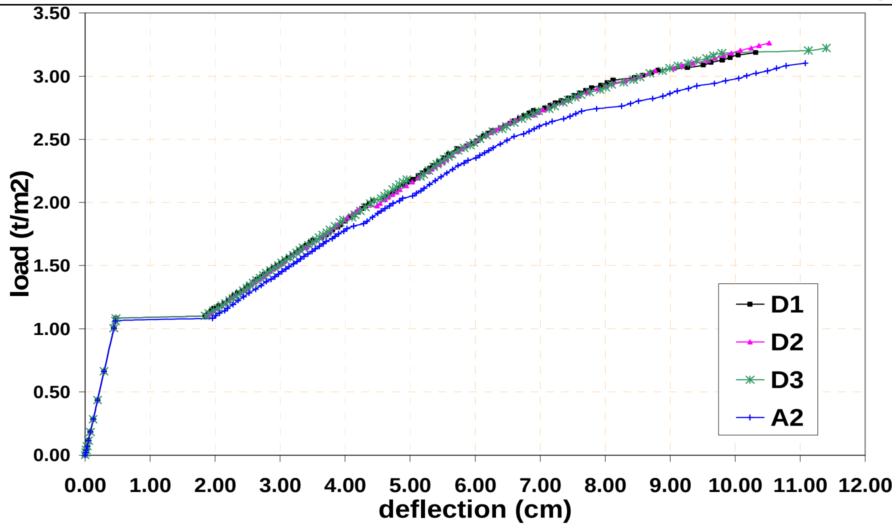
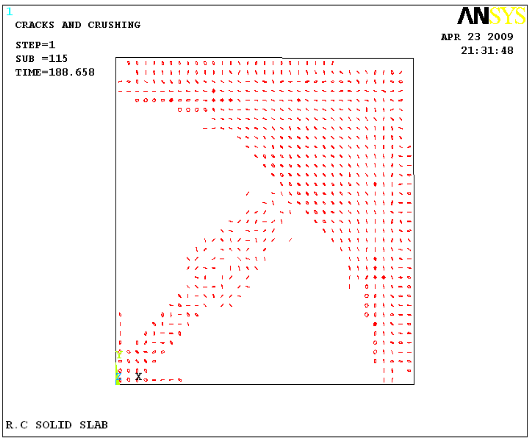


Fig. (20): Load deflection curve for slabs D1, D2, D3, and A2.

Group (E):

- Slabs E1, E2 start to crack at the same loading value (1.089t/m^2) in direction of parallel to the diagonal (at the bottom) and perpendicular to the diagonal (at the top)corner fiber, then it propagate gradually towards slab center with increase loading up to failure load.
- Steel reinforcement reached the yield stress at load (2.480, 2.171 t/m^2) for slabs E1, E2 respectively at the slab center and the additional corner reinforcement due to tension stresses Fig. (22).
- ***When the load is further increase****d*, stress and strain rise correspondingly and are no longer proportional. Eventually the carrying capacity of the slab is reached .failure happens because of the steel will reach its yield point. After that stress the reinforcement yields stretches and the tension cracks in the concrete widen visibly and propagate upwards, with simultaneous significant deflection of the slab. When this happens, the strains in the remaining compression zone of the concrete increase to such a degree that crushing of the concrete.
- All the cracks and stresses shape for slabs E1, E2 taking the same shape as slab A2.
- Using this top and bottom corner reinforcement corner reinforcement with a percent 72 % (E1), 100% (E2) from the main reinforcement improve the ultimate load capacity by (7%-10%) respectively and decrease the max. Displacement by (24% to 30%) respectively at spacing 14 cm Fig (23).
- The foregoing it can be concluded that slab corner subjected to torsional moment produce a tensile stresses at the underside of the slab (perpendicular to diagonal) at the same time it subjected to shear stresses produce tensile stresses at the upper side of the slab (parallel to diagonal), for this reason, steel reinforcing bars are placed on the tension side as close the extreme tension fiber and resist the tension stresses.



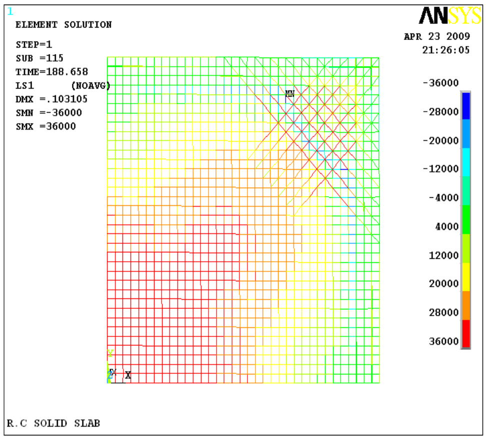


Fig. (21): Cracking shape for slab (E2) at failure load for slab (E2) .

Fig. (22): Yield stress for steel element at failure load for slab (E2) .

- By Increasing the percent of steel reinforcement from µs=0.52% (A2) to µs=0.67% (A3) the ultimate load carrying capacity improved from (3.103 t/m^2 to 3.338 t/m^2) by about 7%. From another view it can be seen that using corner reinforcement with percent 100% and spacing 14cm (E2) improves the ultimate load carrying capacity from (3.103 t/m^2 to 3.430 t/m^2) by about 10% Fig (24). *which means that using corner reinforcement has a better effect than increasing the percent of main reinforcement see from the economic point of view.*

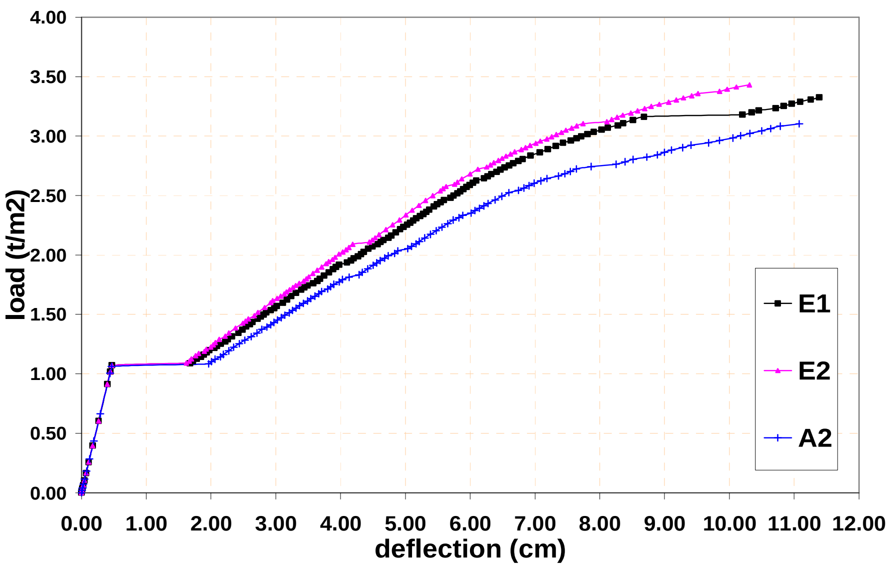


Fig. (23): Load deflection curve for slabs E1, E2, and A2.

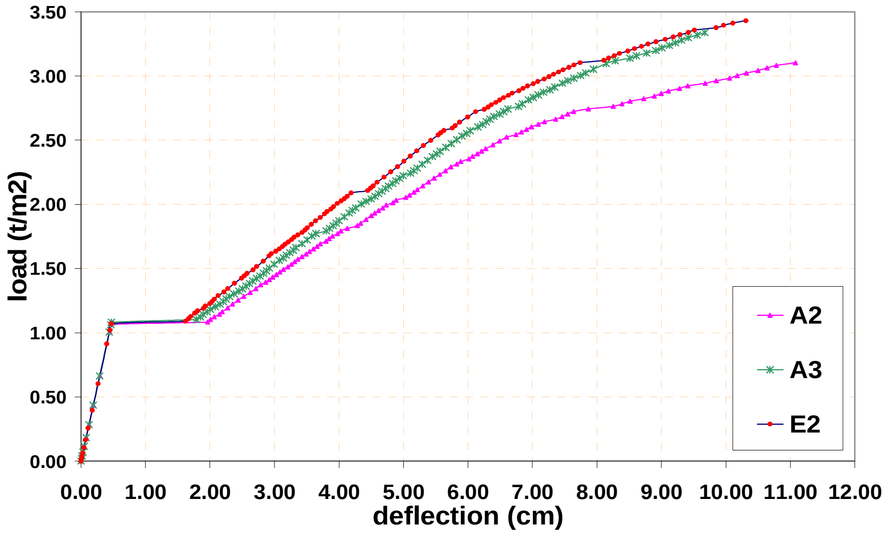


Fig. (24): Load deflection curve for slabs A2, A3, and E2.

Table (4) the results of parametric study.

GROUP NO.	SLAB NO.	PU t/m2	% increase Pu	δmax cm	δ0	% decrease δ0	Pcr t/m2	Py t/m2
A	A1	2.363	-23.85%	8.664	0.000	0.0%	1.083	1.793
	A2	3.103	0.00%	11.08	11.078	0.0%	1.083	2.373
	A3	3.338	7.57%	9.675	8.180	-26.2%	1.103	2.573
B	B1	2.915	-6.04%	9.050	0.000	0.0%	1.180	2.440
	B2	3.155	1.69%	11.515	10.967	-1.0%	1.045	2.235
C	C1	3.390	9.26%	8.606	7.088	-36.0%	1.045	2.650
	C2	2.469	-20.43%	8.143	0.000	0.0%	1.005	2.119
D	D1	3.188	2.74%	10.32	9.627	-13.1%	1.103	2.323
	D2	3.263	5.16%	10.52	9.350	-15.6%	1.103	2.483
	D3	3.223	3.87%	11.4	9.274	-16.3%	1.103	2.303
E	E1	3.326	7.18%	11.39	8.360	-24.5%	1.089	2.480
	E2	3.430	10.55%	10.31	7.740	-30.1%	1.089	2.171

Group (F):

Corner reinforcement effect for rectangular slab can be deduced as follow:

- Using corner reinforcement with percentage 100% of the main reinforcement and spacing 14 cm Increase significantly the slab load carrying capacity from (2.277 to 2.569 t/m^2)by about 12.82% in case of rectangularity=1.25(F3). At the same time it decrease considerably the slab central deflection from [12.081cm, (F1) to 9.520cm (F3)] at the same load value 2.277t/m^2 by about 21.2%.

- When slab rectangularity=1.5 the corner reinforcement has a considerable effect on load carrying capacity which increases from (1.472 to 1.888t/m^2) by about 28.26%. And decrease central deflection from [7.905cm, (F2) to 6.831cm (F4)] by about 13.6%.
- Using corner reinforcement with percentage 100% of the main reinforcement and spacing 14 cm Increase the first yield load from (1.517 to 1.730t/m^2) by about 14.04% for slab rectangularity=1.25.at the same time it increase the first yield load from(1.272 to 1.325t/m^2) by about 4.17% for slab rectangularity = 1.50.

Table (5) the results of parametric study.

GROUP NO.	SLAB NO.	PU t/m2	% increase Pu	δmax cm	δ0	% decrease δ0	Pcr t/m2	Py t/m2	% increase Py
F	F1	2.277	0.00%	12.081	12.081	0.0%	0.857	1.517	0.0%
	F2	1.472	0.00%	7.905	7.905	0.0%	0.744	1.272	0.0%
	F3	2.569	12.82%	12.777	9.520	21.2%	0.854	1.730	14.04%
	F4	1.888	28.26%	11.553	6.831	13.6%	0.761	1.325	4.17%

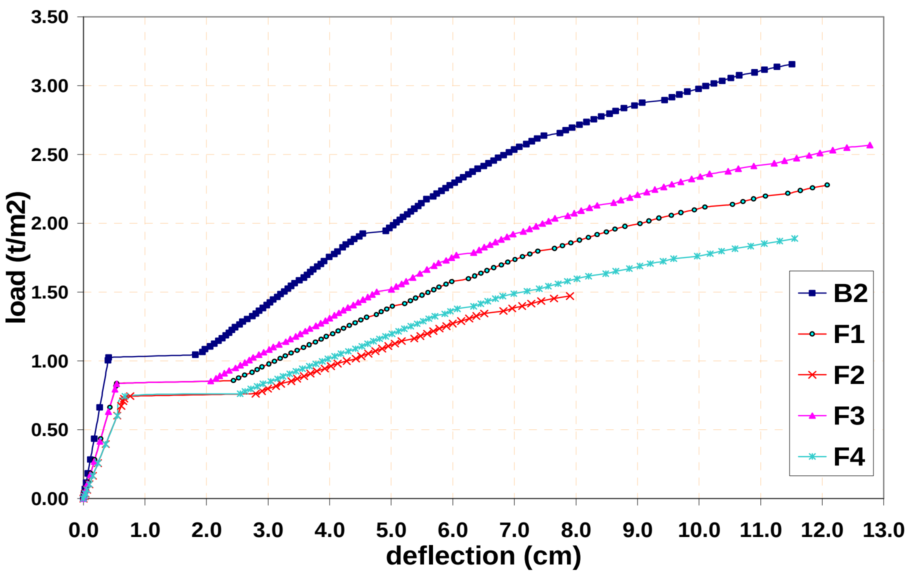


Fig. (4-23): Load deflection curve for group (F).

V- CONCLUSIONS

Several important conclusions have been drawn out of the presented study:

- The exsistance of corner reinforcement in R.C slabs, improves considerably the structural behaviour of such slabs leading to higher ultimate load carrying capacity and lower values for deflection.The increase in load carrying capacity ranges between (5% to 28%) and the decrease in max. deflection ranges between (13% to 30%) depending on slab rectangularity, percentage and spacing of additional corner reinforcement which was taken (43% to 100%) of the required main steel per meter.

- For both top and bottom corner reinforcement the optimum gain can be achieved at a percent value 100% of the main reinforcement of the slab, with spacing between the diagonal corner reinforcement 14 cm.
- Increasing the percentage of main reinforcement from $\mu s=0.52\%$ to $\mu s=0.67\%$ improves the ultimate load carrying capacity by about 7%. meanwhile it can be seen that using corner reinforcement with percent 100% and spacing 14cm improves the ultimate load carrying capacity by about 10 %.*which means that the economic point of view, using corner reinforcement is beneficial than increasing the percent of main reinforcement.*
- Increasing the margin beam stiffness improves significantly the ultimate load carrying capacity by about 20%, and decrease maximum central defflection by about 36%.

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تأثير تسليح الاركان على السلوك الإنشائى للبلاطات الخرسانية المسلحة المصمته

جرت العادة الى إستخدام البلاطات المصمته كنظام إنشائى غير مكلف إقتصادياً وذلك لمعظم الأسقف الخرسانيه الإعتياديه.

غير أن هذا النظام الإنشائى يفضل إستخدامه فى البحور الصغيره نظراً لما تتعرض له من صعوبات تتمثل فى الاتى:

- زيادة إزاحات البلاطات فى البحور الكبيره نسبياً.
- عدم قدرة البلاطه على إستيعاب أحمال كبيره بزيادة البحر.
- زيادة الأجهادات التى تتعرض لها البلاطه خاصةً إجهادات اللى التى تتولد فى أركان البلاطه.

ولذافقد أوصى الكود البريطانى والكود الامريكى بوضع حديد فى الاركان لمقاومة قوى اللى التى تتعرض لها أركان البلاطه

فقد أوصى الكود البريطانى بالاتى:

- إضافة شبكتين سفليه وعلويه فى الاتجاهين فى أركان البلاطات المصمته يتم توزيعها على مسافه تقدر بـ (خمس البحر القصير).
- لا تقل كمية الحديد المستخدمه فى كل إتجاه عن 0.70 من نسبة الحديد اللازم لمقاومه أقصى عزوم موجبه .

أما الكود الامريكى فقد أوصى بالاتى:

- إضافة شبكتين سفليه وعلويه فى الاتجاهين فى أركان البلاطات المصمته يتم توزيعها على مسافه تقدر بـ (خمس البحر الطويل).
- يتم وضع الحديد على هيئة شبكتين سفليه وعلويه فى الاتجاهين أو على هيئة حديد علوى عمودى على قطر البلاطه وسفلى موازى له.
- لا تقل كمية الحديد المستخدمه فى كل إتجاه عن الحديد اللازم لمقاومه أقصى عزوم موجبه تتعرض لها البلاطه.

وبالرغم من وجود العديد من الدراسات التى تقوم بدراسة السلوك الانشائى للبلاطات المصمته إلا أن اى منها لا يوضح تأثيروجود حديد تسليح فى أركان البلاطه على السلوك الانشائى للبلاطه .

ومن ثم كان الغرض الاساسى من هذا البحث هو :

دراسة تأثير حديد الاركان للبلاطه على تقليل الاجهادات والإزاحات وزيادة الحمل الأقصى للبلاطات المصمته. وذلك باستتخدام حديد تسليح فى أركان البلاطه فى اتجاه قطرى أعلى البلاطه مع حديد تسليح سفلى عمودى على المحور القطرى وذلك فى خمس البحرللبلاطه وبنفس كمية الحديد العلوى. وذلك من

منطلق أنه يقوم بتدعيم أركان البلاطات المصمته لمقاومة اجهادات اللى والقص التى تتعرض لها اركان البلاطه.مع الاخذ فى الاعتبار العوامل التاليه:

- دراسة تأسير استخدام الحديد فى أركان البلاطه بالنسب التاليه(43%،72%،100%)
- دراسة تأثير توزيع الحديد فى أركان البلاطه كل(7,14,21 سم)
- دراسة تأثير عرض وعمق الكمرات المحيطه.

وتتم دراسة تأثير هذا الحديد القطرى على الازاحات والحمل الاقصى للبلاطه بإستخدام نظرية العناصر المحددة (3DFEM) مستخدماً برنامج (ANSYS)، وفيه تم تمثيل الخرسانه المسلحة بإستخدام [Eight-node solid element *(solid 65*)], بينما تم نمذجة حديد التسليح بإستخدام [three-dimensional spar element(*Link8)*]

ويمكن تلخيص النتائج التى تم التوصل إليها من خلال الدراسه فيما يلى:

- وجود حديد فى أركان البلاطات ذات الاتجاهين يحسن من قيمة الحمل الاقصى للبلاطات ويقلل من الازاحات الناتجه عن الأحمال الواقعه على هذه البلاطات.
  - نسب الزياده فى الحمل الاقصى الناتجه عن وضع حديد قطرى سفلى فى الاركان تصل الى(10%) بينما تصل نسب التقليل فى الازاحات نتيجة هذا التسليح (30%) وذلك حسب نسبة الحديد الاضافى السفلى فى اركان البلاطات والذى يتراوح من43% إلى 100% من الحديد اللازم لمقاومه أقصى عزوم موجبه.
- النسبه المثلى للحديد المستخدم فى أركان البلاطات العلوى والسفلى هى 100% ويتم توزيعها على مسافات كل S=14cm.
- زيادة جساءة الكمرات المحيطه بالبلاطه يحسن من سلوك البلاطه فى زيادة الحمل الاقصى بنسبة تصل 20% ويقلل من الترخيم الناتج بنسبة 36%.
- عند زيادة نسبة التسليح الرئيسى للبلاطه من 0.52%الى0.67% يزداد قيمة الحمل الاقصى بنسبة7% بينما عند تسليح اركان البلاطه بحديد علوى وسفلى بنسبة 100% من التسليح الرئيسى للبلاطه يزاد قيمة الحمل الاقصى بنسبة 10%،مما يبين ان تسليح اركان البلاطه افضل من الناحيه الاقتصاديه فضلا عن تاثيره على الحمل الاقصى للبلاطه.