Study on Effect of Concrete Compressive Strength and Column Shape on Punching Shear Stress in Flat Plate Systems

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***Abstract*—Flat plate systems are nowadays extensively used in reinforcedconcrete structures. Flat plate systems are those structural systems where beams, drop panels or column capitals are not provided. In such systems, the forces are directly transferred from slab to columns. Flat plate structures are widely used as they have various functional and economic advantages. But in these structures, high stress may be developed at the slab-column connections and failure may occur by punching shear failure. When punching shear failure occurs in these flat plate structures, a truncated pyramid of concrete will be pushed out of the slab. To avoid such shear failure, various parameters which influence the punching shear stress need to be studied by analytical or experimental studies. The factors which affect the punching shear stress of slab-column connections include concrete compressive strength, thickness of slab, column aspect ratio, column shape etc. In this analytical study, the influence of two parameters – concrete compressive strength and column shape on the shear stress at slab-column connections is investigated. The variation in shear stress at various locations (corner, edge and intermediate connections) of the flat plate systems is also studied.**

Keywords*— Punching shear stress, Flat plate systems, Reinforced Concrete, concrete compressive strength. Column shape (key words)

I. INTRODUCTION

The flat plate structures are now being extensively used in construction. Flat plate systems mainly consists of slab of uniform thickness where column capitals or drop panels are not provided. It permits flexibility in architecture, low building height, more clear space, easier formwork, and lesser construction time. Flat plate structures are significantly more ductile than normal concrete structures due to the absence of beams. But when subjected to seismic and wind forces, these structures are more vulnerable. Punching shear failure in flat slab systems is a severe problem. Under the influence of earthquake or lateral forces, unbalancedmoments may be introduced. This produce significant shear stresses in addition to direct shear stress which may subject the slab-column connections to higher stresses leading to brittle punching shear failure.

The strength of flat plate systems is adversely affected by punching shear action at the slab-columns junctions. The flat plate building exhibit poor performance under seismic or lateral loads is poor when compared to frame structure which results in excessive lateral displacement. This causes instability in the flat plate structure. The excessive lateral displacement induces unbalanced moments at slab column connection. When these flat slab structures are situated in seismic zones or subjected to lateral loads, the unbalanced moments induced in the structure causes an increase in shear stress at the slab-column connection in addition to direct stress, and increases the tendency to punching shear failure.

II. CASE STUDY DETAILS

To study the effect of various paramters on the shear stress in flat plate buildings, a sixstorey Reinforced Concrete structure is considered. It consists of three bays in both X and Y directions. The spacing along both the directions is 5m.

A. Design data

a) Live load floor : 3.0kN/m² at typical floor
: 1.5 kN/m² on terrace
b) Dead load : 1.5 kN/m²
c) Concrete grade :M25
d) Rebar material :Fe415
e) Floors : G.F + 5 upper floors

B. Description of building frame

a) No. Bays along X axis : 3
b) No. Of bays along Y axis : 3
c) Spacing along X axis : 5m
d) Spacing along Y axis : 5m
e) No. Of floors : G + 5
f) Size of column : 350mm x 650mm
g) Slab thickness : 150mm

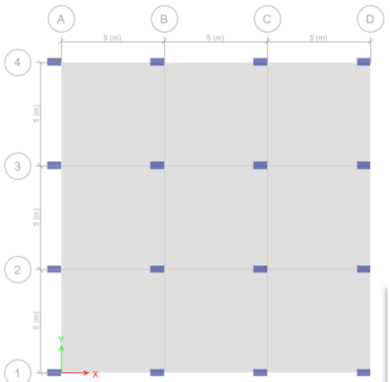


Fig. 1. Plan of building frame

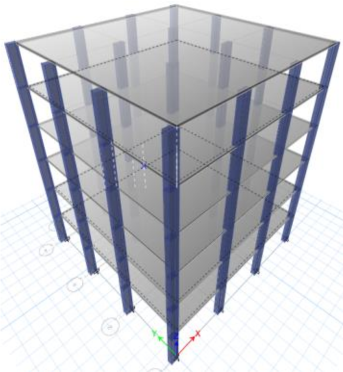


Fig. 2. 3D model of haunched beam frame

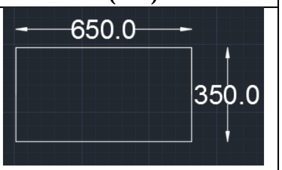
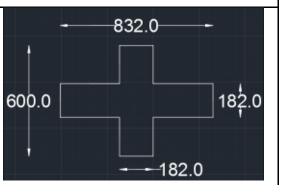
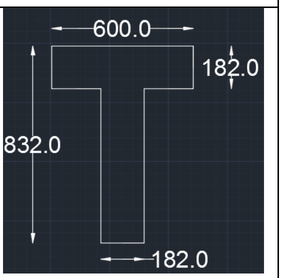
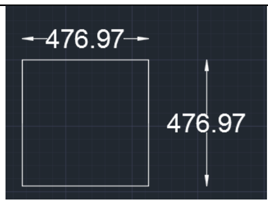
TABLE I. Models considered for variation in concrete compressive strength

Si No.	Model	Concrete grade
1.	A1	M20
2.	A2	M30
3.	A3	M40
4.	A4	M50

TABLE II. Models considered for variation in column shape

Sl No.	Model	Shape of column
1.	B1	Rectangle
2.	B2	Cross type
3.	B3	T-type
4.	B4	Square

TABLE III. Models considered for variation in column shape

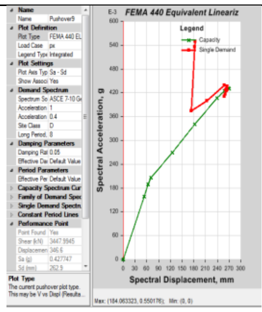
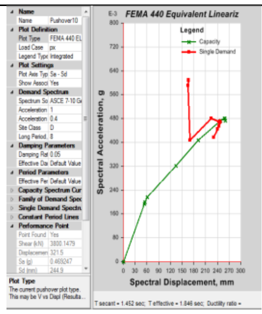
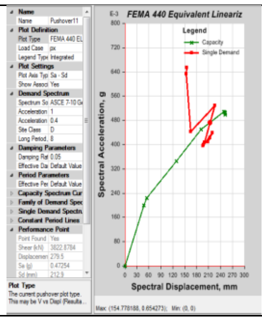
Sl No.	Model	Column dimensions (mm)
1.	B1	
2.	B2	
3.	B3	
4.	B4	

III.RESULTS OBTAINED

C. Pushover analysis

To investigate the effect of lateral force on a structure in terms of shear stress, nonlinear static pushover analysis is carried out on the above building models. In the pushover analysis, a sequence of forces is applied to a model that consists of non-linear properties, and the total force is plotted against a reference displacement to define a capacity curve. This is then be combined with a demand curve which is normally in the form of an acceleration displacement response spectrum. Both the demand curve and capacity curves are considered to obtain the performance point of the structure. The performance point is taken into consideration as per ATC 40 capacity spectrum method. The pushover curves for each model is shown in table IV and V

TABLE IV. Pushover curves details obtained for the models- Concrete compressive strength variation

Sl no	model	Base shear (kN)	Displace ment (mm)	Mode shape(mode 1)
1	A1	3447.994	346.6	
2	A2	3800.147	321.5	
3	A3	3822.878	279.5	

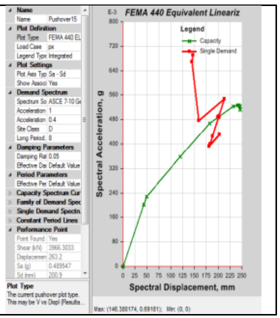
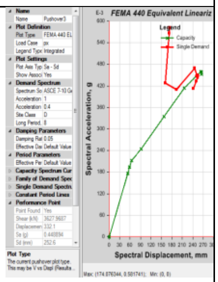
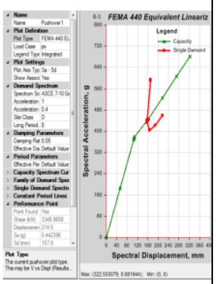
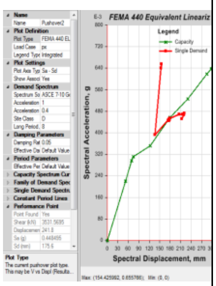
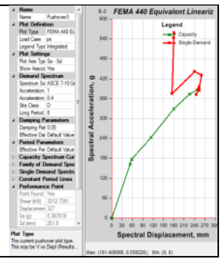
4	A4	3966.303	263.2	

TABLE V. Pushover curves details obtained for the models- Column shape variation.

Sl no	model	Base shear (kN)	Displacement (mm)	Mode shape(mode 1)
1	B1	3627.967	332.1	
2	B2	3348.965	214.5	
3	B3	3531.569	241.8	
4	B4	3312.74	327	

D. *Punching shear stress*

The shear stress at the slab-column connections is considered. The first mode of vibration of the structural models is translation.The shear stress for PUSH X load case for various configuration of flat plate systems are listed in table below:

TABLE VI. :Variation of Shear stress at various locations of slab-column connections

Sl No.	Concrete compressive strength	Shear stress at slab-column connections (N/mm^2)		
		Corner	*Edge*	*Intermediate*
1.	M20	3.51	3.77	2.47
2.	M30	4.31	4.8	2.85
3.	M40	4.83	5.43	3.09
4.	M50	4.92	5.97	3.28

TABLE VII. : Variation of Shear stress at various locations of slab-column connections

Sl No.	Column shape	Shear stress at slab-column connections (N/mm^2)		
		Corner	*Edge*	*Intermediate*
1.	Rectangle	3.96	4.37	2.68
2.	Cross-type	3.97	4.14	3.29
3.	T-type	3.8	3.95	3.13
4.	Square	3.37	3.93	2.54

CONCLUSIONS

1. The shear stress at slab-column connections of the flat plate systems is found to vary with different concrete compressive strengths.
2. For flat plate systems with different column shapes, the difference in shape of columns is found to cause variation in the shear stress at slab-column connections
3. Shear stress is found to increase with increase in concrete compressive strength.
4. About 40% increase in shear stress is obtained for M50 concrete compared to M20 concrete.
5. Shear stress is found to be minimum for square columns equal to $3.93N/mm^2$
6. About 15% decrease in shear stress is obtained in the case of square-shaped columns when compared to rectangular columns.
7. Shear stress is higher at the edgeand corner connections compared intermediate connections.

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