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Review on Columns Dimension and Slab Thickness Effect on Punching Shear Stress in Flat Plate Structures

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Abstract
In the construction industry, various types of structures are used i.e. moment resisting frame and flat plate structures. The latter one is more advantages, and thus become more popular. These structures when subjected to earthquake or lateral loading, cause high shear stress in slab column joint and shear failure occurred when shear stresses exceed their limit. The purpose of this paper is to study two parameters i.e. slab thickness and column dimensions influencing punching shear stress developed at column slab joint. For this purpose, various models with variations in dimensions are considered. The model consisted of reinforced concrete flat plate structures of six stories. After push-over analysis of proposed models punching shear stresses at three points (corner, intermediate, and edge) of column slab joint in flat plate structure are achieved. Based on the above results, it is concluded that the increase in punching shear is observed keeping width same and increase column depth, thus directly proportional. More ever, with an increase in slab thickness reduction in punching shear stress is noted, thus inversely proportional to each other.

Keywords: *Moment Resisting frame, flat plate structure, pushover analysis, punching shear stress, column slab joint*

I. INTRODUCTION

When the slab was supported by columns directly without beams defined as a flat plate structure system and is a form of reinforced concrete construction. More ever column capital and drop panel are also not provided in this type of structure system [1, 2]. This type of system is more advantageous as compared to the conventional moment-resisting frame or reinforced concrete buildings because of less time for formwork and construction, the flexibility of architecture, and building height reduction [3]. Nowadays, for offices, residential and commercial buildings flat plate structure systems are used widely [4, 5]. This type of system also reduced the cost of structure up to twenty percent [6]. But punching shear failure is one of the big problems in this type of column-slab system which occurred in a brittle manner at point load or region of column support [7]. These types of structures when subjected to earthquake or other lateral loading induced an unbalance moment in the junction of slab column due to which addition shear stress resulted also known as eccentric shear stress [8]. Direct shear stress is those stresses caused due to gravity loads. Therefore, slab-column joint became critical due to direct shear stress along with eccentric shear stress and caused punching shear failure also known as two-way shear failure [9]. Due to flat plate slab advantages such as they are economical and functional if punching shear failure occurred caused a catastrophic effect in the structure [10]. Punching shear failure was shown in figure 1. When the slab was supported by columns directly without beams defined as a flat plate structure system and is a form of reinforced concrete construction. More ever column capital and drop panel are also not provided in this type of structure system [1, 2]. This type of system is more advantageous as compared to the conventional moment-resisting frame or reinforced concrete buildings because of less time for formwork and construction, the flexibility of architecture, and building height reduction [3]. Nowadays, for offices, residential and commercial buildings flat plate structure systems are used widely [4, 5]. This type of system also reduced the cost of structure up to twenty percent [6]. But punching shear failure is one of the big problems in this type of column-slab system which occurred in a brittle manner at point load or region of column support [7]. These types of structures when subjected to earthquake or other lateral loading induced an unbalance moment in the junction of slab column due to which addition shear stress resulted also known as eccentric shear stress [8]. Direct shear stress is those stresses caused due to gravity loads. Therefore, slab-column joint became critical due to direct shear stress

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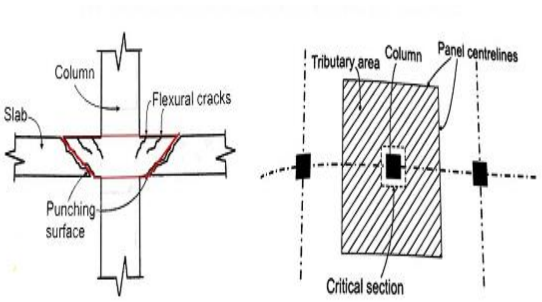

Fig.1 Punching shear failure of flat plate slab structures

Therefore, due to sub-standard performance construction of the flat plate structure is affected when subjected to earthquake loading. In addition, flat plate construction was affected badly during the recent earthquake which increased the investigation of various aspects of such structure to prevent the failure of punching shear. The various factors that may affect the punching shear stress composed i.e. Column depth and shape, thickness and reinforcement ratio of the slab, and grade of concrete. In this paper, to affect the punching shear stress two numbers of factors i.e. the thickness of slab and column dimensions are considered in the flat plate structure.

II. LITERATURE REVIEW

In this study slabs, punching behavior with various flexural and transverse reinforcement ratio was investigated. For this purpose, various series of tests were conducted to examine slabs failing behavior with the ratio of low reinforcement in punching shear. Moreover, during his study, for examining punching shear effects sample and aggregate size were also varied. After conducting tests, the measurements were taken at the concrete surface and through sample thickness the observation of phenomena related to the development of the internal critical shear crack before punching [11].
Punching shear mechanical phenomenon in slabs without transverse reinforcement, based on critical shear cracks openings was studied. Based on slabs rotation, for punching shear new criteria were formulated. The formulated criteria observed during experimental work described failures of punching shear even in low reinforcement ration slabs. A simple mechanical model was proposed due to the required application of the load rotation relationship of the slab. Better results were observed than current design codes, with a very low coefficient of variation [5].

Ultimate punching shear strength was predicted by suggesting an analytical method of a reinforced concrete flat plate, composed of steel fibers, and based on equilibrium forces acting on failure surface to be suggested. During his research, for this purpose, an equation was proposed while around the column critical failure surface was predicted to propose an empirical equation, in terms of the fiber factor [12].

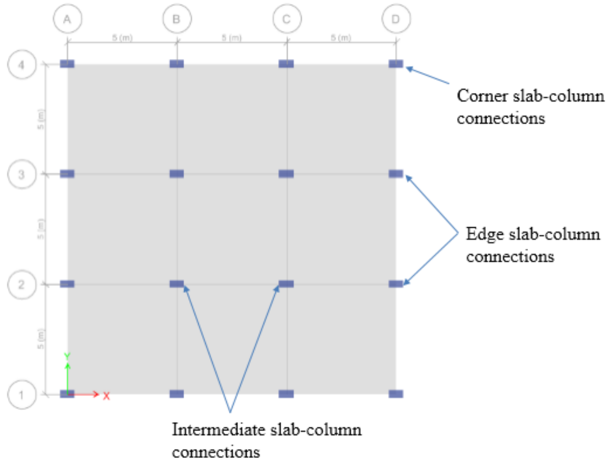

Fig.2 Two-D view of the proposed model

III. RESEARCH METHODOLOGY

To achieve the objectives of this study 06 multi-story RCC structure was considered to know the effect on punching shear stress in flat plate slab by dimensions of column and slab thickness. The structure was composed of three bays in both directions having 5m each in length. ETABS software was used to push over-analysis. The proposed structure 2-D was shown in Figure 2.

The proposed building frame description and design details were shown in Tables I and II respectively.

TABLE I
Building Frame Description

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

TABLE II
Design Details

Dead load (KN/m^2)	1.5
Live load (KN/m^2)	3 (typical floors)
	1.5 (terrace)
Concrete strength (fc’)	1:1:2
Yield strength of steel (fy)	60Ksf

A total of eight models were considered during this study i.e. in the first four models focused on the dimension of the column in which the width of the column remains the same while depth varied from 450mm to 750mm while the thickness of the slab remains fixed 150mm. While in the second case of four models the thickness of the slab varies from 150-210mm, keeping the dimension of the column the same as 350mmx650mm. The details of variations for both cases were shown in table III & IV.

TABLE III
Models with column dimension variation

Models Considered	Column Dimension(mm)	Slab Thickness (mm)
Model A	350 x 450	150
Model B	350 x 550	150
Model C	350 x 650	150
Model D	350 x 750	150

TABLE IV
Models with Slab Thickness Variation

Models Considered	Slab Thickness (mm)	Column Dimensions (mm)
Model 5	150	350 x 650
Model 6	170	350 x 650
Model 7	190	350 x 650
Model 8	210	350 650

IV. RESULTS

The analysis of the above all models was conducted by using ETBAS software. At the joint of slab-column development of punching shear stress were obtained from the diagram of shear stress after pushover analysis of all models were completed. The column dimension and slab thickness variations effect on punching shear stress was studies in flat plate slab structure. In addition, the variation effect on punching shear in flat plate structure was considered to study at three locations of slab-column joint, Corner, edge, and Intermediate Location.

Moreover, at the bottom story shear stresses with maximum value for both cases (Dimension of column and thickness of slab variations) were obtained and were shown in table V and VI. While shear stress vs column dimension plot was shown in figure 3 and shear stress vs thickness of slab plot was shown in figure 4.

TABLE V

Punching shear stress variations at different locations of the slab-column connections

Models	Dimension of Column (mm)	Punching Shear Stress (N/mm^2)		
		Corner	Edge	Intermediate
A	350 x 450	3.49	4.29	1.97
B	350 x 550	3.92	4.35	2.35
C	350 x 650	3.96	4.37	2.68
D	350 x 750	4.09	4.40	2.81

TABLE VI
Punching shear stress variations at different locations of the slab-column connections

Models	Dimension of Slab (mm)	Punching shear stress (N/mm^2)		
		Corner	Edge	Intermediate
5	150	3.96	4.37	2.68
6	170	3.83	4.32	2.24
7	190	3.69	4.13	1.97
8	210	3.5	4.03	1.75

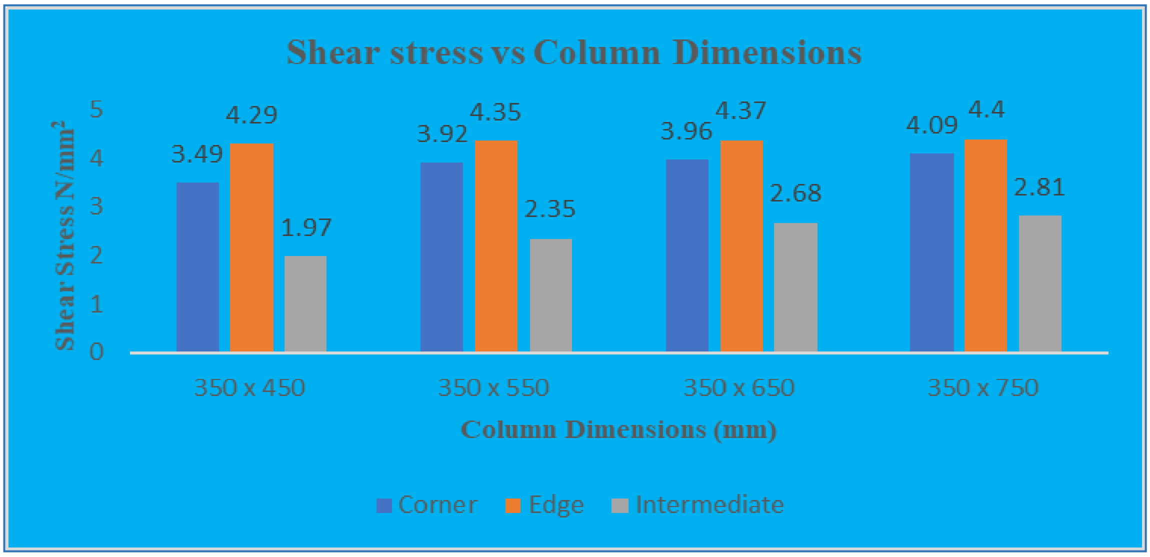

Fig.3 Plot between Shear Stress and Dimension of Column

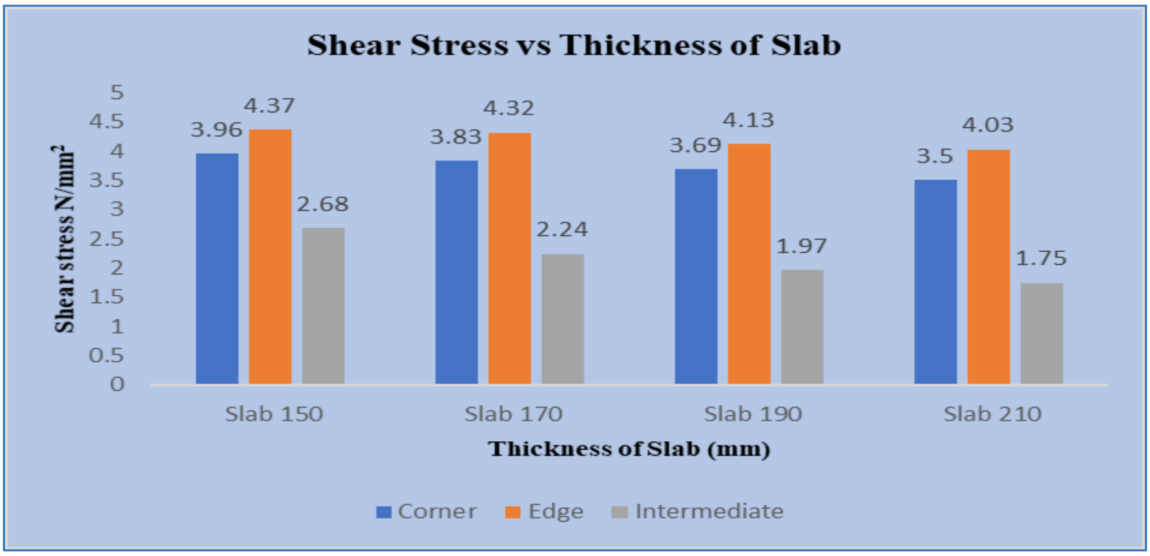

Fig.4 Plot between Shear Stress and Slab Thickness

V. CONCLUSIONS

ETABS software is utilized for modeling and analysis of flat plate slab models. Pushover analysis is performed of models. After analysis, in plat flate models at different locations of the slab -column joint punching shear stress is studied and the following conclusions are made based on the above results.

- An increase in punching shear stress is observed keeping the width the same and increase in column depth.
- A 5% increase in shear stress is noted when comparing a model having a column dimension of 350mm x 750mm with 350mm x 450mm.
- Shear stress is found about 15 and 80 percent more at the edge as compared to the corner and intermediate locations based on the dimension of the column.
- The thickness of the slab is inversely proportional to punching shear stress i.e. With the increase in the thickness of the slab punching shear stress is reduced.
- Shear stress reduced 10% when the thickness of the slab increases from 150mm to 210mm i.e. 60mm
- Shear stress is observed about 15 and 90 percent more at the edge instead of the corner and intermediate locations based on the thickness of the slab.
- More ever, at bottom storeys, shear stress of maximum values was obtained.

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