PARAMETRIC STUDY ON FLAT SLAB WITH AND WITHOUT COLUMN DROP

Jaydeep Chodvadiya[1], Vipul Vyas[2], Dr. G.S. Doiphode[3]

[1]*PG Scholar of Structural Engineering, Charotar University, Gujrat, India*
[2]*Assistent Professor of Civil Engineering Department, Charotar University, Gujrat, India*
[3]*M.S. University, Vadodara, Gujarat, India*

ABSTRACT

In recent era, RCC flat slabs are preferred higher in many country of the world due to their aesthetic appearance as well as economic advantages. However, the punching shear failure at the slab column connection is the major disadvantages of the flat slab. If the punching shear is critical, either the slab thickness may be increase or column drop to be provide or shear reinforcement to be provide. Even though the concrete in the flat slab will provide a certain level of shear resistance around the column, remaining stresses it has to be provided punching shear reinforcement. In this paper, the flat slab with three different size of slab panel (6.5m x 6.5m, 8.5m x 8.5m, 10.5m x 10.5m) with different size of column (500mm x 500mm, 650mm x 650mm, 800mm x 800mm respectively) and three individual size of shear wall (2000mm x 300mm, 2500mm x 300mm, 3000mm x 300mm respectively) with M25 and M30 grade of concrete with and without column drop and analyze by SAFE (Slab Analysis by the Finite Element Method) as per IS-456 of the permissible punching shear criteria and compare the thickness based on stresses. This paper provides guidelines for thickness selection at preliminary stage to the designer for flat slab as well as flat plates.

Keyword: - *Flat slabs, Punching Shear, Column Drop, Shear Stress, Shear Reinforcement.*

---

1. INTRODUCTION

In reinforcement concrete construction, slabs are used to provide flat and useful surfaces. A reinforced concrete slab is a broad, flat plate, usually horizontal with top and bottom surface parallel or nearly so. It may be supported by reinforced concrete beams, by masonry wall or reinforced concrete walls, by structural steel members, directly by the columns or continuous on elastic support as in ground. Slabs in some cases can be carried directly by column, without the help of beams or girders. Such slabs called flat slabs are beamless but usually incorporate a thickened slab region in the vicinity of the column and often employs flared column tops. Both are devices to reduce stresses due to shear force and negative bending moment around the columns. They are referred to as drop panel and column head. For cases where spans are not large and loads not particularly heavy, both the drop panel and column head may be omitted. Such type of flat slab is known as flat plates.

Flat slab system has the advantages of simple construction and formwork and avails a flat ceiling. It reduces ceiling finishing costs, since the architectural finish can be applied directly to the underside of the slab. Even more significant are the cost saving associated with the low storey height made possible by the shallow floor system. Moreover, where the total height of building is restricted, using a flat plate will result in more storeys accommodated within the set height.

1.1 Components of Flab Slab

Main components of flat slab are.

- Drop.
- Panel.
- Column Head
- Column strip.
- Middle strip.

In this paper, 3-D modelling and analysis of flat slab is carried out by SAFE software. Gravity load effect and punching shear stress analyzed by SAFE software. Flat slab analyzed by Finite Element Method through SAFE. Flat slab with different panel size (e.g. 6.5m X 6.5m, 8.5m X8.5m, 10.5m X 10.5m) are consider with two individual grade of concrete like M25 and M30 with different slab thicknesses are used under each grade of concrete selected. In addition, the entire above panel selected the column and wall sizes are different with 4 kN/m^2 live load and 1 kN/m^2 floor finish load.

2. METHODOLOGY TO SOLVE THE FLAT SLAB

Two methods are used for analyses the flat slab.

- Direct design method
- Equivalent frame method

2.1 Direct Design Method

In the direct design method, the total design moment for a span shall be determine by strip, bounded laterally by the centerline of the panel on each side of the centerline of the supports.

The absolute sum of the positive and average negative bending moments in each direction shall be taken as

$$M_0 = W l_n / 8$$

Where,
M_0 = Total moment;
W = Design load on a total area;
$l_n =$ Clear span extending from face to face of columns, capitals, brackets or walls, but not less than 0.65 L

2.1.1 Distribution of Moment in Flat Slabs

The equation is how to distribute this total moment to the column and middle strips. If the slab is completely fixed on both the supports than the total moment M_0 is distributed as 67% M_0 at support and 33% M_0 at the mid span. The internal spans may be considered as fixed on both the supports.
Accordingly, for internal spans, following values of design moment may be taken as,

Negative design moment 0.65 M_0

Positive design moment 0.35 M_0

Note, that the negative design moment is located at the face of the supports.

The distribution of total moment in the exterior panel or end span the total design moment M_0 shall be distributed as follows. The distribution of total moment in the exterior panel depends on relative stiffness of column and slab meeting at a joint.

Interior negative design moment:

$$= \left(0.75 - \frac{0.10}{1+\frac{1}{\alpha_c}}\right) M_o$$

Positive design moment:

$$= \left(0.63 - \frac{0.28}{1+\frac{1}{\alpha_c}}\right) M_o$$

Exterior negative design moment:

$$= \left(\frac{0.65}{1+\frac{1}{\alpha_c}}\right) M_o$$

To take into account, the ratio α_c is define as:

$$\alpha_c = \frac{\Sigma K_c}{K_s}$$

Where,
α_c = the ratio of flexural stiffness of the exterior column to the flexural stiffness of the slab at a joint.
$\sum K_c$ = sum of the flexural stiffness of the columns.
K_s = flexural stiffness of the slab.

Moment in Column Strip:

The column strip moments shall be as follows:

1. Negative moment at an interior support = 75 % of the total negative moment in the panel at that support.
2. Negative moment at an exterior support = 100 % of the total negative moment in the panel at that support.
3. Positive moment for each span = 60 % of the total positive moment in that panel.

Moment in Middle Strip:

The moment to be resisted by middle strip is equal to the moment that is not resisted by column strip.

2.1.2 Shear in Flat Slabs

When designing the flat slab with direct design method, it should be resist shear as well as moment. For shear the critical section is at a distance d/2 from the periphery of the column or capital or drops of the slab, where d is the effective depth of the section.

Types of Shear in Flat Slab

The following three types of shear criteria to be checked for flat slab design:

- One-way shear
- Two-way shear (punching shear)
- Shear caused by moment transfer.

- One-way shear

The critical section for one-way shear is at a d distance from the face of the column where d is the effective depth of the slab. The area from which the load is to be transferred is known as the tributary areas. This area is for wide beam action. The resultant shear is transferred by the full width of the section. The magnitude of the shear stress is given by

$$V_c = V / bd$$

Where,
d = effective depth of the slab.
Normally, this type of failure is impossible in any type of slab for normal loading condition but one-way shear check for slab is carry out in design calculation of slab.

- Two-way shear (punching shear)

If the flat slab is gradually subjected to increase the loading, the first crack will appear at the top of the slab around the column due to negative moment near the column. On further loading if structure is not strong in shear, a truncated pyramid of concrete will be pushed out of the slab. Such failure is called a punching shear or two-way shears. The critical section of punching shear is assumed to locate at a distance d/2 from the face of the

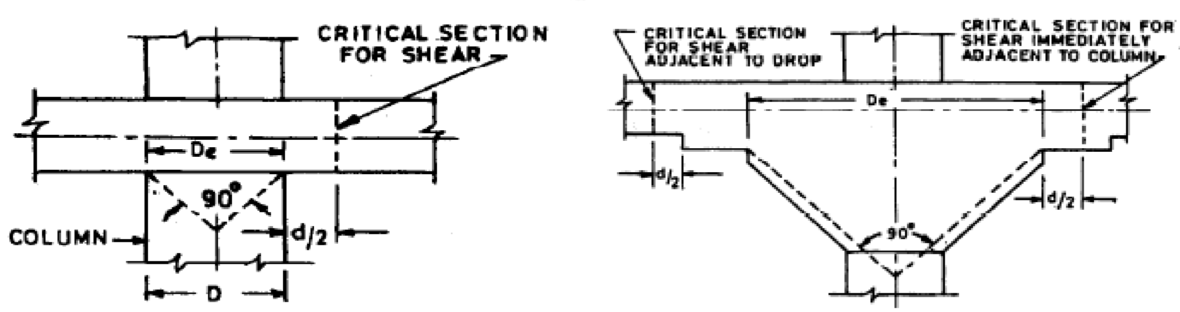


Fig. 2.1: Two-way shear

column. In which d is the effective depth of the slab. Also, if column capital or drop is provided then d/2 distance is considered from face of the capital or drop of the column.

- Shear caused by moment transfer

Let M1 and M2 are the moment of the column strip on either side of the column. In which the difference between this two individual moments, the column strip that abuts directly on the column is transfer some part of the unbalanced moment directly to the column as a bending moment. The other part of the unbalanced moment is transferred as torsion through the portion of the slab along the transverse direction.

3. REMEDIAL MEASURES IN FLAT SLAB

When shear strength is inadequate, we may adopt following changes:

- Increase the size of slab thickness
- Increase the column size
- Increase the grade of concrete
- Provide drop panel
- Provide column capital
- Use different types of punching shear reinforcement.

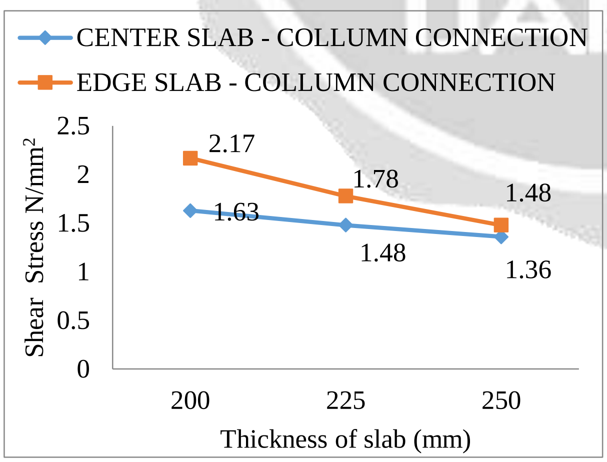
Out of several punching shear reinforcement systems, shear stirrups, shear band, stud rail, shear head are designed based on output values obtained from SAFE. Using traditional links as punching shear reinforcement is time consuming and expensive.

4. SELECTION CRITERIA OF SLAB THICKNESS

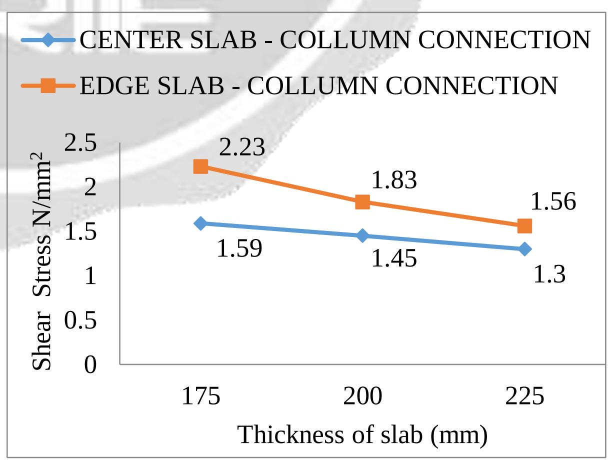
Selection criteria for slab thickness is based on punching shear stress value, when the shear stress value exceed the $V_c = 0.25\sqrt{fck}$ but less than 1.5 times V_c than shear reinforcement to be provide. If the shear stress exceeds the 1.5 times V_c than flat slab shall be redesigned. In which different size of slab thicknesses are used with individual grade of concrete like M25 and M30. The size of column and wall is also different for individual panel size.

5. RESULTS ASSESMENT

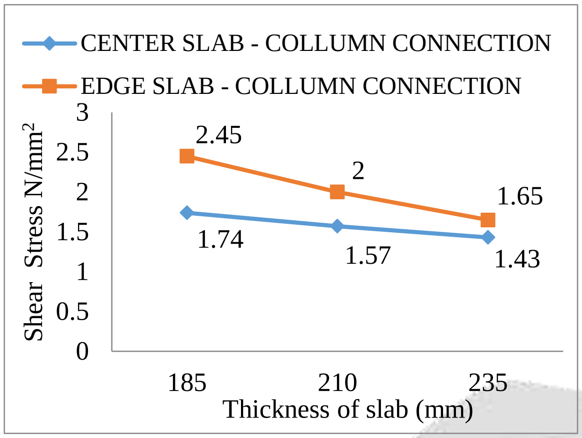
The analytical results is done to compare the shear stresses on flat slab with and without drop by Direct Design approach. It is presented below in graphical represent with different parameters.



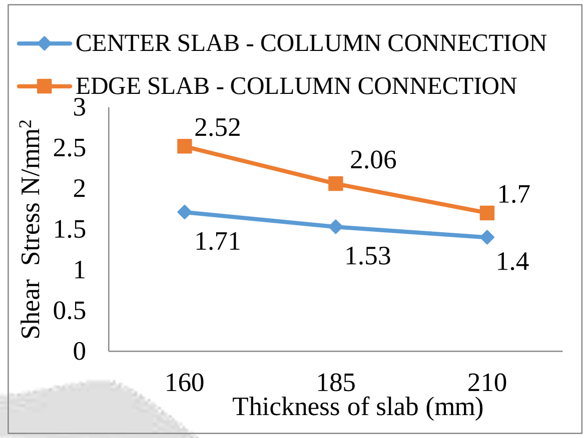
Graph 5.1: 6.5m x 6.5m without drop (M25)



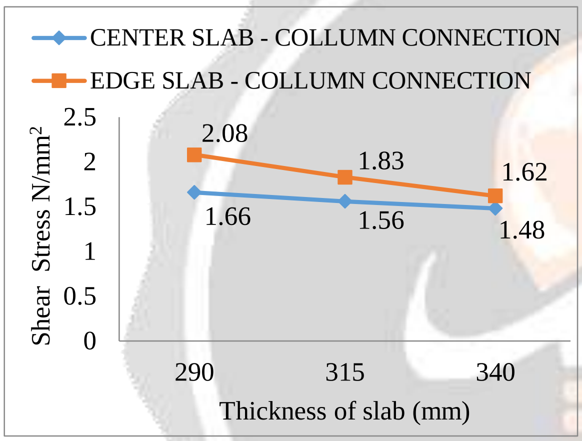
Graph 5.2: 6.5m x 6.5m with 25mm drop (M25)



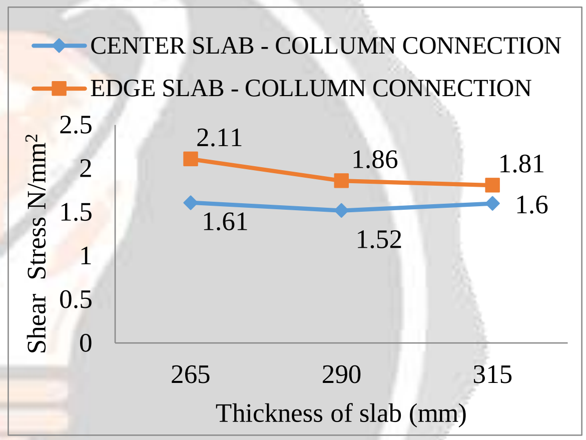
Graph 5.3: 6.5m x 6.5m without drop (M30)



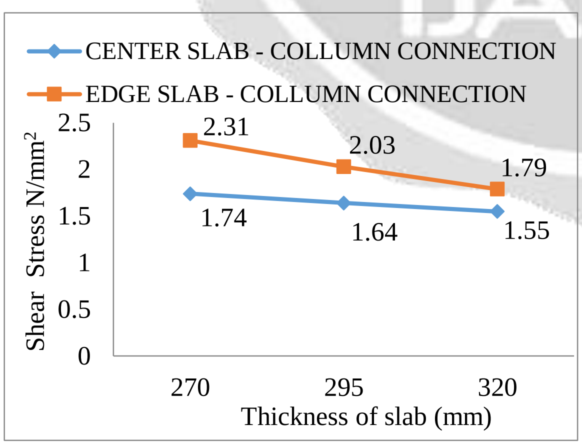
Graph 5.4: 6.5m x 6.5m with 25mm drop (M30)



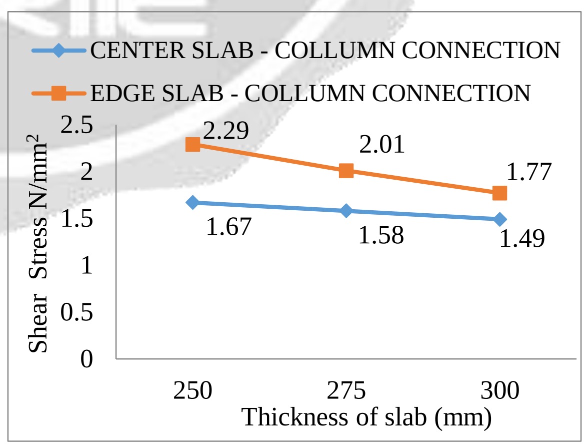
Graph 5.5: 8.5m x 8.5m without drop (M25)



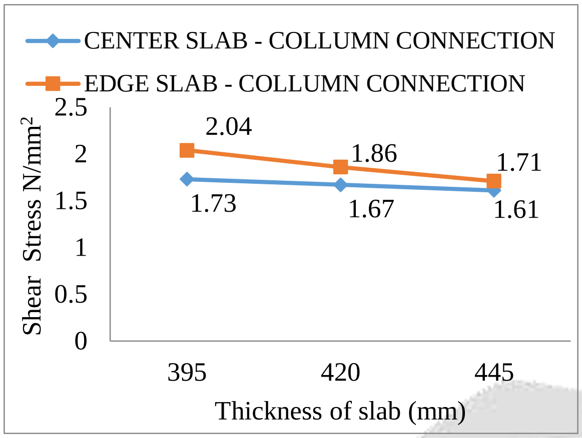
Graph 5.6: 8.5m x 8.5m with 25mm drop (M25)



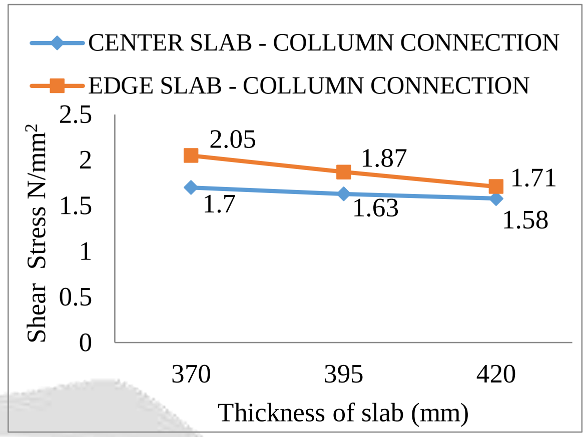
Graph 5.7: 8.5m x 8.5m without drop (M30)



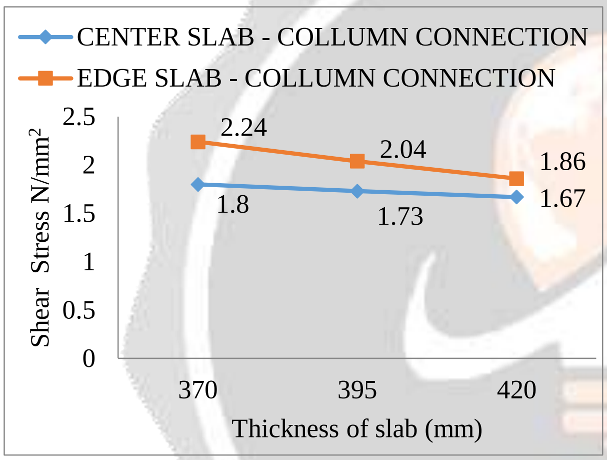
Graph 5.8: 8.5m x 8.5m with 25mm drop (M30)



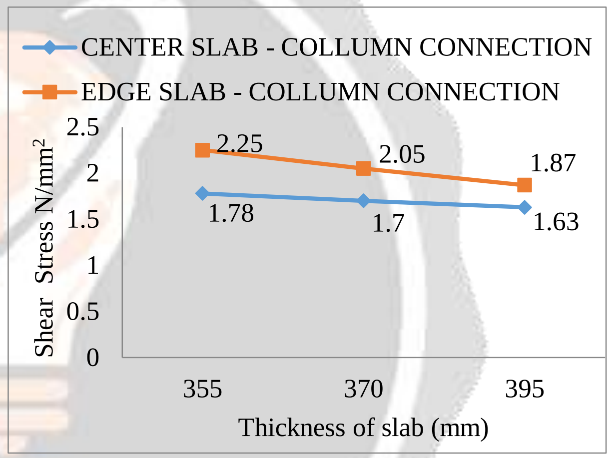
Graph 5.9: 10.5m x 10.5m without drop (M25)



Graph 5.10: 10.5m x 10.5m with 25mm drop (M25)

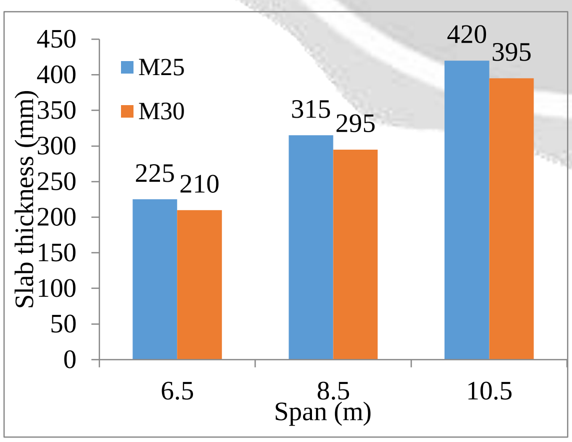


Graph 5.11: 10.5m x 10.5m without drop (M30)

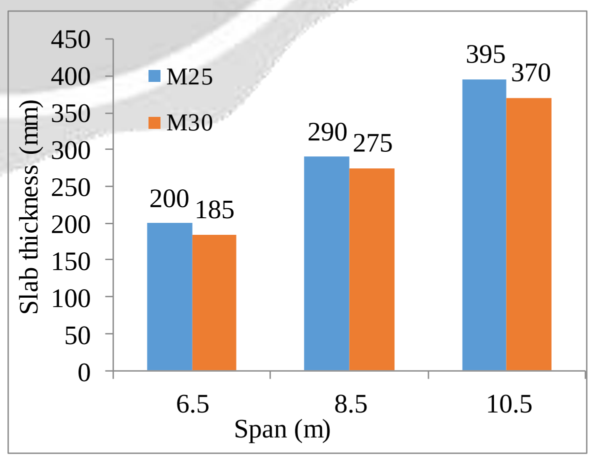


Graph 5.12: 10.5m x 10.5m with 25mm drop (M30)

Here, the value of slab thickness in variant span with different grade of concrete in graph: 5.13 and 5.14.

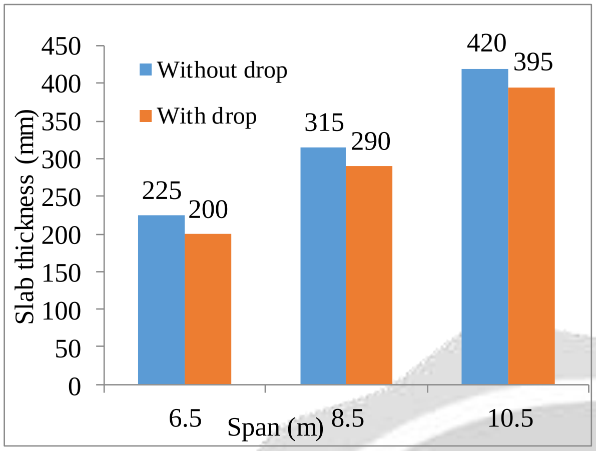


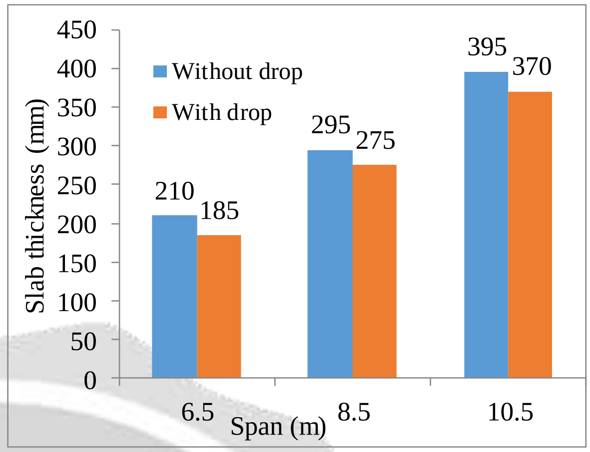
Graph 5.13: Thickness of slab without drop



Graph 5.14: Thickness of slab with drop

Here, the value of slab thickness in variant span with and without column drop represented in graph: 5.15 and 5.16





Graph 5.15: Thickness of slab for M25

Graph 5.16: Thickness of slab for M30

6. CONCLUSION

The final selection of slab thickness with different parameter based on the graph presented in section 5.

Table 1: Optimise value of flat slab from section 5

Panel Size	Column Size	Wall Size	Grade of Concrete	With or Without Drop	Selected Size of Thickness (mm)
mm X mm					
6.5 X 6.5	500 X 500	2000 X 300	M25	Without Drop	225
				With Drop	200
			M30	Without Drop	210
				With Drop	185
8.5 X 8.5	650 X 650	2500 X 300	M25	Without Drop	315
				With Drop	290
			M30	Without Drop	295
				With Drop	275
10.5 X10.5	800 X 800	3000 X 300	M25	Without Drop	420
				With Drop	395
			M30	Without Drop	395
				With Drop	370

Based on the graph 5.13 and 5.14 it can be said that with increase the grade of concrete from M25 to M30, the thickness of flat slab with and without drop is reduced by about 7-8 % and also from the graph 5.15 and 5.16 it should be conclude that for same panel size with same concrete grade with and without drop, thickness of flat slab difference is around 6-12 %. The work can be extended by higher grade of concrete design of both the methodologies and the same can be implement with column head.

7. REFERENCES

[1] N. Subramaniyan; "Alternative Punching Shear Reinforcement For RC Flat Slab", The Indian Concrete Journal, January 2014.

[2] Alkarani, Ravindra. R; "Evaluation OF Punching Shear In Flat Slabs", IJRET, IC-RICE Conference Issue, November, 2013.

[3] Vikunj K.Tilva, B. A. Vyas, Parth Thaker; "Enhancing the Punching Shear Resistance of Flat Plates Using Shear heads, Shear stud rails and Shear stirrups: A Comparative Study", Volume 04, No 06 SPL, pp. 596-599, October 2011.
[4] Aurelio Muttoni; "Punching Shear Strength of Reinforced Concrete Slabs without Transverse Reinforcement", ACI Structural Journal, Title no. 105- S42, pp. 440-450, July-August 2008.
[5] Gaston Kruger, Olivier Burdet, Renaud Favre; "Punching Strength Of R.C. Flat Slabs With Moment Transfer", 2nd Intern. Ph.D. Symposium in Civil Engineering, Budapest 1998, pp. 1-8, Budapest, Hungary, 1998.
[6] Viswanathan T.S., Mohan Ganesh, Santhi A.S.; "Shear Stress Distribution Of Flat Plate Using Finite Element Analysis", International journal Of Civil and Structural Engineering, February, 2012.
[7] N. Subramaniyan; "Evaluation and Enhancing the Punching Shear Resistance of Flat Slabs Using HSC", The Indian Concrete Journal, April 2005.
[8] IS 456:2000, "Indian Standard Code Of Practice For Plain and Reinforced Concrete", Fourth Revision, Bureau of Indian Standards, New Delhi, July 2000.