# Behavior of flat slab with drop and without drop.

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**Abstract: Punching is one of the most important phenomena to be considered during the design of reinforced concrete flat slabs. Three main factors affect the punching behavior. These factors are concrete compressive strength, horizontal flexural reinforcement, and vertical shear reinforcement in the form of stirrups, studs or other forms. Flat-slab system is widely used nowadays. Major and critical problem of this system is its sudden brittle failure is called punching shear failure. To overcome the punching failure problem, there are many ways to increase the punching shear strength of concrete slabs, increasing slab thickness in the area adjacent to the column, increasing column thickness which is against the architectural desire. An attempt has been made to study effect of punching shear in flat slab with drop and without drop in G+15 building.**

Key words: Flat slab, design standard., drop pattern, punching shear.

## 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.

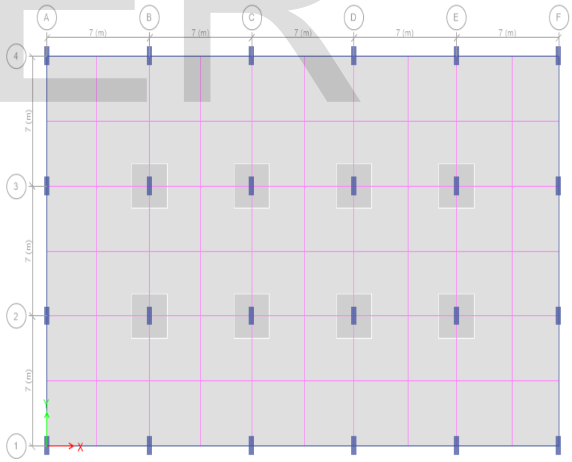
Flat slab system has the advantages of simple construction and formwork and avails a flat ceiling. It reduces ceiling finishing costs, since the architectural finish can be applied directly to the underside of the slab. Even more significant are the cost saving associated with the low story height made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

### 1.1 Components of Flab Slab

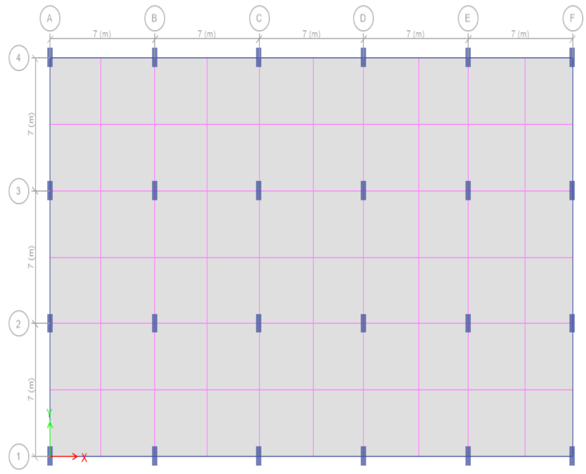
Main components of flat slab are.

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

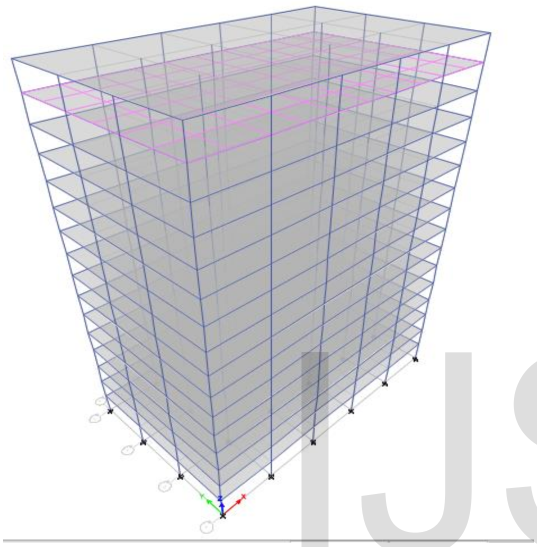
In this paper, 3-D modelling and analysis of flat slab is carried out by SAFE software. Gravity load effect and lateral load effect and punching shear stress analyzed by SAFE software. Flat slab analyzed by Finite Element Method through SAFE. Flat slab with panel size (e.g. 35m X 21m) are consider with G+15 floors made with three individual grade of concrete like M40, M50, M60 with superimposed live load 4 kN/m2 and 1 kN/m2 floor finish load.



Flat Slab with Drop.




Flat Slab Without Drop.



Elevation of G+15 Building.

## 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,

$M_0 = W / 8$

Where,

$M_0$ = Total moment;

W = Design load on a total area;

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

$$= (0.75 - \frac{0.10}{1 + \frac{1}{\alpha_c}})M_0$$

Positive design moment

$$= (0.63 - \frac{0.28}{1 + \frac{1}{\alpha_c}})M_0$$

Exterior negative design moment:

$$= (\frac{0.65}{1 + \frac{1}{\alpha_c}})M_0$$

To take into account, $\alpha_c$ the ratio is define as:

$$\alpha_c = (\frac{\sum K_c}{K_s})M_0$$

Where,

$\alpha_c$ =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.

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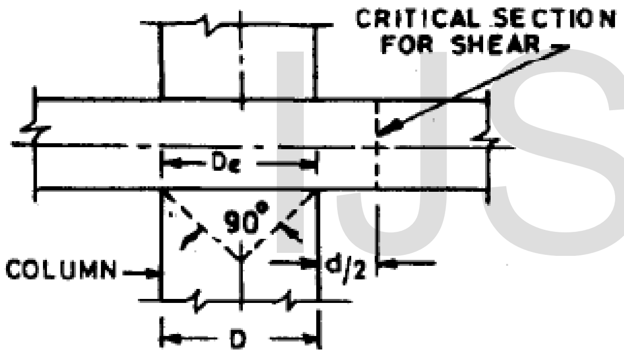
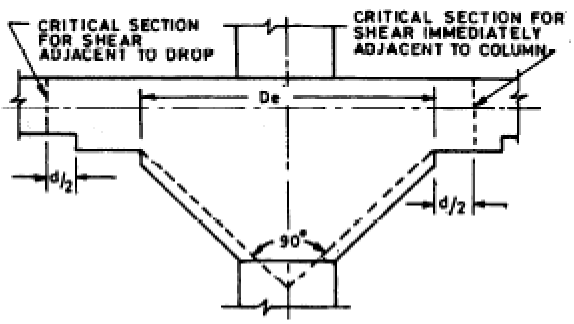
• One-way shear
The critical section for one-way shear is at a d distance from the face of the column where d is the effective depth of the slab. The area from which the load is to be transferred is known as the tributary areas. This area is for wide beam action. The resultant shear is transferred by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

$$V_c = \left(\frac{V}{bd}\right)$$

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



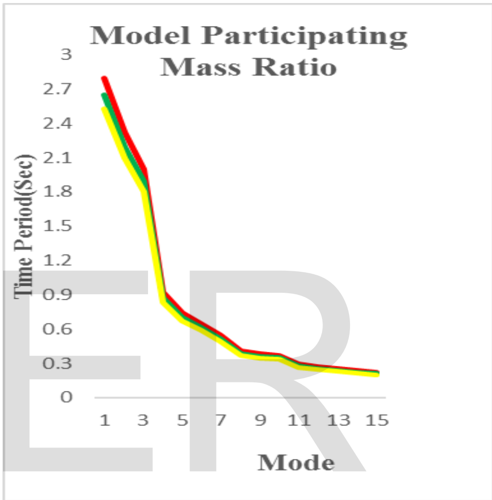




column. In which d is the effective depth of the slab. Also, if column capital or drop is provided then d/2 distance is considered from face of the capital or drop of the column.
• Shear caused by moment transfer
Let M1 and M2 are the moment of the column strip on either side of the column. In which 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.

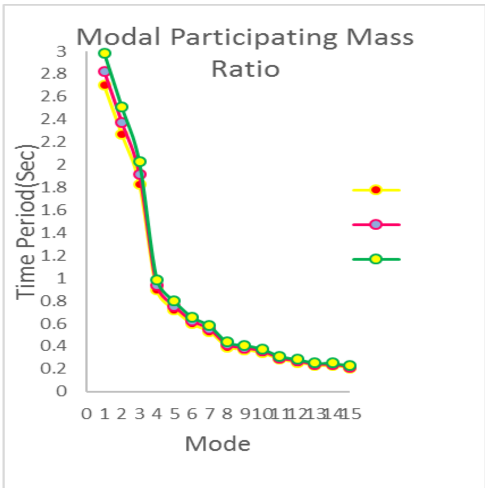
**3. REMEDIAL MEASURES IN FLAT SLAB**
When shear strength is inadequate, we may adopt following changes:
• Increase the size of slab thickness
• Increase the column size
• Increase the grade of concrete
• Provide drop panel
• Provide column capital
• Use different types of punching shear reinforcement.

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.

**RESULTS ASSESMENT**
**A) Modal displacement**



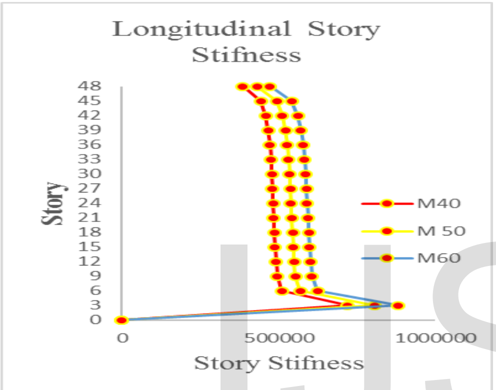

**Modal Time Period-Flat Slab with no Drop**




**Modal Time Period -Flat Slab with Drop**

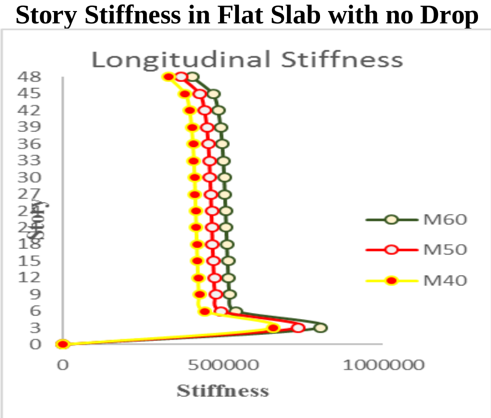
As seen above, the time period for models of Part I and Part II is the different since the stiffness of these models is the different irrespective of the grades in which they are made. The time period is inversely proportional to the stiffness of the structure. The time period for models M40 and M50 grade is found to be more thanM60 grade. But if we compared as Flat slab with no drop and flat slab with drop, time period is more in flat slab with drop this is because presence of drop where, in case of flat slab with no drop their stiffness is increases. This is because of stiffness reduction in the ground story of flat slab with no drop models whereas in case of flat slab with drop the drops are present throughout in all the stories thus increasing the stiffness and reducing the time period. Also modelling of drop further reduced the fundamental natural period which is function of mass, stiffness and damping characteristics of the building.

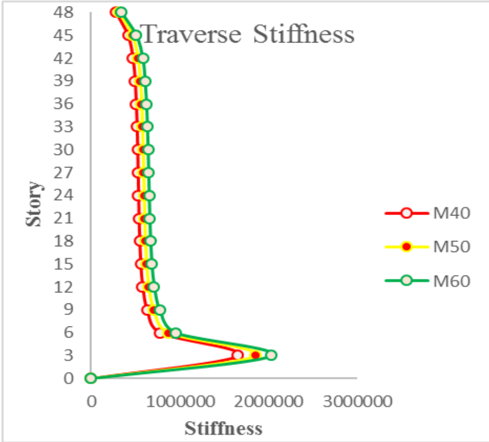
**A)Story Stiffness**





**Story Stiffness in Flat Slab with no Drop**

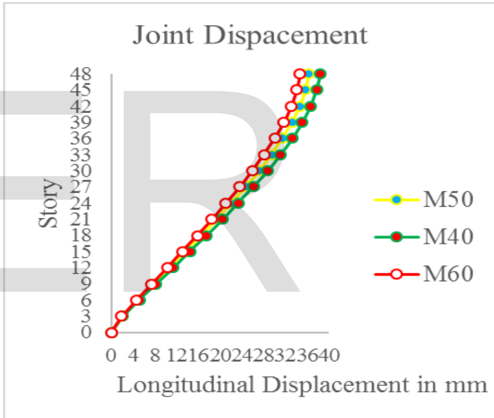


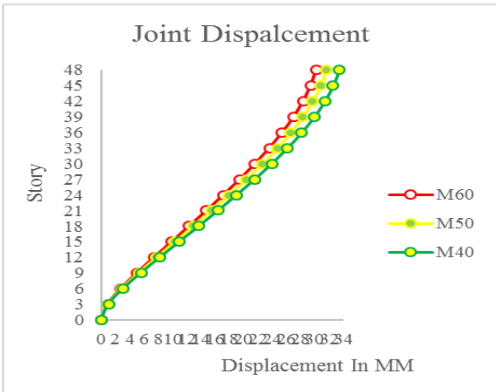




**Story Stiffness in Flat Slab with Drop**

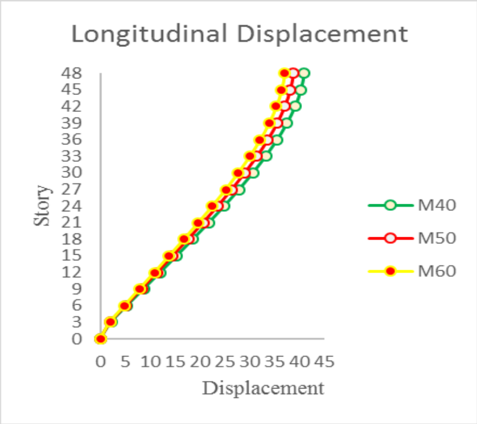
Story stiffness is defined as the rigidity of the object – the extent to which it resists deformation in response to the applied force. Story stiffness in flat slab with drop is 50% more when compared with flat slab with no drop.

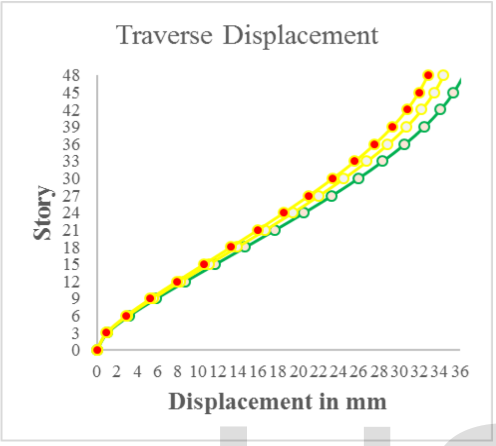
**C) Lateral Displacement:**




**Displacement in Flat Slab with no Drop**

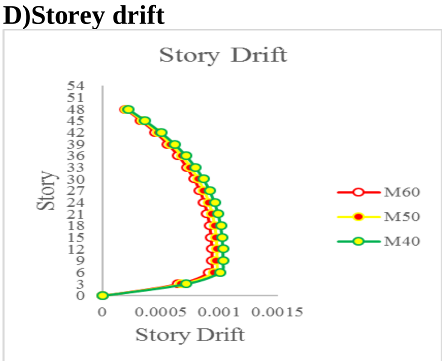



**Displacement in Flat slab with drop**

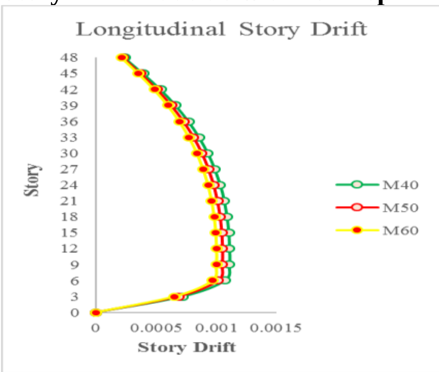
show the comparative graphs of results of lateral displacement in the transverse direction and Longitudinal direction for a building with flat slab with no drop and flat slab with drop. In figures of present study, it is seen that the trends of the lateral displacements obtained for both the studies is the not same in all the figures. There is more lateral displacement in flat slab with drop as compared with flat slab with no drop.

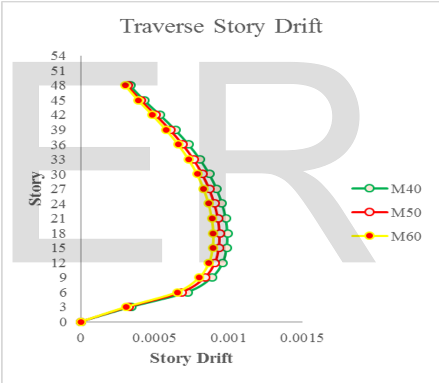
**D)Storey drift**





**Story Drift Flat slab with no Drop**



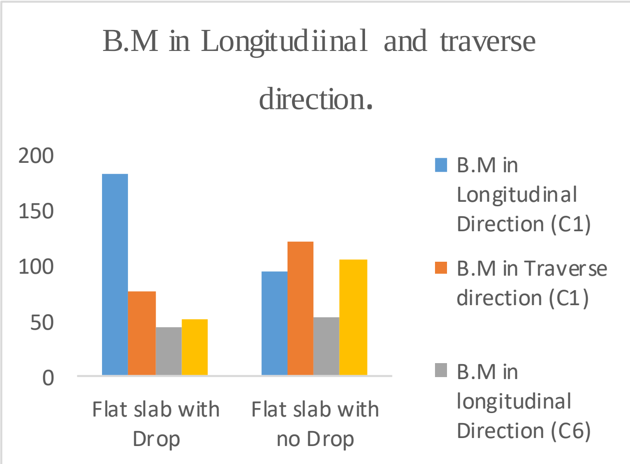






**Story Drift Flat slab with Drop.**

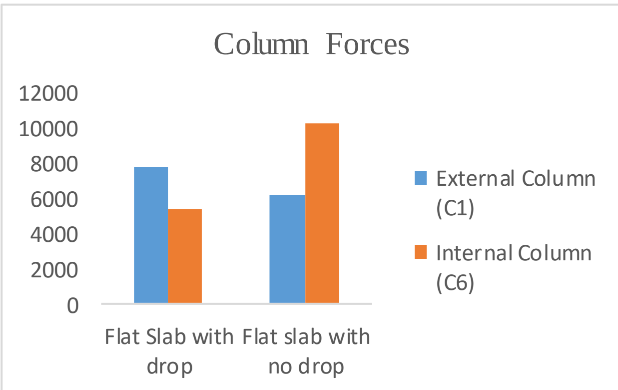
represents the comparative results of longitudinal and traverse story drifts for a RC Flat slab building with no drop and in the figures above, the story drifts of models flat slab with no drop of present study are compared to the story drifts of models flat slab with drop. study. It is seen that the trends of the story drifts of both the studies is nearly same.

**F) Bending Moment Column Forces**




Bending moment is found to be minimum in flat slab with drop as compared to the other models. There is about 50% reduction in bending moment in flat slab with drop as compared to flat slab with no drop. Also the bending moment of external column is found to be less than that of internal column. Bending moment is higher in longitudinal direction as compared to transverse direction. As observed from the figure above, the bending moment decreases in flat slab with drop where drop is not provided when compared to model flat slab with no drop where drop is not provided at any floor. Hence providing drop reduces bending moment.

**G) Column Forces**




**H) Punching Shear:**

| Flat Slab With Drop | | | |
|---|---|---|---|
| Column No | Punching Shear Capacity Ratio | | |
| | M40 | M50 | M60 |
| C6 | 1.0115 | 0.9047 | 0.8259 |
| C7 | 1.0122 | 0.9053 | 0.8264 |
| C10 | 0.9051 | 0.8095 | 0.739 |
| C11 | 0.9046 | 0.8091 | 0.7386 |
| C14 | 0.9034 | 0.808 | 0.7376 |
| C15 | 0.9037 | 0.8083 | 0.7379 |
| C18 | 1.0128 | 0.9059 | 0.827 |
| C19 | 1.0127 | 0.9058 | 0.8269 |

| Flat Slab Without Drop | | | |
|---|---|---|---|
| Column No | Punching Shear Capacity Ratio | | |
| | M40 | M50 | M60 |
| C6 | 1.2361 | 1.1056 | 1.0093 |
| C7 | 1.2363 | 1.1057 | 1.0094 |
| C10 | 1.442 | 1.0234 | 0.9342 |
| C11 | 1.143 | 1.0223 | 0.9332 |
| C14 | 1.1281 | 1.009 | 0.9211 |
| C15 | 1.1293 | 1.0101 | 0.9221 |
| C18 | 1.2511 | 1.119 | 1.0215 |
| C19 | 1.2502 | 1.1182 | 1.0208 |

Punching shear capacity ratio is more in flat slab with no drop as compared with flat slab with drop. There is no punching shear capacity ratio in External column in both flat slab with drop and flat slab with no drop. The Shear stud requirement is more in Flat slab with no drop. As grade increases there is decrease in punching shear capacity ratio.

**Conclusion:**

1)Flat Slab with drop increases story drift in shorter planes with 17% and decreases in longer plane with 20% as compared with flat slab without drop.

2)Lateral Displacement is 7% more in flat slab with drop as compared with flat slab without drop. Lateral Displacement is minimum at plinth level and maximum at terrace level.

3)Punching shear is 18% more in flat slab without drop as compared with flat slab with drop. As grade increases punching shear capacity ratio decreases

4) Base shear is 20% more at plinth level for all types of column. After plinth level base shear decrease as height increases. Base shear is more in flat slab with drop as compared with flat slab without drop.

5)The column moments are 28% more in flat slab with drop compared to flat slab without drop.

6)Column Forces are 20% more in external in flat slab with drop as compared with flat slab with no drop and 50% more in internal column in flat slab without drop as compared with flat slab with drop.

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