Analysis And Design of Flat Slab And Grid Slab  
And Their Cost Comparison

Amit A. Sathawane & R.S. Deotale  
Department of Civil Engineering, Yeshwantrao Chavhan College of Engineering Nagpur, India  
E-mail : amit13_sat@yahoo.co.in & rsdeotale1@rediffmail.com

Abstract - The FLAT slab system of construction is one in which the beam is used in the conventional methods of construction done away with the directly rests on column and the load from the slabs is directly transferred to the columns and then to the foundation. Drops or columns are generally provided with column heads or capitals. Grid floor systems consisting of beams spaced at regular intervals in perpendicular directions, monolithic with slab. They are generally employed for architectural reasons for large rooms such as auditoriums, vestibules, theatre halls, show rooms of shops where column free space is often the main requirement. The aim of the project is to determine the most economical slab between flat slab with drop, Flat slab without drop and grid slab. The proposed construction site is Nexus point apposite to Vidhan Bhavan and beside NMC office, Nagpur. The total length of slab is 31.38 m and width is 27.22 m. total area of slab is 854.16 sqm. It is designed by using M 35 Grade concrete and Fe 415 steel. Analysis of the flat slab and grid slab has been done both manually by IS 456-2000 and by using software also. Flat slab and Grid slab has been analyzed by STAAD PRO. Rates have been taken according to N.M.C. C.S.R.

It is observed that the FLAT slab with drop is more economical than Flat slab without drop and Grid slabs.

Keywords- Flat slab with drop, Flat slab without drop, grid slab, drop, column capital.

I. INTRODUCTION

A. FLAT SLAB

A reinforced concrete flat slab, also called as beamless slab, is a slab supported directly by columns without beams. A part of the slab bounded on each of the four sides by centre line of column is called panel. The flat slab is often thickened closed to supporting columns to provide adequate strength in shear and to reduce the amount of negative reinforcement in the support regions. The thickened portion i.e. the projection below the slab is called drop or drop panel. In some cases, the section of column at top, as it meets the floor slab or a drop panel, is enlarged so as to increase primarily the perimeter of the critical section, for shear and hence, increasing the capacity of the slab for resisting two-way shear and to reduce negative bending moment at the support. Such enlarged or flared portion of and a capital. Slabs of constant thickness which do not have drop panels or column capitals are referred to as flat plates. The strength of the flat plate structure is often limited due to punching shear action around columns, and consequently they are used for light loads and relatively small spans.

METHODS

DESIGN OF FLAT SLAB

Methods of Design: 

Two approximate method methods are adopted by the codes for the design of flat slab or flat plate. These method can be used provided the limitations specified therein are satisfied. The two design methods are a) The direct design method. (b) The equivalent frame method
1.2 GRID SLAB

Grid floor systems consisting of beams spaced at regular intervals in perpendicular directions, monolithic with slab. They are generally employed for architectural reasons for large rooms such as auditoriums, vestibules, theatre halls, show rooms of shops where column free space is often the main requirement. The rectangular or square void formed in the ceiling is advantageously utilized for concealed architectural lighting. The sizes of the beams running in perpendicular directions are generally kept the same. Instead of rectangular beam grid, a diagonal.

ANALYSIS OF GRID SLAB

1) Approximate Methods
2) Analysis of grid Floor by Plate Theory

II. DESIGN OF FLAT SLAB WITH DROP INTERIOR PANEL OF SIZE 10.6 × 8.86 M

Size of columns = L1/16 or H/8 = 500 mm
Estimate size of column capital = D = L2/5 = 1772 mm
Length of drop = 1/3 span = 3.5 x 3.0 m
slab thickness = Ln = L1 - b = 300 mm.
thickness of drop H = 1.25 to 1.5 h = 450 mm
Size of external column = 500 mm square
Size of edge beam = 300 × 600 mm
fck = 35 ; fy = 415 ;

Load Calculations:
(a) Dead Load: bDy = 1 x 0.3 x 25 = 7.5 KN/m
(b) Floor Finish = 1 kN/m
(c) Live Load = 4 kN/m
Total Design Load = 18.75 KN/m

Analyze the Interior X frame:
M0=wL2Ln^2 / 8 = 1618.34 kNm

DISTRIBUTION FACTORS:
longitudinal distribution Inter span
Support (-ve) = 0.65, Span (+ve) = 0.35
End spans: Interior –ve = 0.75 - 0.1R = 0.69
Span +ve = 0.63 - 0.28R = 0.45; Exterior –ve = 0.65
R = 0.42
Transverse distribution
Interior –ve : 75% to column strip; 25% to mid
Span +ve : 60% to column strip; 40% to mid-strip
Exterior –ve: 100% to column strip

Check for shear:
Effective depth of slab = 270 mm,
Effective depth of slab = 270 mm,
Weight of drop projection below slab = 25 x (0.3 – 0.24) x 1.5 = 2.25 kN/m²

Design shear at critical section around capital
Vui = 16.125 (10.6 × 8.86 - (π x (2.26 /4)) + 2.25 (3.6 - π x (2.26 /4))
= 1450.0 + 15.0 = 1936.5 KN.

Design Shear strength of concrete:
τe = k. τc where, τc = 0.25√fck
τc = 0.25√35 = 1.48 N/ m²
$k = (0.5 + \beta) \tau_c \quad \text{but} \leq 1.0$

$k = 1.0 \quad \Rightarrow \quad \tau_{uc} = 1.48 \text{ N/mm}^2$

Shear resistance of concrete

$\tau_{uc} = \tau_{uc} \times p \times d = 1.48 \times (\pi \times 2260) \times 0.260$

$= 4723.42 \text{ KN} \geq \tau_{ud} \quad (= 1936)\text{ }$

Design shear at critical section:

$\tau_{ud} = 18.125 \{(\text{10.6} \times 8.86) - (3.6+0.20) \times (3.6 + 0.270)\} = 1480.4 \text{ KN}$

Shear resistance of concrete,

$\tau_{uc} = 1.48 \times (3800+3800) \times (270/1000)$

$= 6185 \text{ KN} \geq \tau_{ud}$

check for shear around the drop: The critical section is at a distance $d/2 = 270/2 = 135 \text{ mm}$ from the periphery of the drop

### Table

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>Longitudinal</th>
<th>Transverse</th>
<th>AREA OF STEEL</th>
<th>DIAMETER OF BARS</th>
<th>Spacing (mm c/c)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Interior</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Transverse</td>
<td>Longitudinal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>direction</td>
<td>Column</td>
<td>Middle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-ve support</td>
<td>237.453</td>
<td>178.09</td>
<td>59.363</td>
<td>2775.30</td>
<td>20</td>
</tr>
<tr>
<td>+ve support</td>
<td>127.85</td>
<td>76.72</td>
<td>51.143</td>
<td>1398.10</td>
<td>20</td>
</tr>
<tr>
<td>End span</td>
<td>ACI METHOD</td>
<td>Interior</td>
<td>Transverse</td>
<td>Longitudinal</td>
<td>Column</td>
</tr>
<tr>
<td>(-ve )</td>
<td>255.71</td>
<td>191.79</td>
<td>63.929</td>
<td>3026.87</td>
<td>20</td>
</tr>
<tr>
<td>Span + ve</td>
<td>182.656</td>
<td>109.59</td>
<td>73.062</td>
<td>2061.24</td>
<td>20</td>
</tr>
<tr>
<td>Exterior</td>
<td>(-ve )</td>
<td>109.594</td>
<td>82.195</td>
<td>27.398</td>
<td>186.63</td>
</tr>
<tr>
<td>End span</td>
<td>IS 456</td>
<td>Interior</td>
<td>Transverse</td>
<td>Longitudinal</td>
<td>Column</td>
</tr>
<tr>
<td>(-ve )</td>
<td>250.28</td>
<td>187.72</td>
<td>62.572</td>
<td>2951.28</td>
<td>20</td>
</tr>
<tr>
<td>Span + ve</td>
<td>163.797</td>
<td>98.278</td>
<td>65.518</td>
<td>1827.81</td>
<td>1057.99</td>
</tr>
<tr>
<td>Exterior -ve</td>
<td>154.028</td>
<td>154.03</td>
<td>1709.10</td>
<td>1709.10</td>
<td>20</td>
</tr>
</tbody>
</table>

### Table III

#### III. COMPARISION

3.1 Comparison of Maximum Moments obtained Manually and by Software for Flat Slab

<table>
<thead>
<tr>
<th>Maximum Moments</th>
<th>Manually</th>
<th>Software</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column strip positive kNm</td>
<td>76.72</td>
<td>73</td>
</tr>
<tr>
<td>Column strip negative kNm</td>
<td>178.1</td>
<td>177</td>
</tr>
<tr>
<td>Middle strip positive kNm</td>
<td>51.14</td>
<td>54.06</td>
</tr>
<tr>
<td>Middle strip negative kNm</td>
<td>59.36</td>
<td>61.66</td>
</tr>
</tbody>
</table>

3.2 Comparison of Maximum Moments obtained Manually and by Software of Grid Slab

<table>
<thead>
<tr>
<th>MAXIMUM MOMENT kNm</th>
<th>MANUALLY</th>
<th>SOFTWARE</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAXIMUM SHEAR FORCE kN</td>
<td>625</td>
<td>618</td>
</tr>
</tbody>
</table>
3.3 Flat Slab With Drop:

<table>
<thead>
<tr>
<th>SPAN (m)</th>
<th>7 × 6</th>
<th>8 × 7</th>
<th>9 × 8</th>
<th>10 × 9</th>
<th>10.6 × 8.86</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONCRETE (m³)</td>
<td>88.20</td>
<td>137.52</td>
<td>190.696</td>
<td>270.10</td>
<td>293.01</td>
</tr>
<tr>
<td>AMOUNT (Rs)</td>
<td>853360</td>
<td>1348540</td>
<td>2052690</td>
<td>2972681</td>
<td>3009600</td>
</tr>
</tbody>
</table>

3.4 Rate Comparison:

<table>
<thead>
<tr>
<th></th>
<th>FLAT SLAB WITH DROP</th>
<th>FLAT SLAB WITHOUT DROP</th>
<th>GRID SLAB</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONCRETE (m³)</td>
<td>293.01</td>
<td>281.87</td>
<td>314.63</td>
</tr>
<tr>
<td>STEEL (KG)</td>
<td>29800</td>
<td>38125</td>
<td>36500</td>
</tr>
<tr>
<td>TOTAL AMOUNT (Rs)</td>
<td>3009600</td>
<td>3292650</td>
<td>3420780</td>
</tr>
<tr>
<td>RATE PER Sqm</td>
<td>3524</td>
<td>3855</td>
<td>4005</td>
</tr>
<tr>
<td>RATE PER Sqft</td>
<td>327</td>
<td>358</td>
<td>372</td>
</tr>
</tbody>
</table>

4. Graphs:

**Concrete (cum) vs. Slab Type**

**Steel (KG) vs. Slab Type**

**Conclusion**:

1) Drops are important criteria in increasing the shear strength of the slab.
2) Enhance resistance to punching failure at the junction of concrete slab & column.
3) By incorporating heads in slab, we are increasing rigidity of slab.
4) The negative moment’s section shall be designed to resist the larger of the two interior negative design moments for the span framing into common supports.
5) Concrete required in Grid slab is more as compared to Flat slab with Drop and Flat slab without Drop.
6) Steel required in Flat slab without Drop is more as compared to Flat slab with Drop and Grid slab.
7) Flat slab with drop is more economical than flat slab without Drop and Grid slab.
8) Rate per square meter of flat slab with drop (3524) was found to be more economical than flat slab without drop (3855) and grid slab (4005).
9) Rate per square feet of flat slab with drop (327) was found to be more economical than flat slab without drop (358) and grid slab (372).
REFERENCES

Papers:


[3] Ahmed Ibrahim’ , Hani Salim and Hamdy Shehab El-Din; Moment coefficients for design of Flat slabs with and without openings. (11-06-2011)

[4] Dario Coronelli; ‘Grid Model for For Flat Slab Structures

[5] Lawson,Patrick D; STRUCTURAL GRID FOR SLAB FACING MATERIALS; (03-28-1972)

P. C Books: