SIMPLY SUPPORTED REINFORCED CONCRETE SQUARE SLABS SUBJECTED TO CENTRAL LINE - LOAD EXPRIMENTAL STUDY

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ABSTRACT

This paper presents the results of an experimental programme conducted on seven reinforced concrete square slabs subjected to control line-load. The object was to study the effect of the steel arrangement on the behaviour and the strength of the slab. The sets of support conditions were tried, namely; slabs simply supported on rollers with provisions against corner lefting and slabs with adge beams supported at the four corners. The results proved that the most efficient arrangement of steel is when the main steel is placed perpendicular to the line of load.

INTRODUCTION

In ordinary residential building, some engineers used to place additional steel under internal walls to strengthen slabs at this region to cater for the additional load from the walls. The concept was to consider a strip of the slab under the wall to act as a beam and to place the reinforcement in this direction.

Although this concept is defended by some engineers and may be acceptable if looked at in view of Hillerborg's strip method. Yet, it contradicts the expected behaviour of flexural members which bend about contact line between the slab and the load. Also it contradicts the clauses of the Egyptian code for the design of slabs subjected to concentrated loads.

The present study was intended to clarify the behaviour of slabs subjected to central line-load experimentally, in view of obtaining data useful for design practice. Thorough studies in the elastic and post-elastic ranges of loading along with comparison of the results of those studies with the 1989 Egyptian Code of practice elastic method were published elsewhere [4].

DESCRIPTIVE OF TEST SLABS

All slabs were square in plan with side length = 2.0 m and thickness = 5 cm. Slabs S-1 through S-4 were supported on rollers with the axes of the rollers parallel to the edges of the slab. this rollers can accept large rotations and displacements. Moreover the use of several separated rollers has the advantage over using a single long roller, since the former can cater for the possible variation in the magnitude of the edge rotations and displacement. Also any deformation of the edge along its length can be conveniontly accomodated.

Two groups will be refered to in studing the parameters. The first group included for slabs S-1 through S-4, see Table (1).

The second group included three test slabs, (S-5) through (S-7), see Figure (1) for the slabs dimensions and reinforcing arrangements. The 5 cm thick test slabs, of this group, were cast monolithically with the 10 × 25 cm adge beams. The beams form the continuous spport for the slab and the beams were supported at their four corners. Three of these corners were supported on balls placed between two plates of dimension 100 × 100 × 25 mm.

The main variable for both slab groups was the reinforcement arrangements, see Fig. (1).

LOADING AND TESTING PROCEDURE

The line load was applied to the test slabs by means of a 20 ton capacity hydraulic jack. The jack load was

Table 1. Test results.

Group No.	Test frame No.	Cylinder * Compressive Strength f'_c kg/cm^2	Cube Compressive Strength C kg/cm^2	Age at testing days	Failure Load (tons)	Max deflection / slab depth	Failure mode see Figs. (7) and (8)
A	S-1	223	286	44	7.8	0.75	a
	S-2	250	306	29	8.5**	0.75	a
	S-3	221	277	30	9.6	0.83	a
	S-4	241	291	34	9.0	0.96	a
B	S-5	224	284	30	9.0	1.03	a***
	S-6	218	271	23	12.0	0.96	b
	S-7	246	298	29	12.0	0.99	a

* Average cylinder to compressive strength ratio = 0.81 .
** (S-2) failed by bond failure accross the yield line .
*** One point of looding punched through the slab at falure .

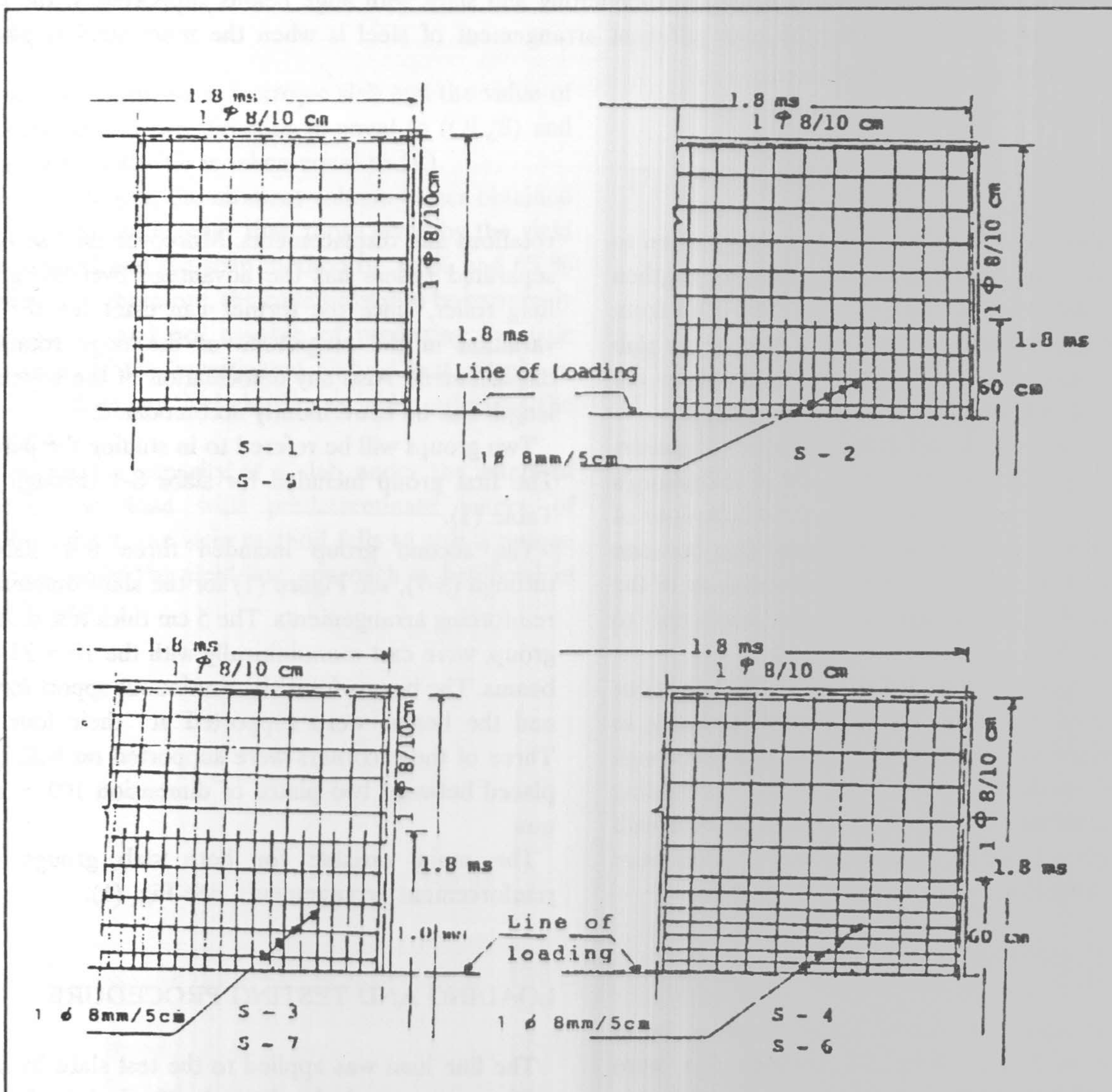

Figure 1. Details of reinforcement of Slabs(S-1) through (S-7) (only one quarter of each slab has been drawn),

distributed equally to four contact points by a system of spreading beams the contact surfaces were square steel plates of dimensions 100 × 100 × 25 mm. The load of the hydraulic jack was measured by a 20 ton capacity load cell connected to the strain indicator. Each specimen was loaded in increments up to failure. The concrete and the steel strains and the slab deflection readings were recorded before and during the test and after each loading increment and the crack patterns were marked.

BEHAVIOUR OF THE SPECIMENS AND MODES OF FAILURE

For the slabs without edge beams, the group A, flexure cracks were observed on the underside (tension side) at a load of about 2.0 tons (20.8 - 25.6% of the ultimate load). The cracks started at the center region of the test specimen parallel to the line loading and then spread towards the corners under further increases of the load. The measured deflections remained small up to the starting of the cracking Figure (2). Deflections increased more rapidly at load higher than the cracking loads. It was clear from the obtained load-deflection relationships Figure (2) that the differences in the magnitude, between the deflection of Slab (S-3) and that of Slab (S-4), along the curve through the loading stages, ranges between 0.0 at the start of loading to 25% at the final stages of loading.

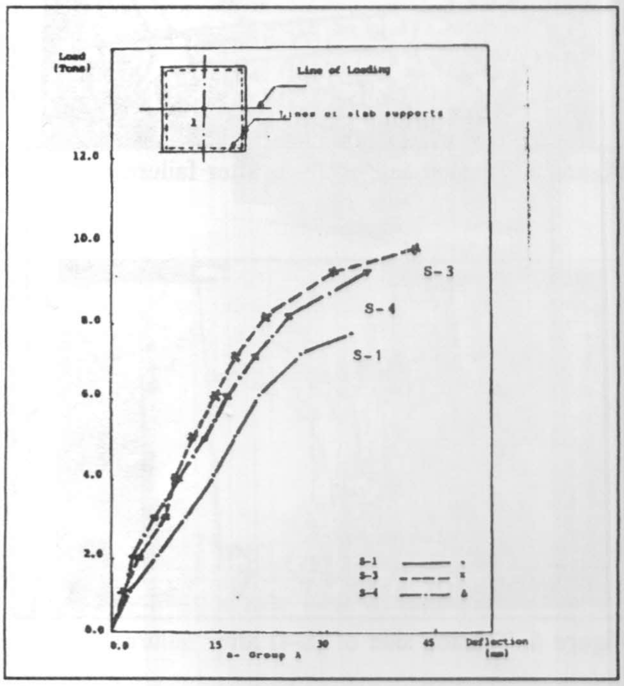

Figure 2a. Load-deflection curves at point 1.

The load-deflection relationships for other points away from the centre point throughout the test slabs show the same trends. As mentioned before Slab (S-3) is the model which was provided with additional central steel perpencular to the loading line and Slab (S-4) was the model which was provided with additional steel in the direction of the loading line, while Slab (S-1) had no additional central steel reinforcement. It is clear from the load-deflection relationships that Slab (S-1) suffers larger deflection than Slabs (S-3) and (S-4). Its deflection was higher than those of Slabs (S-3) and (S-4) by about 30 % of their average deflection.

When comparing the relationships between load and deflection, Figure (2), it can be seen that the stiffness of the slab increases when the additional steel was added, test Slabs (S-3) and (S-4), in the central region, whether this additional steel was parallel or perpendicular to the line of loading. The placing of the additional steel perpendicular to the line of load gave a higher rises to the

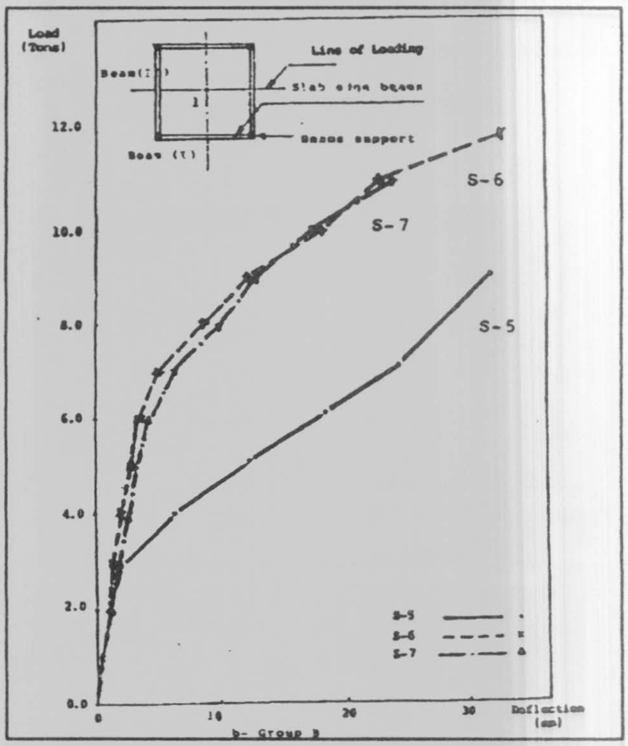

Figure 2b. Load-deflection curves at point 1.

stiffness than placing the steel parallel to the line of load, and the rise remains so even at higher stages of loading.

Generally, the modes of failure of the slabs of this group were similar, see Figures (3) through (6). This mode can be idealized to follow the yielding pattern as shown in Figure (7).

For the slab with edge beam, group (B), flexure cracks were observed on the tension side at a load of about 3.0 ton (25% to 33.3% of the ultimate load). The initiation and propagation of cracks are generally similar to those in group A, Figures (9) and (10), however for the Slab (S-6) the main crack spreads right under the loading line to the beam having axis perpendicular to the line of loading as shown in Figure (11). From the load-deflection curves, Figure (2-b), for group B one can notice that the measured deflections remain small up to the starting of the cracking and the deflection increased more rapidly at loads higher than those caused the initial cracking. As in group A, the difference in the magnitude between the deflection of Slab (S-6) and Slab (S-7), along the curve through the loading stages, were small and does not exeed 10% in most cases. But differences between the deflection of Slab (S-5) and the average values of the deflection of Slab (S-6) and (S-7) at the same load were very large.

From the load-deflection curves for the mid-points of the Beams (I) and (II), it was clear that the deflection of the mid-point of Beam (I) in (S-5) was larger than the deflection of the corresponding point in (S-6) and less than the deflection of the same point in (S-7). But the deflection of the mid-point of the Beam (II) in Slab (S-5) was less than the deflection of that point of Slab (S-6) and higher than the deflection of the same point in Slab (S-7).

It is clear from the load-deflection relation,ships, Figure (2-b) that the stiffness of the slab increased by adding the additional steel in the central region, parallel or perpendicular to the line of loading.

The modes of failure of Slabs (S-5) and (S-7) were similar to the modes of the slabs of group A, see Figures (9) and (10), and may be idealized to follow the yielding pattern shown in Figure (7) (mode a); but the mode of failure of Slab (S-6) occured as a result of the failure of the two edge beams perpendicular to the line of loading, and this mode was idealized to follow the yielding pattern shown in Figure (8) (mode b).

A summary of the test results is given in Table (2). The load deflection curves and photographs of modes for all the tested slabs are shown in Figure (2) through (6) and Figures (9) through (11).

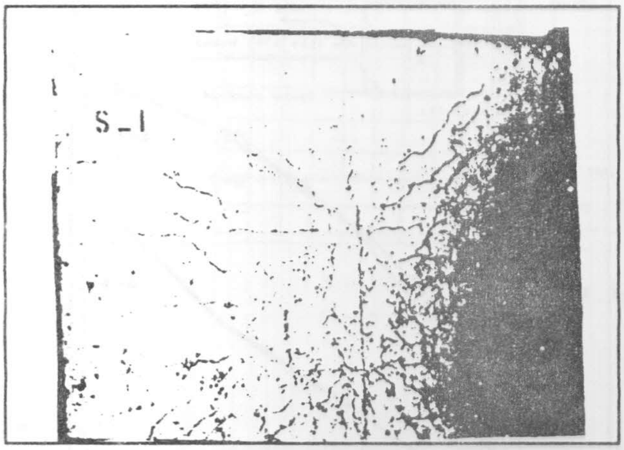

Figure 3. Tension side of (S-1) after failure.

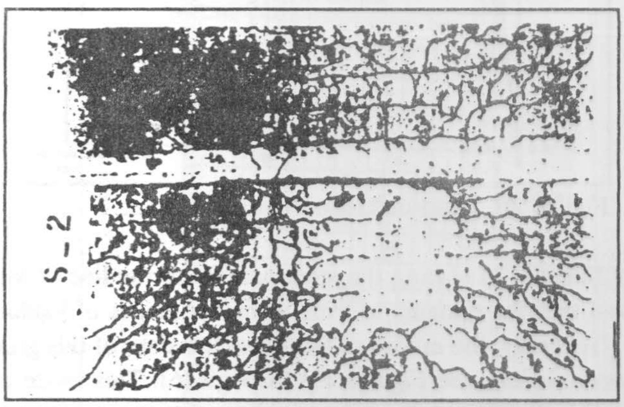

Figure 4. Tension side of (S-2) after failure.

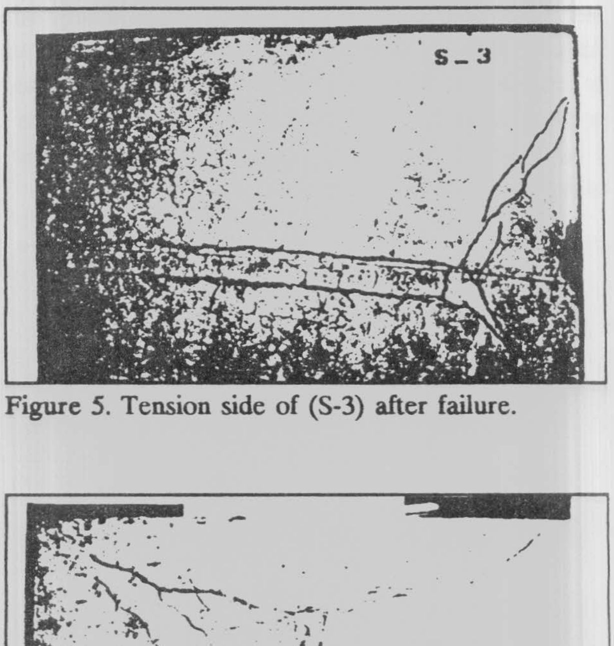

Figure 5. Tension side of (S-3) after failure.

Figure 6. Tension side of (S-4) after failure.

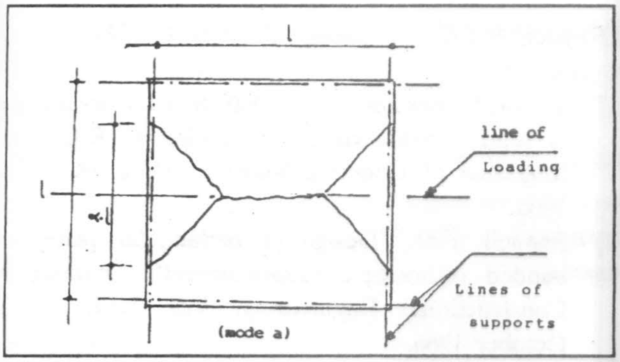

Figure 7. Failure mode for all slabs except (S-6).

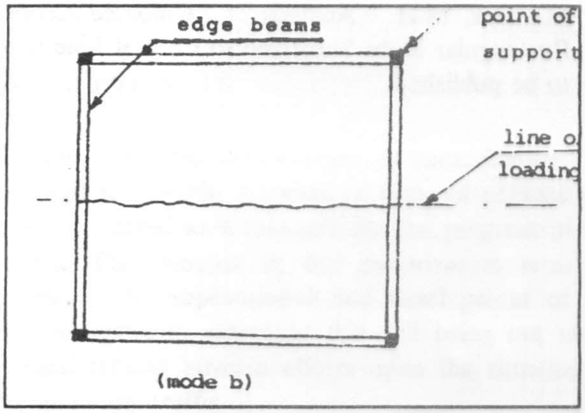

Figure 8. Failure mode for (S-6).

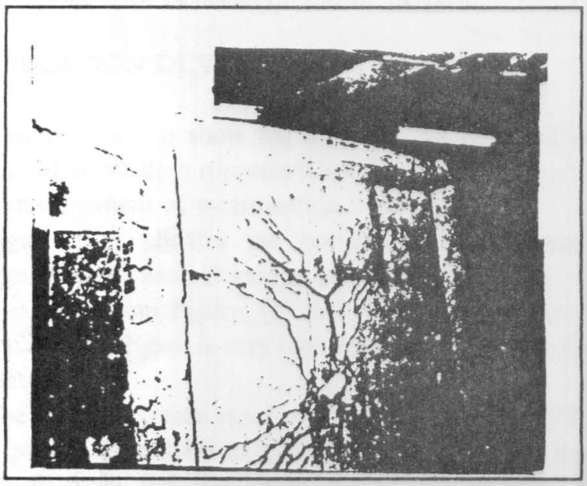

Figure 9. Tension side of (S-5) after failure.

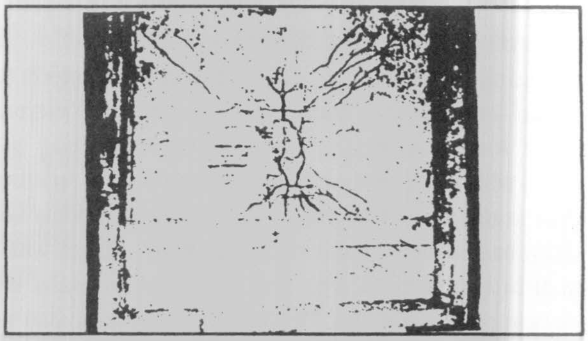

Figure 10. Tension side of (S-7) after failure.

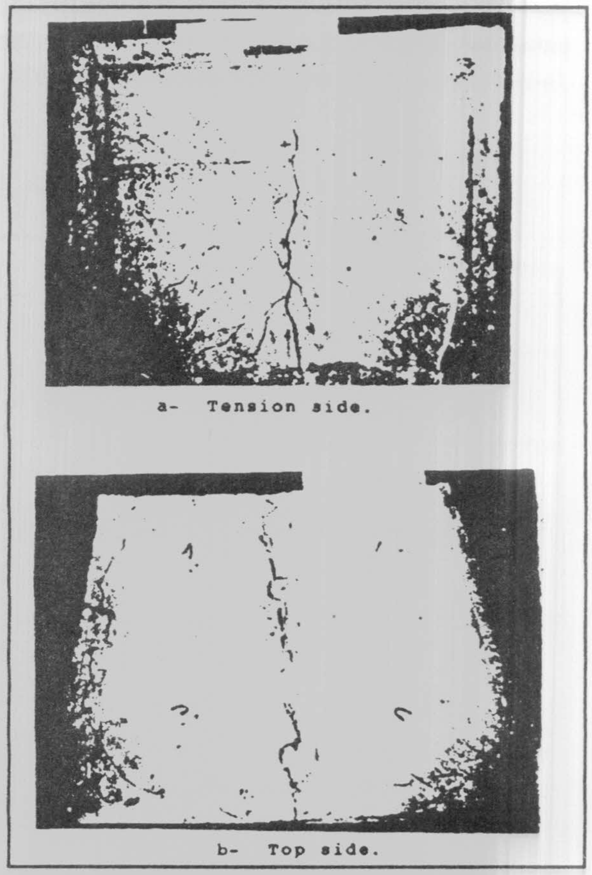

Figure 11. Crack pattern and mode of failure for (S-6).

CONCLUSIONS

1. Results of the test slab models showed that increasing the stiffness of the slab by additional reinforcement in the central region parallel or perpendicular to the line of loading did not change the mode of failure.
2. Crack widthes in the central region for slab with additional reinforcement of proper length perpendicular to the line load were less than the crack width observed on the slabs with additional

reinforcement parallel to the line of loading.

3. Increasing the reinforcement in the central region parallel to the line of loading will cause small increase in the load transmitted to the two supporting side beams which are perpendicular to the line of loading.
4. After cracking, deflection of the test slab models with additional reinforcement in the central regions was small in comparison with the deflection of slabs with uniform reinforcement. The same phenomena also was recorded when measuring strains.

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