Experimental Study on Self Compacting RC Slab With and With Out Opening

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Abstract: **Many times openings are required to be provided in reinforcement slab in buildings to provide way for lifting of cables, ducts or other instrument to pass through one floor to the other floor mainly in the case of industrial buildings. But in that case special care needs to be taken while detailing of reinforcement for such opening in slabs.**

Detailing of opening in slabs is based on factors like size of opening, load on slab, floor vibration etc. In the case of large openings it is desirable to place beams under the opening are so that no additional detailing of slab reinforcement is needed and load is directly transferred to main beams through secondary beams.

In the present study experiment is carried out to study the behavior of self-compacting RC slab with and without opening. To study the behavior, 14 slabs of dimension 600X600X60mm is casted, out of these 14 slabs 2 slabs are casted without opening and remaining slabs are casted with different size and shapes of openings such as square opening of 50mm and square opening of 150mm (with and without diagonal reinforcement) and circular opening of diameter 50mm and circular opening of diameter 150mm (with and without diagonal reinforcement). The slabs are subjected to 4 point loading and the behaviors of the slabs are observed by plotting load deflection curve is plotted and comparisons between the slabs with and without openings are given.

Keywords— Self-Compacting Concrete, circular opening, square opening, diagonal reinforcement, size of opening.

I. INTRODUCTION

Slab is a structural element whose thickness is small compared to its own length and width. Slabs are usually used in floor and roof construction. The slab supports all the loads imposed on it and transfers them on to supporting beams, and columns. Reinforced concrete slabs are the most common elements amongst structural elements in the construction of buildings. In these buildings, many pipes and ducts are necessary to accommodate essential services such as electricity, telephone, computer network, water supply, sewerage and air conditioning. Due to the need for installing these and ducts, slabs of buildings may need to provide openings for them to be interconnected. Larger openings that could amount to the elimination of a large area within a slab panel are sometimes required for stairs and elevators shafts. For newly constructed slabs, the locations and sizes of the required openings are usually predetermined in the early stages of design and accommodated accordingly. One of the major problems in such slabs is the punching shear failure at the connection between the slab and the column. Such type of failure is usually sudden and leads to progressive failure of flat plate structures .Therefore, caution is needed in the design of such slabs and attention should be given to avoid the sudden failure condition.

Self-compacting concrete (SCC) has been described as "the most revolutionary development in concrete construction for several decades". Originally developed to offset a growing shortage of skilled labour, it has proved beneficial economically because of a number of factors, including:

- Faster construction.
- Reduction in site manpower.
- Better surface finishes.
- Easier placing.
- Improved durability.
- Greater freedom in design.
- Thinner concrete sections.
- Reduced noise levels, absence of vibration and Safer working environment.

A. *Openings in Existing Slabs*

Small openings in existing slabs are usually core-drilled to the required diameter. Larger openings are cut with a circular saw or a concrete chain saw with plunge cutting capabilities. Because a circular saw makes a longer cut on the top of the slab than on the bottom, small cores drilled at the corners can be used to help avoid over-cutting the opening when a circular saw is used. Cutting openings in existing slabs should be approached with caution and avoided if possible. When cutting an opening in an existing slab, the effect on the structural integrity of the slab must be analysed. It's advisable to analyse the slab for excess capacity and possible moment redistribution before making the final decision on the sizes and locations of the openings.

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B. Structural Design of Reinforced Concrete Slab with Openings

For the purposes of design, two-way slab systems are divided into column and middle strips in two perpendicular directions. The column strip width on each side of the column centreline is equal to 1/4 of the length of the shorter span in the two perpendicular directions. The middle strip is bounded by two column strips. ACI 318-052 permits openings of any size in any new slab system, provided you perform an analysis that demonstrates both strength and serviceability requirements are satisfied.

As an alternative to detailed analysis for slabs with openings, ACI 318-05 gives the following guidelines for opening size in different locations for flat slabs. These guidelines are illustrated in Fig.1.1

- In the area common to intersecting middle strips, openings of any size are permitted.
- In the area common to intersecting column strips, the maximum permitted opening size is 1/8 the width of the column strip in either span.
- In the area common to one column strip and one middle strip, the maximum permitted opening size is limited such that only a maximum of 1/4 of the slab reinforcement in either strip may be interrupted.

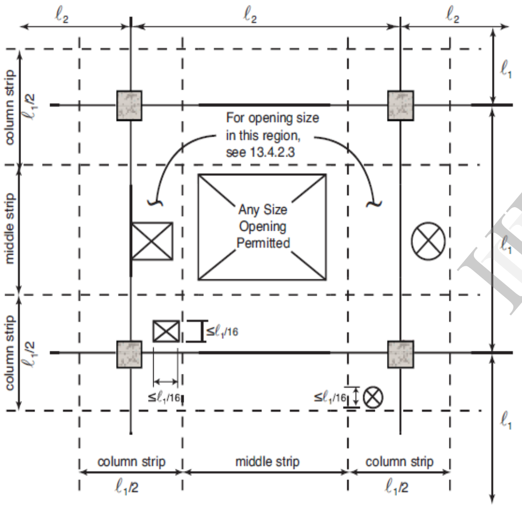

Figure 1.1: Suggested opening sizes and locations in flat plates with $l_2 \geq l_1$.

II. OPENING IN EXISTING SLAB

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Openings in Existing Flat Plates and Flat Slabs

Because the punching shear capacity of the slab around the columns typically governs the thickness of flat plates, any openings at the intersection of column strips (Area 3 in Fig. 1.2) should be avoided as much as possible. This is especially critical near corner and edge columns where the shear in the slab is typically highest. If openings must be made in Area 3, to install a drainage pipe for example, the size of the opening should be no larger than 12 in. (300 mm).

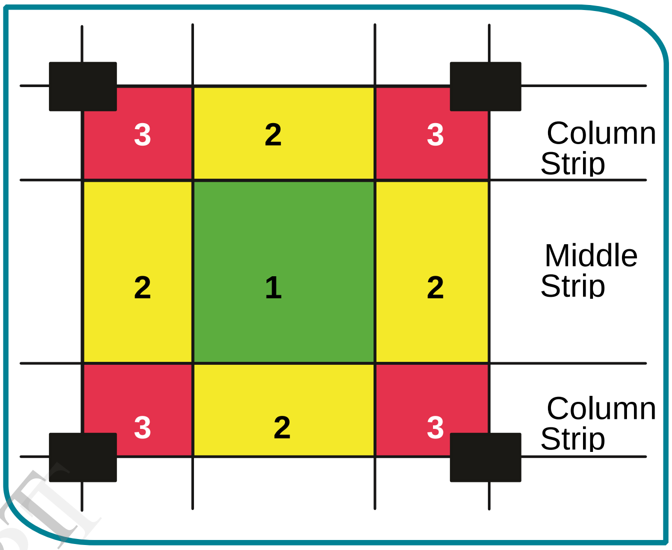

Figure 1.2: Areas for slab openings

Because they reduce the critical section for resisting punching shear (ACI 318-05), openings cut in this area should be evaluated carefully. One possible exception to this guideline is when column capitals, commonly seen in older structures, are present to reduce shear stresses in the slab.

Openings in Area 2, located at the intersection of column and middle strips, are less critical than in Area 3, and small openings having a width less than 15% of the span length can often be made in this area. The most favourable location for openings from a structural point of view is often the intersection of two middle strips (Area 1). This is also often the least favourable location from an architectural point of view, however, because it's the most disruptive to the function of the space.

The guidelines for openings in flat slabs generally follow the recommendations for flat plates, but the chances of accommodating larger openings in Area 3 are increased due to the lower shear stresses in the region of the drop panels.

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III. EXPERIMENTAL PROGRAMME

A. Materials

- Cement
- Fine aggregates
- Coarse aggregates
- Water
- Super-plasticizer
- Reinforcement

B. Specification of slabs

Seven type's series were casted, out of seven types each type consist of two slabs with different size and shapes of openings such as square and circular. Each slab is of span 600 mm length and 600mm width. The overall depth of the slab is 60mm.Equally spaced 6mm MS bar on both direction at tension zone are used as reinforcement with 10mm cover at the bottom.

Table 1: Specification of slabs

Shape and size of opening	***Figures***	***Diagonal Reinforcement***	***Abbreviation used***
Slab without opening		Without diagonal reinforcement	S1-1
			S1-2
Square with 50x50mm		Without diagonal reinforcement	S2-1
			S2-2
Circular with 50x50mm		Without diagonal reinforcement	S3-1
			S3-2
Square with 150x150mm		With diagonal reinforcement	S4D-1
			S4D-2
		Without diagonal reinforcement	S4-1
			S4-2
Circular Opening 150mm dia		With diagonal reinforcement	S5D-1
			S5D-2
		Without diagonal reinforcement	S5-1
			S5-2

C. Casting of slabs

The slabs were casted in a timber mould. A thin layer of oil was applied to the surface of the vertical timber formwork. All the ingredients as calculated and mixed in the laboratory by drum mixer.

In this experimental work moulds of size 600x600x60mm, were prepared using wood and fourteen slabs were casted. The cover blocks were placed along the bottom edges inside the mould, upon which reinforcement is placed in the vertical manner. The mixed concrete were poured onto these moulds. Due to self-compacting behavior no need of compacting using vibrator or tamping rod. All the specimens were prepared in accordance with IS516:1959. After the final setting time of self-compacting concrete, the specimens were demoulded and allowed the slabs specimens to get cured for 28 days.

D. Experimental setup

This chapter describes tests carried out on concrete slabs with generally in accordance with Indian standard on series of composite slabs. The results are used to make a comparison between strength parameters of slabs with and without opening. Slabs were casted tested in the Structures Laboratories at Dr.Ambedkar institute of technology, Bangalore.

Figure 1.3 shows the set up used for testing the reinforced concrete slabs. When slabs are ready for testing, having reached the required strength they were lifted manually and positioned as shown in the figure 1.3.

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Figure 1.3: Flexural test setup

The middle of the slab coincident with the centerline of the jack. All slabs were simply supported on two sides. A distance of 50mm was left between the inner edge of the support and the end of slab.

Rigid Plate of size 420×320mm welded with four steel bars of 300mm spacing around the corners to serve as a point loads was used for loading of slabs.

Figure 1.4: Rigid plate welded with four bars

The loading of all slabs was of static loading. Testing started with static loading applied by the hydraulic jack to the rigid plate, and transmitted to the slab as a four point load at a distance of 150mm from each support. The load was increased gradually in small increments (2.5 kN), and all the loads and displacement readings were taken at each increment.

IV. RESULTS AND DISCUSSIONS

This chapter describes the observations and results of flexure tests carried out in accordance with Indian Standards. At every interval of 2.5kN the behaviour of slab in flexure was enumerated till ultimate load. The first crack load and ultimate loads were treated as important parameter with central maximum deflection and end slip for the comparative study of the behaviour. The crack patterns for all slabs were carefully observed to discuss modes of failure. These results are used to make a comparison between composite slab with opening and without opening by plotting load -deflection relationship.

A. *Comparative Study*

The necessary parameters such as ultimate load, load at which first crack appeared, maximum deflection are as tabulated below. Figure 1.5 and 1.6 shows the variation of ultimate load of all slabs.

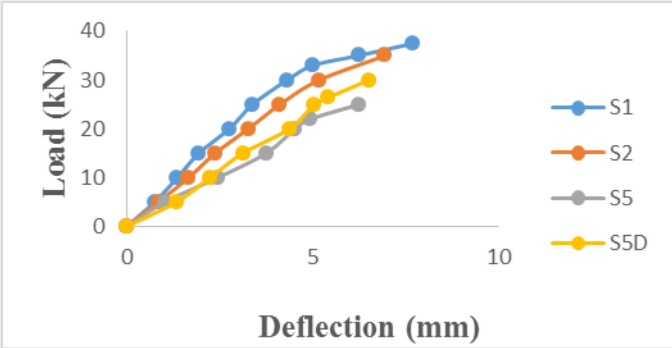

Figure 1.5: Comparison of load deflection curve among square openings

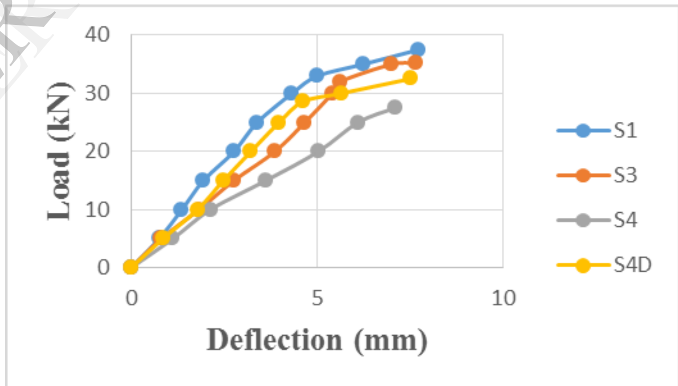

Figure 1.6: Comparison of load deflection curve among circular openings

Table 2: Summary of Flexure Test Results.

Slabs		*First crack*	*Ultimate Load*	*Maximum Deflection*
S1	Sample 1	32.5	36.0	7.3
	Sample 2	33.0	37.5	7.71
	Average	32.75	36.75	7.50
S2	Sample 1	30.0	35.0	6.95
	Sample 2	29.0	33.0	7.45
	Average	29.5	34.0	7.2

S3	Sample 1	30.5	34.5	7.62
	Sample 2	32.0	35.2	7.63
	Average	31.25	34.85	7.62
S4	Sample 1	23.5	26.0	6.22
	Sample 2	25.0	27.5	7.08
	Average	24.25	26.75	6.65
S4D	Sample 1	28.6	32.5	7.5
	Sample 2	27.0	32.5	7.16
	Average	27.8	32.5	7.33
S5	Sample 1	22.0	25.0	6.25
	Sample 2	22.4	25.0	5.66
	Average	22.2	25.0	5.96
S5D	Sample 1	26.4	30.0	6.51
	Sample 2	25.0	29.4	6.63
	Average	25.7	29.7	6.57

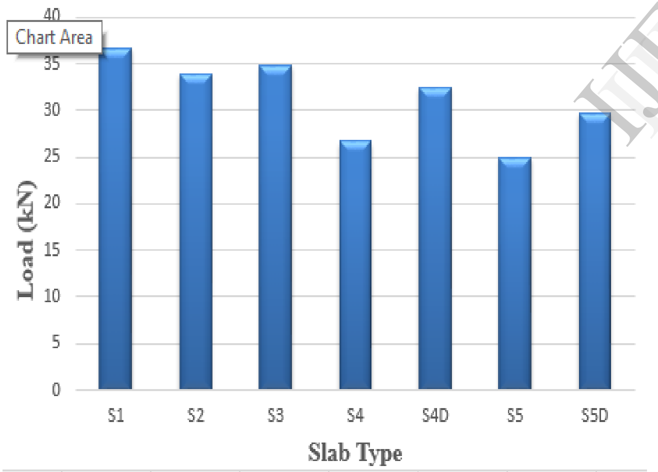

Figure 1.7: Variation of Ultimate Loads

CONCLUSIONS AND RECOMENDATION

The following conclusions are achieved from the present work.

1) The percentage decreases in strength of slabs with openings are compared with slab without opening are as shown below.
   - Decrease in strength of slab with 50mm square opening is 6%.
   - Decrease in strength of slab with 50mm circular opening is 4.10%.
   - Decrease in strength of slab with 150mm square opening is 31.5%.
   - Decrease in strength of slab with 150mm circular opening is 26.02%.
2) The strength variation of slab with 150mm square opening is decreased by 26.4% compared with slab with 50mm square opening.
3) The strength variation of slab with 150mm circular opening is decreased by 22.8% compared with slab with 50mm circular opening.
4) To increase the strength of slab with 150mm square opening, diagonal reinforcements are provided around the opening and it is observed that the increase in strength is 9.2%.
5) To increase the strength of slab with 150mm circular opening, diagonal reinforcements are provided around the opening and it is observed that the increase in strength is 16.9%.

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