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STUDY ON EFFECT OF COLUMN DIMENSION AND SLAB THICKNESS ON PUNCHING SHEAR STRESS IN FLAT PLATE STRUCTURES

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Abstract —*The construction of flat plate structures are becoming more popular as they exhibit several advantages over conventional moment-resisting frames. Flat plate structures are a structural system in which the slabs are supported by columns without the provision of beams. In such structures, high shear stress may be developed at the slab-column junctions when subjected to earthquakes or other lateral loads. When this shear stress exceeds the limit, it can resulting in punching shear failure. This paper aims to study the effect of different parameters on the punching shear stress developed at the slab-column connections in flat plate structures. The parameters considered in this study are: column dimension and slab thickness. Pushover analysis of a six-storied reinforced concrete flat plate structure is carried out for different models with variation in parameters considered. The punching shear stress at the corner, edge and intermediate slab-column connections in a flat plate structure is obtained. It is found that punching shear stress varies proportionally with column depth while it is inversely proportional to slab thickness.*

Keywords- *Punching shear stress, Flat plate systems, Reinforced Concrete, Column dimension, Slab thickness.*

I. INTRODUCTION

Flat plate systems are a form of reinforced concrete construction where the slabs are supported by means of columns. In such structural systems, beams, drop panels or column capitals are not provided. Flat plate buildings are becoming more popular as they have major advantages over conventional reinforced concrete buildings such as lesser construction time, reduction in building height, architectural flexibility, requires lesser formwork etc. Reinforced concrete flat slabs are a structural solution widely used nowadays for office, commercial and residential buildings.
One of the major issues observed in flat plate buildings is punching shear failure. When flat plate structures are subjected to earthquakes or excessive lateral loads, unbalanced moments may be induced at the slab-column junctions. These unbalanced moments result in additional shear stresses known as eccentric shear stresses. The shear stresses caused by gravity loads are called as direct shear stresses. So, the direct shear stresses along with the eccentric shear stresses makes the slab-column junctions critical. This results in punching shear failure, also known as two-way shear failure. Punching shear failure is shown in Figure 1.

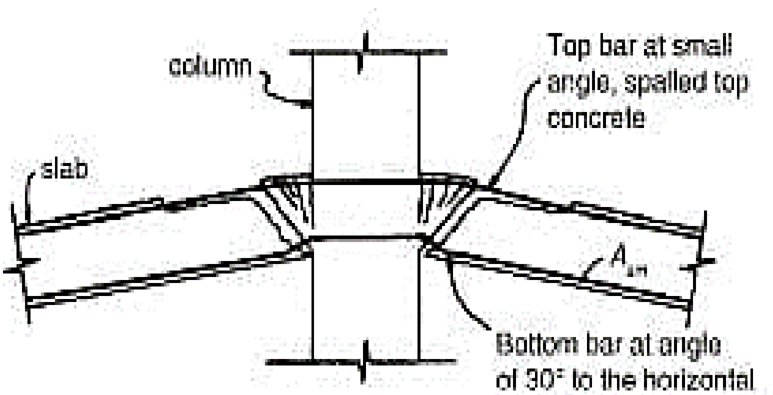

Figure 1. Punching shear failure in flat plate structures

Thus, under earthquake loading, the structural effectiveness of flat-plate construction is hindered by its inferior performance. The adverse impact of recent earthquakes on flat plate structures and potential seismic hazards associated with it has increased the need to further study the various factors which cause punching shear failure. The different parameters affecting punching shear stress include depth of column, slab thickness, concrete grade, shape of columns, slab reinforcement ratio etc.
In this study, the two major parameters affecting the punching shear stress in flat plate structures are considered which are: column dimensions and slab thickness. A six storied reinforced concrete flat plate structure is considered for the

study. Pushover analysis is done in ETABS 2015. The punching shear stress at the various locations of the slab-column connections is obtained. The effect of variation in column dimensions and slab thickness on the punching shear stress is evaluated and the corresponding graphs are also plotted.

II. CASE STUDY DETAILS

To study the effect of column dimensions and slab thickness on the punching shear stress in flat plate buildings, a six storey reinforced concrete structure is considered. It consists of three bays in both X and Y directions. The spacing along both the directions is 5m.

Table 1. Design details

Dead load	1.5kN/m^2
Live load	3.0kN/m^2 at typical floors
	1.5kN/m^2 on terrace
Concrete grade	M25
Rebar material	Fe415

Table 2. Description of Building Frame

No of bays along X direction	3
No of bays along Y direction	3
Spacing along X direction	5m
Spacing along Y direction	5m
No of floors	G+5
Column size	350 x 650mm
Slab thickness	150mm

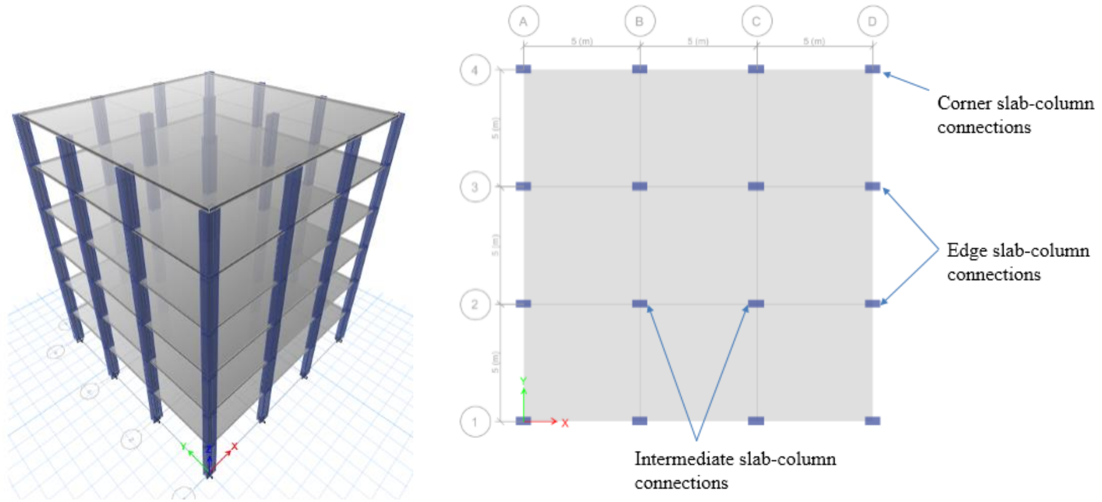

Figure 2. 3-D view and plan of the model

The 3D view and plan of the flat plate models considered is given in Figure 2. Considering the parameter: column dimension, the width of the column is fixed as 350mm and the depth is varied from 450mm to 750mm. For these models, the slab thickness is fixed as 150mm.

Table 3. Models considered with variation in column dimensions

Models considered	Column dimensions (mm)
Model 1	350 x 450
Model 2	350 x 550
Model 3	350 x 650
Model 4	350 x 750

Considering the parameter: slab thickness, the depth of the slab is varied from 150mm to 210mm. Here, the column dimension is fixed as 350 x 650mm.

Table 4. Models considered with variation in slab thickness

Models considered	Slab thickness (mm)
Model 5	150
Model 6	170
Model 7	190
Model 8	210

III. RESULTS OBTAINED

The pushover analysis of the above flat plate models is carried out in ETABS 2015. After the pushover analysis is done, the punching shear stress developed at the slab-column junctions is obtained from the shear stress diagrams. The effect of variation in column dimension and slab thickness on the punching shear stress in flat plate systems is studied. The variation in shear stress at the corner, edge and intermediate slab-column connections in flat plate structure is considered. The maximum shear stress values are obtained at the bottom storeys. The maximum values of punching shear stress corresponding to the bottom storey is given in the below Tables 5 and 6.

A. Variation in Column dimensions

Table 5. Variation in punching shear stress at various locations of the slab-column connections

Sl No.	Column dimensions (mm)	Punching shear stress (N/mm^2)		
		Corner	Edge	Intermediate
1	350 x 450	3.49	4.29	1.97
2	350 x 550	3.92	4.35	2.35
3	350 x 650	3.96	4.37	2.68
4	350 x 750	4.09	4.40	2.81

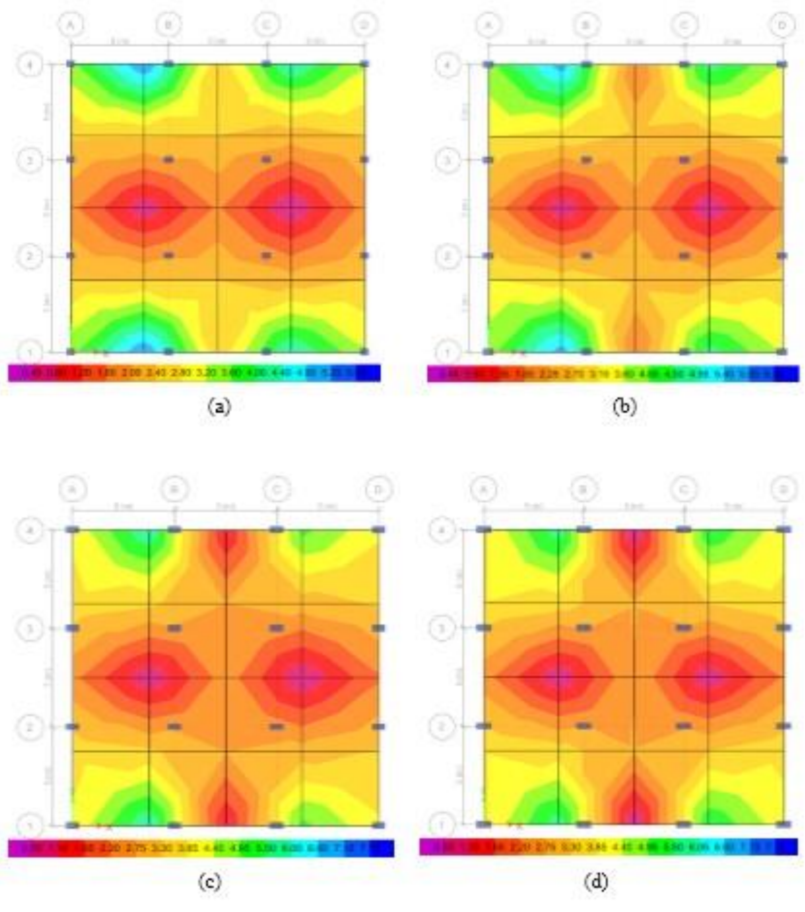

Figure 3. Shear stress diagram of the models with column dimensions:
(a) 350 x 450mm (b) 350 x 550mm (c) 350 x 650mm (d) 350 x 750mm

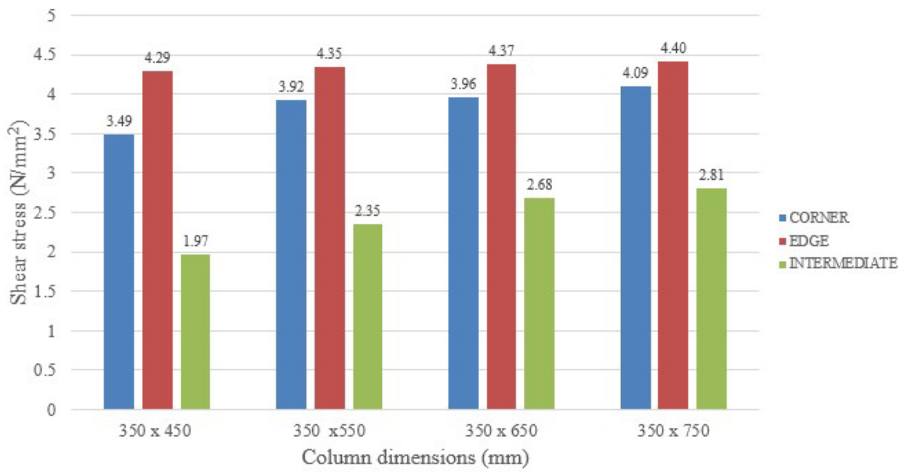

Figure 4. Plot with shear stress v/s column dimension

A. Variation in Slab thickness

Table 6. Variation in punching shear stress at various locations of the slab-column connections

Sl No.	Slab thickness (mm)	Punching shear stress (N/mm^2)		
		Corner	Edge	Intermediate
1	150	3.96	4.37	2.68
2	170	3.83	4.32	2.24
3	190	3.69	4.13	1.97
4	210	3.5	4.03	1.75

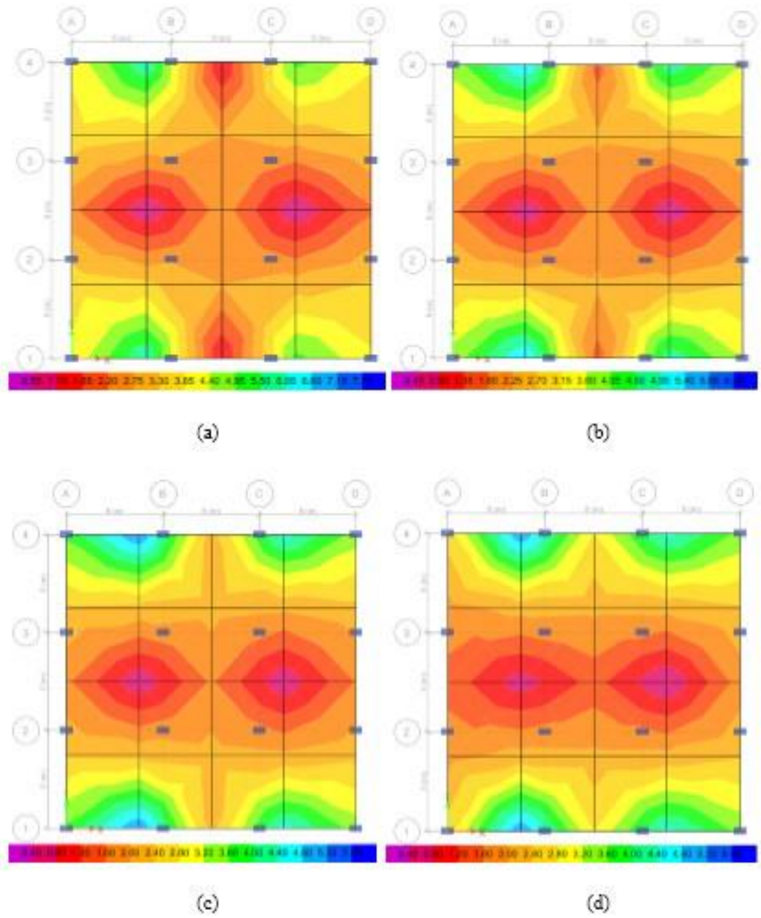

Figure 5. Shear stress diagram of the models with slab thickness: (a) 150mm (b) 170mm (c) 190mm (d) 210mm

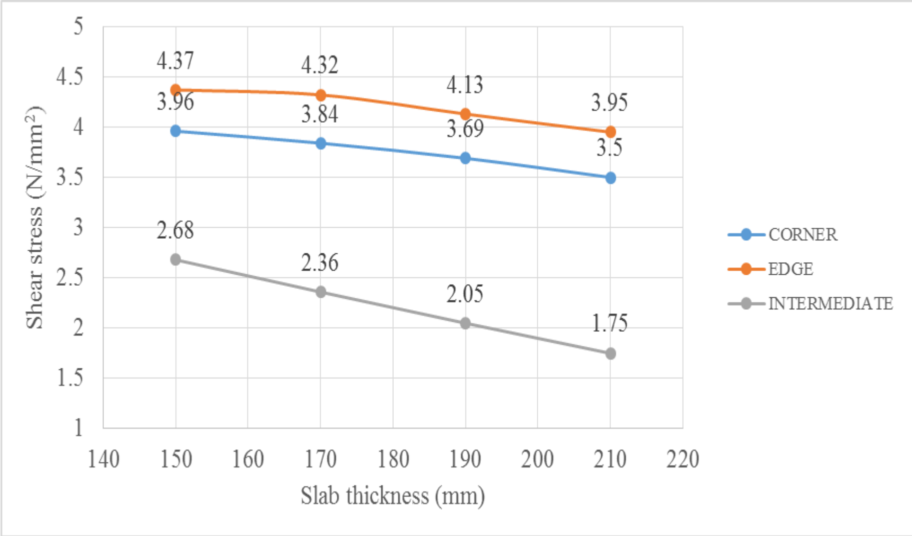

Figure 6. Plot with shear stress v/s slab thickness

IV. CONCLUSIONS

The modelling and analysis of flat plate models is done in ETABS 2015. Pushover analysis of the models is performed. The punching shear stress corresponding to various locations of the slab-column junctions in the flat plate buildings is studied.

The following conclusions are then obtained:

1. Keeping the width same, as column depth increases, punching shear stress is found to increase.
2. When model with 350 x 750mm column dimensions is compared to model with 350 x 450mm column dimensions, about 5% increase in shear stress is observed.
3. Considering column dimensions, shear stress at the edges is about 15% and 80% more than the shear stress at the corner and intermediate positions respectively.
4. As thickness of the slab increases, punching shear stress is found to decrease as shear stress is inversely proportional to slab thickness.
5. For 60mm increase in slab thickness, about 10% decrease in shear stress is observed.
6. Considering slab thickness, shear stress at the edges is about 15% and 90% more than the shear stress at the corner and the intermediate positions respectively.
7. It is observed that maximum shear stress is obtained at the bottom storeys.

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