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EFFECT OF CHANGING THE REINFORCEMENT DIRECTIONS FOR R. C. TWO-WAY SOLID SLABS

BY

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ABSTRACT: Improvement of the response for two- way solid slabs is the main important which increase the ultimate strength capacity and decrease the maximum deformations. The aim of this experimental investigation was to study the effect of change in the steel reinforcing bars directions on the response of two- way solid slabs. The investigated parameters in this study were carried out three different solid slab thicknesses and the change in the angle of steel reinforcing bars mesh directions, which make with the major axis of the slab. Three thickness (8, 10, and 12) Cm and ten angles of inclination (0, 5, 10,15,20,25,30,35,40, and 45) degrees were considered.
In this paper, thirty specimens were tested experimentally, and divided into three groups according to the solid slab thickness**.** Each group contains ten specimens, one as a reference and the other nine were reinforce by steel bars by one of the inclination angle. The obtained results in this study indicated that, under static loading, the response of the two- way solid slabs depends on the reinforcing bars directions and the solid slab thickness.
Very encouraging results and conclusions were obtained and presented in shape of figures and curves, which may be useful for designer and increasing the safety when dealing with the design of concrete slabs.

KAYWORDS: Response – Two- way solid slabs **-** Steel bar directions – Angle of inclination – Improvement.

1. INTRODUCTION

The widely used structural system consisting of concrete slabs with uniform thickness supported directly on beams is called solid slab. It has several advantages over other types of slabs systems such as, small quantities of reinforcements, good serviceability and avoids the punching shear problems. Sometimes two-way solid slabs in wide panels subjected to higher loads such as, in hospitals, schools, and other buildings.
Codes[1. 2. 3. 4. 5. 28] and specifications consider requirements for design and construction of solid slabs as, minimum thickness, maximum allowable (deflections, stresses), and others minimum reinforcements. While some codes neglecting the reinforced bars directions because it interested to needs more workability. And at the same time it recommended to corners reinforcements.

Creep deflections in slab buildings and forces in shores during construction, deflection control of slabs using allowable span to depth ratios, and deflection of R.C slabs under construction loading have been studied by Aguinaga, Gilbert, and Graham [6. 7. 8].
Graham[9], investigated the long time multipliers for estimating two-way slab deflections,
Grossman[10] fined simplified computations for effective moment of inertia, and minimum thickness to avoid deflection computations; wherever Grundy11 and Jensen12 have studied the construction loads on slabs with shored formwork in multi-story buildings and solutions rectangular slabs continuous over flexible support.
Jokinen[13] introduced the field measured two-way slab deflections, Nilson[14] studied the deflection of two-way floor systems by the equivalent frame method and Rangan[15] studied the prediction of long-term deflections of flat plates and slabs, but the practical calculation of two-way slab deflections have produced by Scanlon[16]
Tarn[17] study the deflection of two-way slabs subjected to restrained volume change and transverse loads and the minimum thickness requirements for control of two-way slab deflections and the deflections of multiple-panel reinforced concrete floor slabs have find by Thompson[18] and Vanderbilt[19].
Shear reinforcement for concrete slabs, design of concrete slabs for transverse shear, have been studied by Dilger[20], Marti[21] and others[22. 23. 24. 25].
In this study, an experimental investigation of using variable reinforcing bars inclination angles for studying R.C. two-way solid slab was performed to compare the efficiency and performance under flexure loading. The investigated parameters were the reinforced bars inclination angles and the slab thickness. For this type of slab, the effects of its parameters in the performance of these slabs have been studied. The results were compared with respect to (cracking, ultimate) loads capacity and intermediate central deflections.

2. MODEL PREPARATION AND TEST PROGRAM

Some trials of concrete mixes were designed to produce an average cube compressive strength after 28 days equals 250 kg/Cm^2, with the following proportion: -
Cement: sand: gravel: water, are - 1: 2.8: 4.2: 0.50 by weight respectively. The maximum nominal size was 10 mm for coarse aggregate and the cement used was ordinary Portland cement.
A reference specimen was casted for every mix, All tested slabs models had a 90 x 90 Cm^2 two-way slab and with different thickness (8, 10, 12) Cm with constant steel reinforcement of a typical test specimen containing main and secondary reinforcement reinforcements 6 ϕ 10 mm perpendicular with them. That reinforcement making ten angles of inclinations (0, 5, 10, 15, 20, 25, 30, 35, 40, and 45) degrees on the slab axis respectively, as shown in Fig (1).
The amount of steel satisfied the Egyptian code requirements for the reinforced section. A mechanical vibrator was used to compact the concrete and ensures homogenous distribution around steel bars. The specimens were cured with water by sprinking twice a day for 14 days followed by air curing for another 14 days.
Thirty slabs including references were casted and divided into three main groups (I, II, and, III), with different thickness (8, 10, 12) cm respectively. Each group contains one reference S10 and nine slabs (S11, S12, and S13 to S19), (S20, S21, S22, and S29), (S03, S31, S32, and S39) for each groups respectively. The solid slabs dimensions and test program have been shown in table (1).
These slabs were tested under four concentrated loads, one load at each quarter pointes of the slab shown in Fig (2) for a typical model.
The cracking, ultimate load capacity and mid-span deflection had been measured every 5.0 KN increment up to at failure.

Table 1: Program of the tests specimens.

Group No	*Specimen No*	*Two-Way Slab Thickness (Cm)*	*Bars Inclination Angle Degrees*
I	S10	8	0.0
	S11	8	5
	S12	8	10
	S13	8	15
	S14	8	25
	S15	8	25
	S16	8	30
	S17	8	35
	S18	8	40
	S19	8	45
II	S20	10	0.0
	S21	10	5
	S22	10	10
	S23	10	15
	S24	10	25
	S25	10	25
	S26	10	30
	S27	10	35
	S28	10	40
	S29	10	45
III	S30	12	0.0
	S31	12	5
	S32	12	10
	S33	12	15
	S34	12	25
	S35	12	25
	S36	12	30
	S37	12	35
	S38	12	40
	S39	12	45

3. RESULTS AND DISCUSSION

The ultimate load of the tested slab model is defined as the load at which the specimen cannot sustain any more capacity load. The cracking load was determined using two methods, by visual inspection or from the load-deflection relationship, which was experimentally measured and plotted for each specimen.

The relation between the applied loads and mid-span vertical deformations of the tested specimens from zero loads until failure were self-drawn by test machine. Ultimate loads of the tested specimens were measured as well as the crack loads.

The reference specimens failed due to flexure failure, at the lower third wherever all specimens were failed due to flexure failure in the lower middle third.

Table (2) shows the analysis of the test results for all tested specimens of all groups (I, II, and III). Photo (1) shows the tested slab under machine loads after failure.

Figure (3, 4, and 5) are histograms showing the relations between crack, ultimate loads and variable steel bars inclination angles for all specimens in groups (I), (II), and (III) respectively, which indicate the affect of bars inclination angles on crack, ultimate loads. It can be noticed that there is a similar behavior, such that, as the bars inclination angle was increased the crack, ultimate load capacity increased.

By comparing, these specimens with the reference specimen S10, S20, and S30 for each group, the percentage of increasing in the crack, ultimate load capacity for all groups are given as follows:

For group (I), the percentages of increasing were :- (5%... to 41%), and (3%... to 39%), in the crack, and ultimate load capacity for specimens (S11… to S19) respectively;

Group (II), the percentage of increasing were :- (2%… to 33%), and (1%... to 33%), in the crack, and ultimate load capacity for specimens (S21... to S29) respectively;

Moreover, in the same manner group (III), the percentages of increasing were :- (3%... to 36%), and (2% .to 34%), in the crack, and ultimate load capacity for specimens (S31... to S39) respectively.

Figures (6), (7), and (8) showing the relations between the load of variable steel bars inclination angles for all specimens in groups (I), (II), and (III).and vertical mid-span deflections respectively, which indicate the affect of bars inclination angles on mid-span deflections for each group. The trend of these figures are similar, such as, the load increase the vertical mid-span deflections increase gradually by small rate from zero load to near the crack load and increase by big rate of increasing to at failure load. This is observed for all groups.

Figures (9), and (10) showing the effect of bars inclination angle on max deflection, and the effect of bars inclination angle on ultimate loads for all groups respectively**.** From these figures, it can be seen that, the effect of the variation in steel bars inclination angles on the response of vertical mid-span deflections, and can be noticed that, all specimens gives smaller trend of vertical mid-span deflections and smaller than the control specimen according to the variation in steel bars inclination angles as follows: -

For group (I), the percentage of decreasing in maximum vertical mid-span deflections comparing with the results from control specimen S10 were - (-1%… to -15%) for specimens S11, to.., S19 respectively. While in group (II), the percentage of decreasing in maximum vertical mid-span deflections comparing with the results from control specimen S20 were: - (-1%... to -13%) for specimens S21 .to S29 respectively,

In addition, for group (III), the percentage of decreasing in maximum vertical mid-span deflections comparing with the results from control specimen S30 were - (-1%… to -13%) for specimens S31 to... S39 respectively,

Hence, it can be seen that, the good deflections results from the variation in reinforcing steel bars inclination angles for two-way solid slabs observed for bigger steel bars inclination angles to 45.0 degree.

The present analysis was conducted on two-way slabs with degree of rectangularity equal (1.0). The present technique will further examine on the variable degree of rectangularity over than (1.0) and on two-way slabs with variable boundary conditions in the future work.

The Figures, shows the best results according to the biggest inclination angles used from 5.0 to 45.0 degrees and higher than 0.0 degree. However, the best steel bars inclination angle is 45.0 degree. More over the maximum effect of increasing in crack, and ultimate load capacity from higher to lower for group (I, III, and II) respectively.

Photo (1) Shows test setup for tested solid slab.

Table 2: Shows the analyses of test results

Group No	*Specimen No*	*PC (KN)**	*PU (KN)**	Δ Max Mm x10^{-3}	*PC/PC0 %*	*PU/PU0 %*	Δ Max / Δ Max0 %
I	S10	44.0	63.0	7256	100	100	100
	S11	46.0	65.0	7154	1.05	1.03	.99
	S12	47.0	67.0	7053	1.07	1.06	0.97
	S13	48.0	69.0	6957	1.09	1.10	0.96
	S14	50.0	72.0	6858	1.14	1.14	0.95
	S15	52.0	75.0	6753	1.18	1.19	0.93
	S16	55.0	78.0	6601	1.25	1.24	0.91
	S17	57.0	81.0	6456	1.30	1.29	0.89
	S18	59.0	84.0	6308	1.34	1.33	0.87
	S19	62.0	88.0	6155	1.41	1.39	0.85
II	S20	58.0	82.0	9102	100	100	100
	S21	59.0	83.0	9006	1.02	1.01	0.99
	S22	60.0	85.0	8904	1.03	1.04	0.99
	S23	61.0	87.0	8807	1.05	1.06	0.97
	S24	63.0	90.0	8703	1.09	1.10	0.96
	S25	66.0	93.0	8555	1.14	1.13	0.94
	S26	68.0	96.0	8408	1.17	1.17	0.92
	S27	71.0	100.0	8254	1.22	1.22	0.91
	S28	73.0	104.0	8106	1.26	1.27	0.89
	S29	77.0	109.0	7905	1.33	1.33	0.87
III	S30	70.0	102.0	10802	100	100	100
	S31	72.0	104.0	10707	1.03	1.02	0.99
	S32	74.0	107.0	10604	1.06	1.05	0.98
	S33	76.0	110.0	10508	1.09	1.08	0.97
	S34	79.0	114.0	10403	1.13	1.12	0.96
	S35	82.0	118.0	10252	1.17	1.16	0.95
	S36	85.0	122.0	10101	1.21	1.20	0.94
	S37	88.0	126.0	9905	1.26	1.24	0.92
	S38	91.0	131.0	9707	1.30	1.28	0.90
	S39	95.0	137.0	9403	1.36	1.34	0.87

* PC (KN), and PU (KN): are the Crack and Ultimate Loads in Kilo Newton.

** Δ Max: is the Maximum mid span deflection.

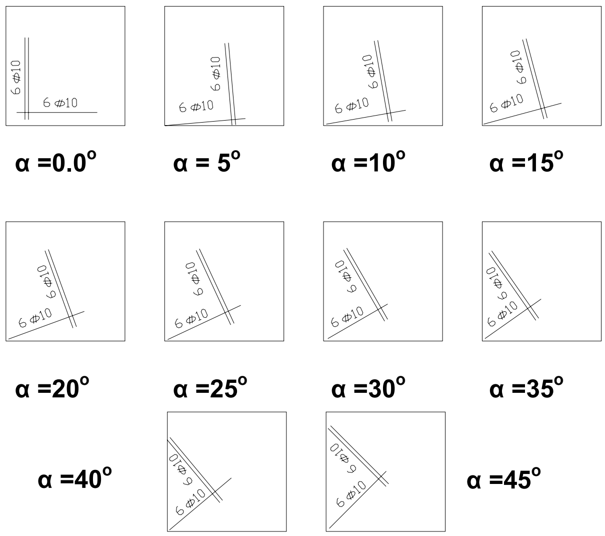

Fig (1): Reinforcement of slab and bar inclination angles.

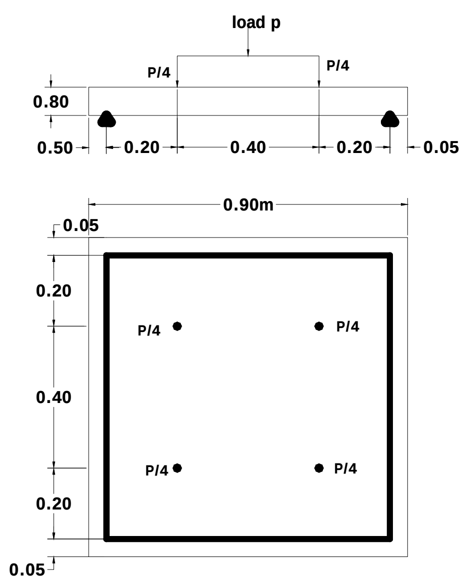

Fig (2): Typical model of the slab under loads and their dimensions.

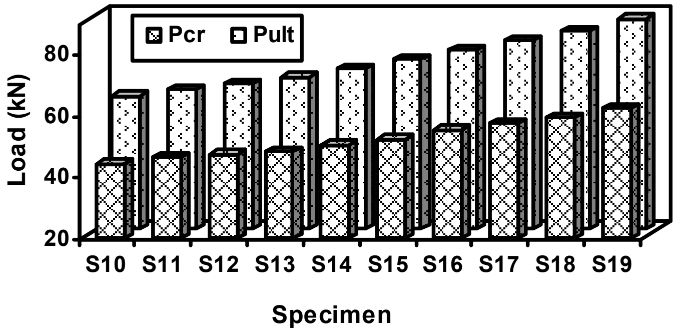

Fig (3): Histograms of crack and ultimate loads for group (I).

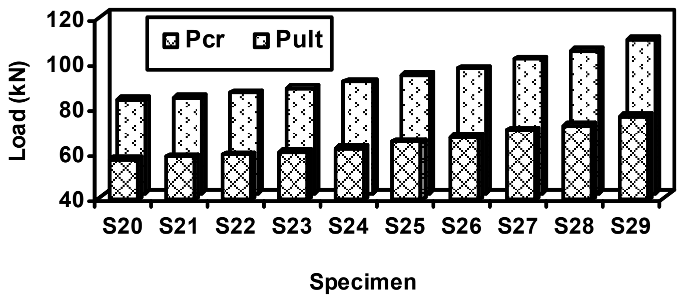

Fig (4): Histograms of crack and ultimate loads for group (II).

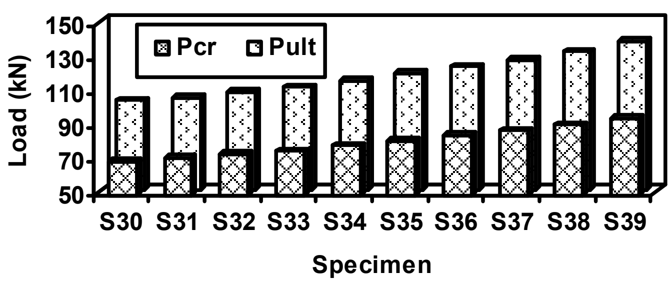

Fig (5): Histograms of crack and ultimate loads for group III).

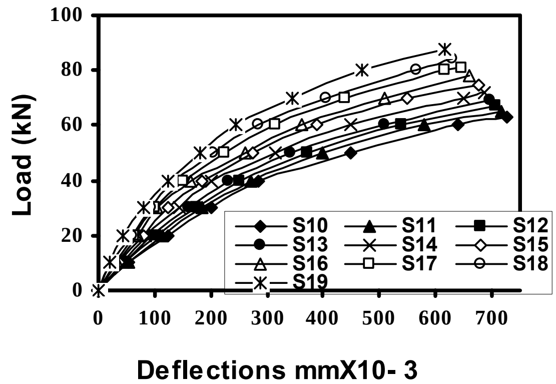

Fig (6): Load-deflection relation for group (I)

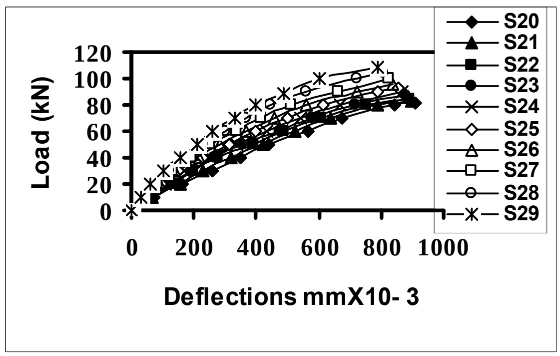

Fig (7): Load-deflection relation for group (II)

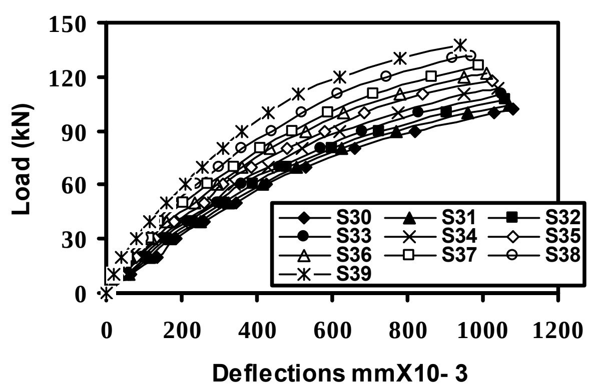

Fig (8): Load-deflection relation for group (III).

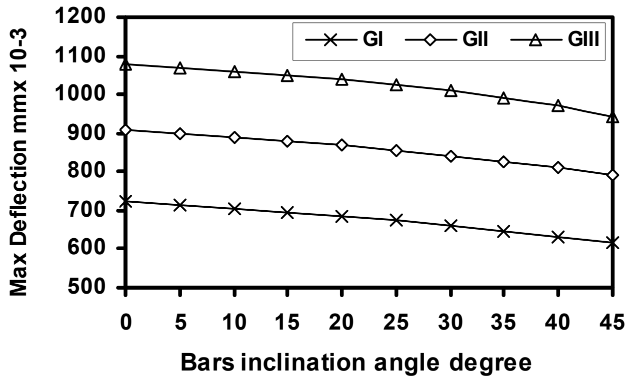

Fig (9): Effect of bars inclination angle on max deflection for all groups.

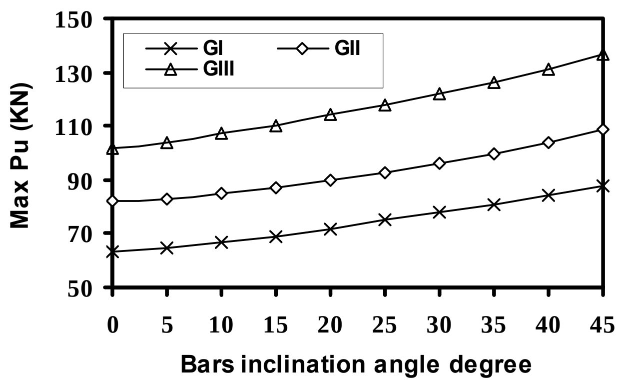

Fig (10): Effect of bars inclination angle on ultimate loads for all groups.

4. CONCLUSIONS

The experimental work presented regarding the effectiveness of using variable steel bars inclination angles for reinforcing the experimental two–way simply supported reinforced concrete square slabs compared with the similar specimens, which include the following conclusion: -

(1) All solid slabs specimens reinforced by steel bars with inclination angles more than zero degree showed significant increase in cracking, ultimate loads capacity and decrease mid-span deflection. The maximum increasing and decreasing are (41%, 39%, and –15%) respectively.

(2) At a considerable value of ultimate load for control specimen, all slabs reinforced by inclined bars exhibited much lower deflections and the difference between cracking and ultimate load value were achieved. In addition, at any load level.

(3) For economy using reinforcing steel bars with inclination angles more than zero degree gives considerable good results because it save a 30% approximately from steel reinforcements and using all small length's in the site.

(4) The reinforcing by using this technique of reinforcement must be distributed about centerline of diagonal for main steel and perpendicular for secondary steel. In addition, needs to professional for steel manufacture. However, the saving in expensive steel covers this item.

(5) Reinforcing two-way solid slabs by using these steel distribution technique more effective in the large spans and give a small solid slab thickness. The modes of failure were flexure and gives micro cracks at middle third propagate with increasing the load with high ductility until failure. The cracks propagation direction depends on the bar inclination angles.

(6) Reinforcing two-way solid slabs by this technique of reinforcement covers the codes recommendation for corner reinforcements.

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