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A Study of Flat Slabs Using Different Shear Reinforcement Parameters

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ABSTRACT

Flat-Slab building is very popular from the aesthetic and architectural point of view. From functional aspect a flat-slab building is more efficient than a R.C. frame building. So, construction of Flat-Slab building is increasing also in high seismic zone. Sometimes international building codes remain silent about the seismic response of flat slab buildings. In this paper the response of Flat-Slab building and a normal symmetric R.C. frame building of same dimension have been studied for varying seismic intensities. Static, Response Spectrum, Pushover, and Time history analysis have been performed to assess the performance of the two buildings. The costs of construction for these two buildings have also been compared. An extensive study on lumped plasticity model as per FEMA 356 with varying position of plastic hinge and its effect on pushover curve has also discussed in the paper. The paper also comments on the plastic hinge pattern.

1. INTRODUCTION

Common practice of design and construction is to support the slab by beam and beams by column. This may be called as beam-column construction. The beam reduces the available net clear ceiling height. The aesthetically this type of construction is poor but performance of those buildings are quite good. In recent practice slabs are directly put on the column for aesthetic and architectural point. There are numerous strategies which can be implemented to prevent the punching shear failure in a flat slab. Some of them are increasing the thickness of the slab, providing drop panels and column heads, reducing the application of loads and providing shear reinforcement. But these methods must be adopted during the design of flat slab. The first four options just add to the cost of construction and thus not recommended. So, we provide shear reinforcement to avoid the punching shear failure.

2. EXPERIMENTAL PROGRAM

A. Experimental program matrix

The experimental program matrix consists of six RC flat slabs. The six slabs were cast with central column; one as a control slab without adding crushed ceramics, five specimens with ratios of 20%, 35%, 50%, 60% and 70% see Fig 1. The slabs with dimension 1650 x 1650 x 150 mm with bottom reinforcement fay 10@100 mm and top reinforcement fay 10 @ 200 mm.

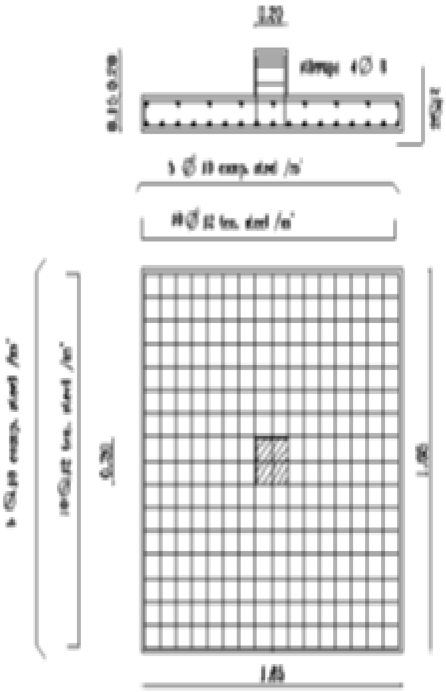

Figure 1: Slab layout and reinforcement arrangements

B. Shear Reinforcement

Out of the three slab specimens, only two specimens were provided with punching shear reinforcement in the form of shear stirrups and structural shear bands. For slab FS2, punching shear reinforcement was provided in the form of shear stirrups. Shear stirrup is one of the most commonly used types of shear reinforcement. It can be provided in the form of single or multiple legs, closed or castellated. In this study, sin- gle legged stirrups were used to connect the top and bottom reinforcement of the slab-column joint. 8mm diameter bars of Fe500 grade steel is bent into required lengths and are placed around the column connecting the top and bottom horizontal reinforcement at a distance of 45mm from the column face.

C. For Cement

The shear bands were made of high ductility and high strength steel strips of width 30mm and a thickness of 0.5mm [3]. The tensile strength of the strip was found to be 1200N/mm2. The steel strips were also punched with 8mm diameter holes. These holes proved to improve the anchoring characteristics over short lengths. These strips were bent with vertical legs and then an- chored to the top mat of the reinforcement around the column at a distance of 45mm from the column face.

D. Reinforcement Details

The longitudinal reinforcement for all three slab specimens was the same. But, for the slabs FS2 and FS3, additional shear reinforcement was provided. The detailing of reinforcement for the slab and column is shown in table 2 and table 3 respectively. Figure 1 shows the reinforcement details of slab FS1, which has no shear reinforcement in it. Figure 2 shows the reinforcement details of slab FS2, which has shear reinforcement in the form of open legged stirrups

Table 1: Detailing of reinforcement in the slab

Specimen	Longitudinal Reinforcement			Shear Reinforcement		
	No & Dia	Ast (mm2)	pt (%)	No & Dimensions	Ast (mm2)	pt (%)
FS1	8No-10 mm (Top)	1533.1	0.82			
FS2	8No-12mm (Bottom)	1533.1	0.82	12No-8mm Dia	603.19	0.32
FS3	8No-10mm (Top) 8No-12mm (Bottom)	1533.1	0.82	4No-30mm wide, 0.5mm	60	0.16

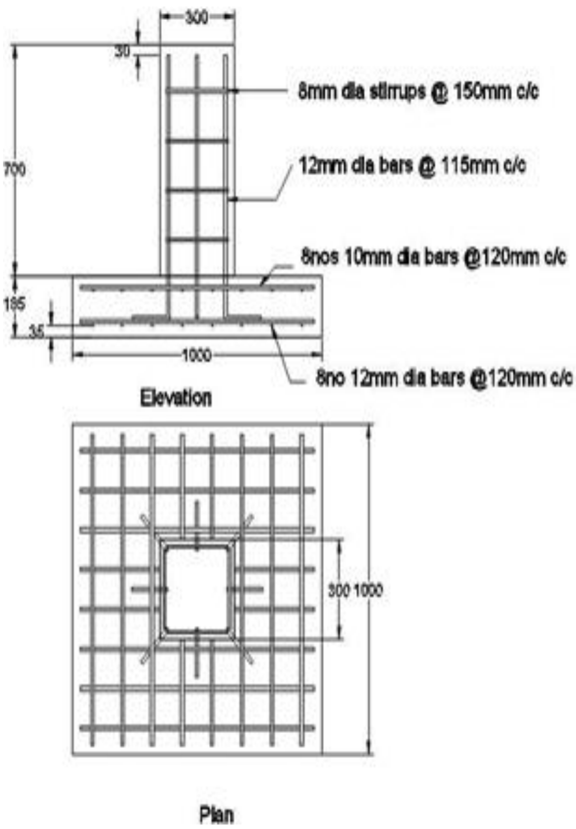

Figure 1: Reinforcement detailing ofslabFS1

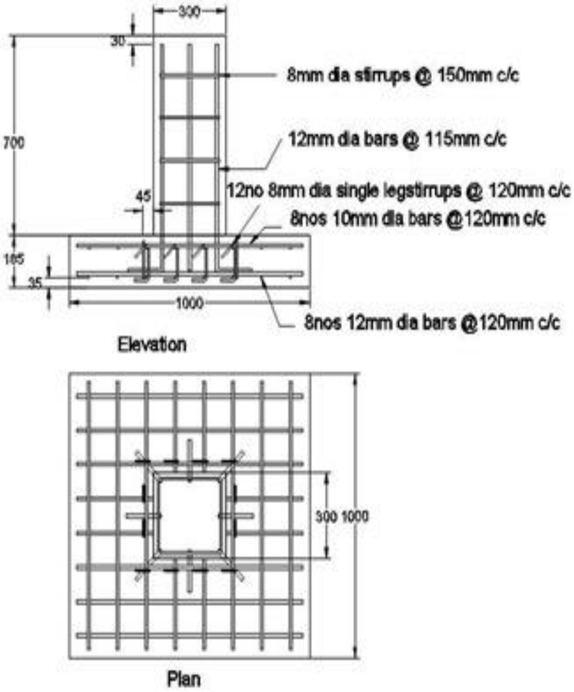

Figure 3: Reinforcement detailing of slabFS2

Table 2: Detailing of reinforcement in the column

Specimen	Longitudinal Reinforcement			Shear Reinforcement		
	No & Dia	Ast (mm2)	pt (%)	No & Dimensions	Ast (mm2)	pt (%)
FS1	8No-12mm	904.78	0.43	4No-8mm	201.66	0.09
FS2	8No-12mm	904.78	0.43	4No-8mm	201.66	0.09
FS3	8No-12mm	904.78	0.43	4No-8mm	201.66	0.09

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Figure 4: Crack pattern and mode of failure S1-0

Figure 5: Crack pattern and mode of failure S3-35

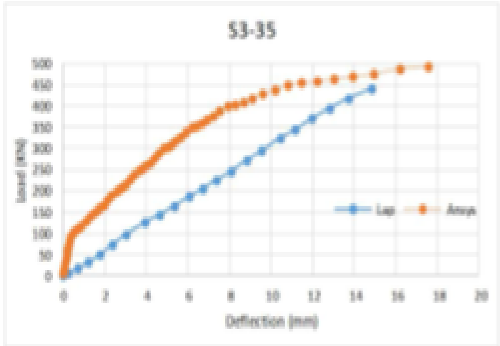

Figure 6: Load deflection curve S3-35

CONCLUSION

A brief introduction about flat slab is presented in this paper, together with the issue of punching shear failure. Various solutions to overcome the failure due to punching including different types of punching shear reinforcement were also mentioned.

In addition, three flat slabs were cast, where two specimens are equipped with punching shear reinforcement in the form of shear stirrups and structural shear bands and they are tested for punching. The objective of this experiment was to study and evaluate the behavior of flat slabs with and without punching shear reinforcement. The conclusions drawn from the experimental program are listed below.

1. The load carrying capacity of flat slab specimen with punching shear reinforcement is found to be greater than that of flat slab without punching shear reinforcement.

2. The failure of FS1 was brittle in nature, whereas the failure of FS2 and FS3 was ductile.

3. The shear strength of specimens with shear reinforcement is greater than that of specimens without punching shear reinforcement. It shows that FS2 and FS3 had higher ability to withstand the failure due to applied load thanFS1.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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