THE EFFECT OF OPENINGS IN THE SLAB STIFFENED WITH SHALLOW BEAMS

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Abstract - *Many architectural uses may call for openings in reinforced concrete slabs which unpredictably changes the behavior of floor diaphragms. Designers must therefore take into consideration the negative consequences of these openings. The aperture in the slabs strengthened with shallow beams has not been the subject of any specific investigation. Therefore, for 24 slabs with openings, three alternate stiffened beam depths (span/10, span/15, and span/20) were modelled in this study with aspect ratios of 1. Slabs were divided into two and three panels with the use of shallow beams, and these slabs had openings cut in them at various locations. Every slab was modelled in Staad Pro to ascertain its orthotropy for designing slabs reinforced with shallow beams. After design, the slabs were numerically modelled using ATENA 3D software to examine their ultimate load carrying capacity and deflection behavior. The findings demonstrated that the ultimate load carrying capability of every slab simulated was higher than the design load and that the deflection complied with serviceability standards and their trends in their behavior provides an insight on the effect of opening to the slabs with shallow beams.*

Key Words: Shallow beam, Orthotropy, Critical beam Strength, Opening, Ultimate load carrying capacity etc

1.INTRODUCTION

The problem of giving utility services easy access within existing reinforced concrete slabs is one that structural engineers deal with on a regular basis. Businesses require larger manufacturing facilities and greater machinery to keep up with the continuous development in client demand and technical advancement. Since every factory is different, its designs are complicated by the necessity for each one to be built with cable channels, gas and water pipes, ventilation holes, and fire-extinguishing systems placed precisely according to the requirement. These holes will lessen the diaphragm's stiffness, which will decrease the member's capacity to sustain a heavier load. Usually, the impact of opening is overlooked during the fabrication of these slabs. Their actual response can therefore be different from what is expected. Said another way, the complexity and unpredictable nature of floor diaphragm activity are significantly increased when apertures are present. It is up to designers to compensate for these openings' shortcomings. These slabs' openings usually cause undue strains, which could be dangerous if not properly planned and inspected.

There are numerous cases where architects limit the beam-drop and spans to an amount that is not enough to provide the slab a rigid edge. Therefore, it is essential to grasp the concept of the shallow beam in order to understand the behavior and capacity of slabs with yielding edges. Under applied loading, a shallow beam deflects along with the supporting slab and in its ultimate state, the beam will allow a yield line created in the slab it supports to cross through it at the plastic hinge point. (Singh,H., et al 2010). Shallow beams can be added to the slab to increase its stiffness and help it satisfy serviceability standards. Compared to the advantages stiffening slabs provide, the quantity of labor required is quite little. Finding out how apertures in these slabs affect them—and whether or not they change the design requirement—is important when evaluating the benefits of the slab reinforced with shallow beams. By utilizing ATENA to investigate the effects of opening in stiffened slabs, we may be able to better understand the behavior of these slabs and develop a more useful and efficient application.

2. FINITE ELEMENT MODELLING

2.1 Test Specimen

Slabs with aspect ratio (r) of 1 will be modelled with size of 9 m by 9 m. With the aid of shallow beams, slabs will be divided equally into two and three panels; hence, the number of panels (n) is two and three, respectively. Slabs will have shallow beam depths as span/10, span/15, and span/20, that is, the depth will be 900 mm, 600 mm, and 450 mm. The opening size of slabs with two panels will be 4.5 m by 4.5 m, and for slabs with three panels, it will be 4.5 m by 3 m. As a result, this study will simulate a total of 24 slabs. Figures 1 and 2 display the locations of openings for slab with two panels and figures 3,4,5, and 6 represent the position of opening for slabs having three panels. Position of openings are chosen such that in every portion of slab the effect of opening can be studied. There is no opening in the right or lower portion of slab because the slabs studied in this research are symmetrical, hence the effect of opening in the right portion or lower part of slab will be similar to the left portion and the upper section of slab.

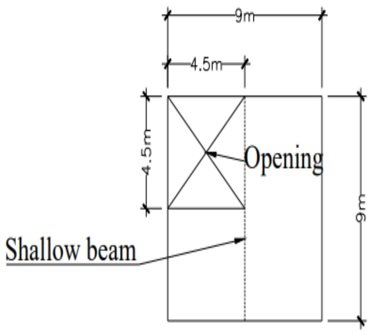

Fig-1: opening position 1 for two panel slab (o1)

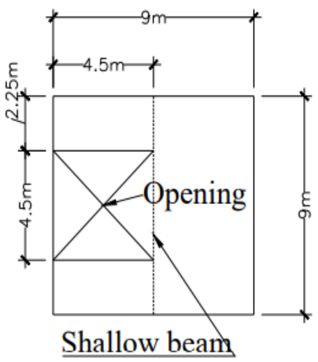

Fig-2: opening position 2 for two panel slab (o2)

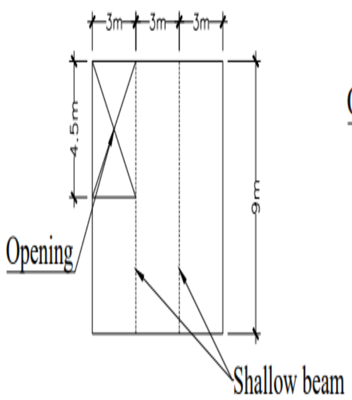

Fig-3: opening position 1 for three panel slab (o1)

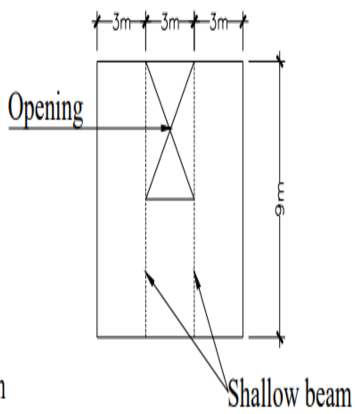

Fig-4: opening position 2 for three panel slab (o2)

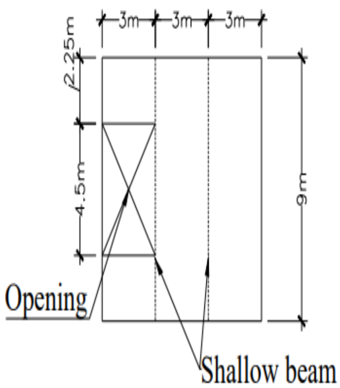

Fig-5: opening position 3 for three panel slab (o3)

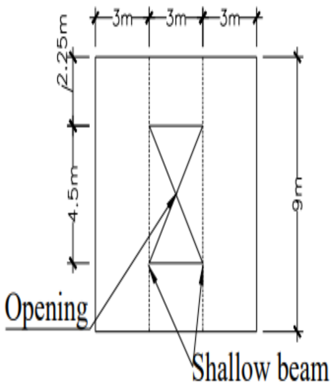

Fig-6: opening position 4 for three panel slab(o4)

The orthotropy of a slab determines both the upper and lower bound of the plate parameter, it is a crucial component in the design of slabs stiffened using shallow beams. The slab must be modelled using numerical modelling software in order to determine the orthotropy of the slab; Staad pro is utilized in this study. Orthotropy obtained from the numerical analysis of the models in Staad pro are presented in the table 1.

Table -1: Orthotropy of slab and critical beam strength parameter values

n	o	d	μ	α_{bc}
2	0	0.9	0.632141	3.374077
		0.6	1.057152	9.73651
		0.45	1.015839	9.062673
	1	0.9	0.601197	2.962093
		0.6	0.889913	7.080767
		0.45	1.194963	12.06702
	2	0.9	0.547927	2.270145
		0.6	0.796252	5.678413
		0.45	1.216987	12.45113
3	0	0.9	0.728077	7.538361
		0.6	0.866855	10.41423
		0.45	0.931758	11.80266
	1	0.9	0.709253	7.158305
		0.6	0.897805	11.07294
		0.45	1.011144	13.53741
	2	0.9	0.831564	9.670749
		0.6	0.848466	10.02581
		0.45	1.075068	14.96287
	3	0.9	0.680346	6.579459
		0.6	0.89179	10.94443
		0.45	1.040324	14.18497
	4	0.9	0.509562	3.282217
		0.6	0.947599	12.14564
		0.45	1.101296	15.555

Every slab that needed to be modelled had its reinforcement calculated utilizing the orthotropy found in the numerical modelling in Staad Pro. During the reinforcement calculation the critical beam strength parameter was calculated which is compiled in table 1 and this parameter separates the shallow beams from rigid beams. if the beam strength parameter is more than the critical beam strength parameter then the beam will act as rigid beam otherwise the beam will behave as the shallow beam, if all other criterions of shallow beam are met [9]. Each slab's reinforcement details are compiled in table 2. Reinforcement of shallow beams for two panel slab is compiled in table 3 and for three panel slab is presented in table 4.

Table -2: Reinforcement details of slabs

n	o	d	Dia x	Spacing x	Dia y	Spacing y
2	0	0.9	10	100	10	165
		0.6	10	120	10	120
		0.45	10	110	10	110
	1	0.9	10	100	10	175
		0.6	10	120	10	140
		0.45	10	120	10	100
	2	0.9	12	115	10	155
		0.6	10	120	10	155
		0.45	10	120	10	100
3	0	0.9	8	120	8	175
		0.6	8	120	8	145
		0.45	10	120	10	135
	1	0.9	8	120	8	180
		0.6	8	120	8	140
		0.45	10	120	10	125
	2	0.9	8	130	8	165
		0.6	8	120	8	150
		0.45	10	150	10	145
	3	0.9	8	110	8	170
		0.6	8	120	8	140
		0.45	10	150	10	150
	4	0.9	10	120	8	160
		0.6	8	120	8	135
		0.45	10	150	10	145

Table -3: Reinforcement details of shallow beams for slabs with two panels

o	d	Dia of Bottom bar	No. of bottom bar	Dia of Top bar	No. of Top bar
0	0.9	25	3	12	2
	0.6	25	5	20	2
	0.45	25	5	25	3
1	0.9	25	3	12	2
	0.6	25	5	20	3
	0.45	25	5	25	4
2	0.9	25	3	12	2
	0.6	25	5	20	3
	0.45	25	5	25	4

Table -4: Reinforcement details of shallow beams for slab with three panels

o		d	Dia of Bottom bar	No. of bottom bar	Dia of Top bar	No. of Top bar
3	0	0.9	25	3	12	2
		0.6	25	4	16	2
		0.45	25	4	16	2
	1	0.9	25	3	12	2
		0.6	25	4	16	2
		0.45	25	3	16	2
	2	0.9	25	3	12	2
		0.6	25	4	16	2
		0.45	25	4	25	2
	3	0.9	25	3	12	2
		0.6	25	4	16	2
		0.45	25	4	25	2
	4	0.9	25	2	12	2
		0.6	25	4	16	2
		0.45	25	4	25	2

2. RESULTS AND DISCUSSION

Outputs derived through slab finite element modelling indicates that the deflection of shallow beams grows with the span to depth ratio which are represented in chart-1 and 2. Slabs with three panels exhibit the same pattern of deflection as those with two panels, and the deflection at various opening positions is quite close to each other. This tendency can be explained by the fact that as shallow beams get smaller, their stiffening effect likewise gets smaller, which leads to an increase in deflection. Nevertheless, each slab's maximum deflection value still meets the serviceability requirements.

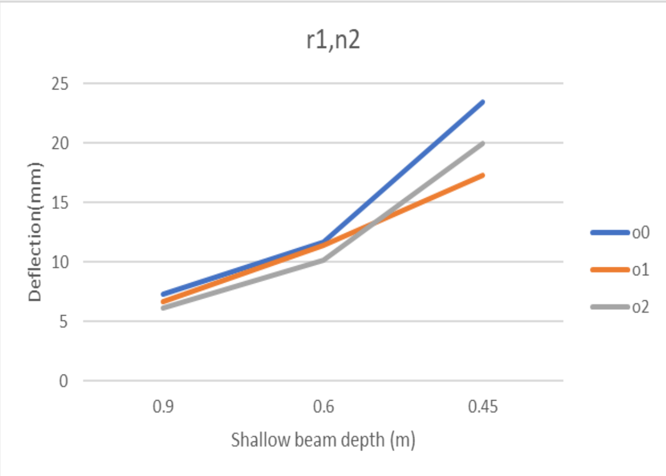

Chart-1: Deflection vs shallow beam depth for two panel slab

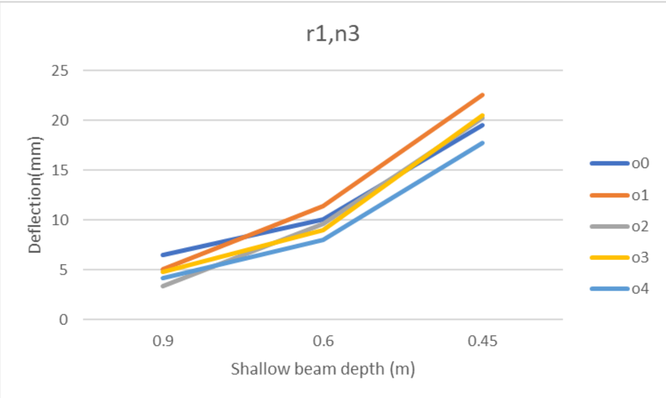

Chart-2: Deflection vs shallow beam depth for three panel slab

When the span to depth ratio of shallow beams increased, so did the slab's ultimate load carrying capacity as represented in chart-3 and 4. The increase is more noticeable between 600 and 450 mm in depth as opposed to 900 and 600 mm. When compared to the other two, the slab with opening o2 has the largest ultimate load carrying capacity. The ultimate load carrying capability of slabs with three panels resembles the slabs with two panels in terms of pattern.

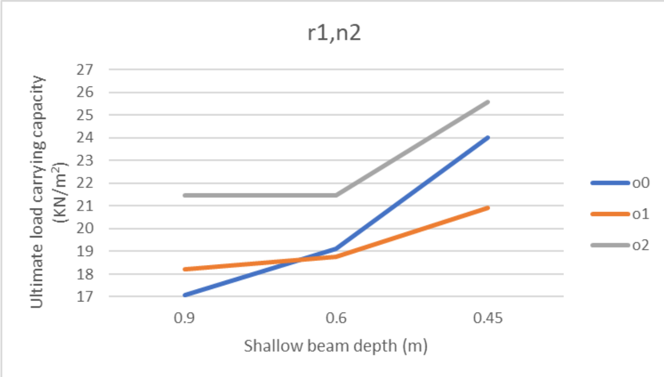

Chart-3: Ultimate load carrying capacity vs shallow beam depth for two panel slab

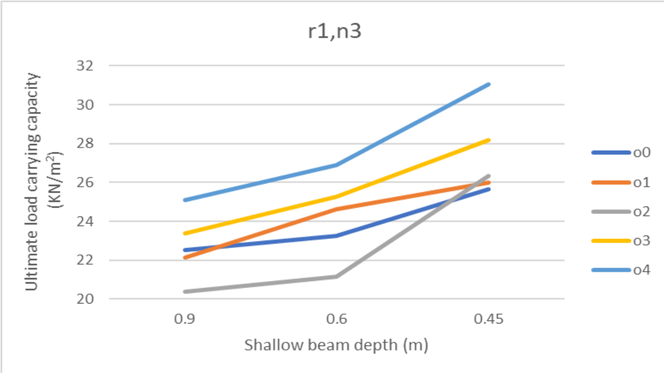

Chart-4: Ultimate load carrying capacity vs shallow beam depth for three panel slab

When compared to other slabs, the slab with the aperture o4 and the shallow beam depth of 450 mm has the highest ultimate load carrying capacity. When compared to other slabs, the slab with aperture o2 exhibits a greater increase in ultimate load carrying capability when shallow beam depth decreases from 600 mm to 450 mm. The quantity of reinforcement in the slabs and the stress created in them can both be used to explain trends in the ultimate load carrying capability of the slabs.

3. CONCLUSIONS

Based on the findings of this study, the following conclusions are drawn:

1. If the orthotropy is computed using the intended opening position, the design based on that orthotropy value will be adequate to allow the ultimate load bearing capacity to exceed the design load.

2. The shallow beams' span to depth ratio grew along with the slabs' deflection, but the slabs' deflection never exceeded span/250, meeting the serviceability requirements.

3. Trends in the ultimate load carrying capability of the slabs can be explained with the quantity of reinforcement and the stress created in the slabs.

4. Slab with opening at the centre of slab and the shallow beam depth of 450 mm has the highest ultimate load carrying capacity.

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