Abstract- The objective of this paper is to avail a cost comparison between flat slab panel with drop and without drop in four storey lateral load resisting building. A four storey building (having 6mx6m panel) is subjected to gravity load + lateral load in ETABS (Extended 3D Analysis of Building Systems) software and then each storey is exported to SAFE(Slab Analysis by the Finite Element Method) software for analyzing punching effect due to lateral loads. On the basis of permissible punching shear criteria according to IS 456, economical thickness of flat slab with drop and without drop are selected and cost comparison is done by using S.O.R. (Schedule Of Rates 2008-09).

Keywords-Punching shear stress, slab size, drop size, column size, and shear wall size.

I. INTRODUCTION

Recent market conditions show that the modern infrastructure development is aimed to utilize the available resources to their optimum levels, may the resources be in terms of economy or in terms of space. When the space criterion comes into picture, the utility of maximum space and aesthetics is the main concern of present day architects and designers. The slab that satisfies architectural demand for better illumination, requires simple formwork that can be removed faster (than other slabs) and guarantees open vision while making optimum use of the available space leads to an admired concept in field of structural engineering i.e reinforced concrete flat slab. Thus flat slabs give an economical alternative in utilizing the internal space to maximum extent. Flat slab is provided in malls, theatres and other structures where large beam free spaces are required. But today shear walls are compulsory for flat slab construction when earthquake resistance is considered.

II. DROP PANEL

Flat slab structures in areas of low seismicity (Zone I & II) can be designed to resist both vertical and lateral loads as permitted by code IS 1893 Part1:2002. However for areas of high seismicity (Zone III, IV & V) code does not permit flat slab construction without any lateral load resisting system. In a building having frames(without beam) and shear wall, the frames are designed for at least 25% of the seismic force and 75% is taken by the shear wall.[1] If effect of lateral load analysis and other design features are to be studied in flat slabs; punching shear is a matter of concern for any structural designer.

Figure 1. ETABS plan of flat slab with drop for four-storey building
In flat slab construction, the slab is sometimes thickened around the column as shown in figure 1. The standard practice is to thicken it to at least 1.25 times, but it should not be more than 1.5 times the thickness of the main slab. Drop can reduce the deflection and assist in the resistance against punching shear. Such thickening is usually made rectangular in plan with its length measured from the center line of the column to not less than \(\frac{1}{6}\) the smaller span of the surrounding panels. The total width of the enlargement from both sides of the center line of the column is called the drop width as shown in figure 1.[2]

III. WORK PROCEDURE

![ETABS plan of flat slab without drop for four-storey building](image)

**Steps:**

1. A 3 bay-4 storey frame with drop panel and without drop panel is modeled in ETABS with shear wall at four corners as shown in figure 1&2.
2. Gravity and lateral loads are assigned and analysis is performed in ETABS software. Slab is exported to SAFE.
3. Punching shear effect is analyzed in SAFE software.
4. On the basis of column dimension, shear wall dimension is selected so as to resist 75% earthquake force.(ref)

**Model data**

Panel size for an Office Building -6mx6m.
Dead load: self weight of slab & floor finish 1kN/m²;
Live load: 4kN/m²;
Zone (III); Soil condition - medium;
Importance Factor (I) =1;
Response Reduction Factor SMRF(R) =5;
Grade used: M25 and Fe- 415.
All columns are assumed to be square where lateral dimension D=500,550,600 and 650 mm.
Locations of shear wall are sw1, sw2, sw3, sw4 as shown in figure 1&2.
Earthquake force acts in both directions.

IV. PUNCHING FAILURE

Flat slab exhibits higher stress at the column connection. They are most likely to fail due to punching shear which will occur due to the concentration of shear forces and the unbalanced bending and twisting moments. It has to be noted that the punching shear failure is rather more critical than the flexural failure. Such a concentration of shear force and moments leads to unsymmetrical stress distribution around the slab-column connections. The local and brittle nature of the punching shear failure is in the form of crushing of concrete in the column periphery before the steel reinforcement reaches the yield strain. The observed angle of failure surface is found to vary between 26° and 36°. Thus the punching shear capacity of a slab (in absence of shear reinforcement) depends on the strength of concrete, the area of tension reinforcement, the depth of the slab and the column size.[3] The sudden disaster effect of the punching shear is a critical problem for any designer.

![Shear and flexural cracks near vicinity of column](image)
Stud rail

Stud rail is probably the most suitable type of reinforcement to arrest the punching shear damage. The system consists of studs that are welded onto a metal strip; the studs are fabricated from plain or deformed reinforcement bars, with an enlarged head welded to one or both ends. Shear stud rails are to be designed from output value of SAFE software to resist punching shear stress.

V. TO SELECT DIMENSION OF FLAT SLABS (WITH DROP AND WITHOUT DROP)

For flat slab without drop, the thickness of slab is considered as 200mm, 225mm, 250mm, 275mm, 300mm. and critical punching shear stress value is obtained from SAFE software analysis results. According to IS 456, when the shear stress at the critical section exceeds the value of \( \tau_c = 0.25 \sqrt{f_{ck}} \), but is less than 1.5 times \( \tau_c \) shear reinforcement shall be provided. If the shear stress exceeds 1.5\( \tau_c \), the flat slab shall be redesigned. [4].

Permissible shear stress: \( \frac{0.25 \sqrt{f_{ck}}}{1.25} = 0.25 \sqrt{f_{ck}} \)

(cl. 31.6.3.2) IS 456 = 1.5x1.25 = 1.875 N/mm²

Without drop

Below graph is prepared which shows the value of punching shear stress at edge slab-column connection and center slab-column connection at critical storey. Y axis indicates slab depth in mm and X axis indicates shear stress in N/mm².
From the graph of figure 4(b), dimension of slab depth 225 mm, column size 550mmx550mm and shear wall 1550mmx200mm are selected. This dimension is minimum requirement for this model and shear stirrups are required at slab-column connection. If designer wants to design without shear reinforcement then from figure 7, dimension of slab depth 250mm, column 650mmx650mm and shear wall 2000mmx200mm are selected.

VI. RESULT OF COST COMPARISON

From the graph of figure 5, when drop is provided, thickness of slab depth 150 mm and drop 50 mm, column size 550mmx550mm and shear wall 1550mmx200mm are selected. This dimension is minimum requirement for this model and shear stirrups are required at slab-column connection.

With drop

From the graph of figure 4(c), dimension of slab depth 225 mm, column size 600mmx600mm and shear wall 1750mmx200mm are selected. This dimension is minimum requirement for this model and shear stirrups are required at slab-column connection.
Figure 6. Cost comparison between flat slabs with drop and without drop

From the graph of figure 6, a cost comparison between case 1: A flat slab of depth 225 mm without drop and case 1: flat slab of depth 150 mm with 50 mm drop (at critical third storey) is shown by bar chart.

VII. CONCLUSION

As per the cost comparison for flat slab panel 6mx6m for with drop and without drop, the results show that from economic point of view slab with drop provision is preferable. Also punching shear stress is reduced by adopting drop at slab-column connection. Projected cost for flat slab without drop slab is 29% higher than with drop slab.

Table 1. Result of cost comparison

<table>
<thead>
<tr>
<th>Cost comparison of slab in accordance to Schedule of Rates (S.O.R- R&amp;B2008-09)[5]</th>
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<tr>
<td>Flat slab of depth 225 mm without drop</td>
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<tr>
<td>Flat slab of depth 150 mm with 50 mm drop</td>
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References


