Flat Slab Dynamic Analysis

1 Nalini Thakre, 2 Mahesh Janbandhu, 3 Dipak Mangrulkar
1, 2, 3 S.B. Jain College of Engineering, Nagpur University, Department of Civil Engineering, Nagpur, Maharashtra

Abstract - The seismic effect on the structure is the most important factor while designing the civil engineering structures which will cause adverse effect later on. In present study efforts being taken while analyzing the structure for Earthquake resistance. In this we have taken a live project a five storied building with flat slab and dynamic analysis is done by Response Spectrum Method taking all load combinations as per IS-1893. We have used software SAP 2000 for this purpose. Main emphasis is given on the structural response when flat slab is provided. Behaviour of the structure is studied for four types of models like a flat slab only, Flat slab with head, with drop and with both head and drop with equal thickness as well unequal thickness. The results of all four types are then compared for time period, axial forces, shear forces, moments in each direction and the slab panel moments. The structure is designed as per IS-456-2000 and IS-13920 guidelines.


1. Introduction

1.1 General

Flat slab is a reinforced concrete slab supported by columns with, or without drops. The columns may be with, or without, column heads. Flat-slab is one of the most widely used systems in reinforced concrete construction because of its high degree of structural efficiency. It use simple formwork and reinforcing arrangements, and requires the least storey height. Although efficient in resisting gravity load, the flat slab system is inherently flexible and can have excessive lateral drift when subjected to seismic loading. Its susceptibility to severe damage during strong earthquakes is well documented (Rosenblueth 1986; Hawkins 1980).

In zone of high seismicity, the flat-slab systems are designed such that slab-column space frame supports gravity loads and the shear walls provide resistance to lateral load (Wey and Durani 1992; Robertson and Durani 1992; Moehle and Diebold 1985). However, it is required by the building codes [IS: 456; ACI: building 1989] that the gravity load subsystem must be able to deform with the lateral load resisting system without any loss of its load carrying capacity. Thus, in reality the two subsystems act together. Furthermore, since the design seismic force recommended by the codes are generally much less than what the structure would experience during a major earthquake, a certain degree of nonlinear response is to be expected.

1.2 Advantages

Some of the advantages of Flat Slab are:-
1. Rapid construction
2. Maximum design flexibility
3. Economy
4. Headroom height requirements large
5. Minimum storey heights
6. Controlled deflection
7. Optimum clear span
8. Sufficient lateral displacement capacity

1.3 Terminology Related With Flat Slab

1.3.1 Column Strip

Column strip means a design strip having a width of 0.25 \( l_1 \), but not greater than 0.25 \( l_2 \), on each side of the column.
centerline, where $l_1$ is the span in the direction moments are being determined, measured centre to centre of supports and $l_2$ is the span transverse to $l_1$, measured centre to centre of supports.

1.3.2 Middle Strip

Middle strip means a design strip bounded on each of its opposite sides by the column strip.

1.3.3 Panel

Panel means that part of a slab bounded on each of its four sides by the centre-line of a column or centre-lines of adjacent-spans.

2. Analysis of Flat Slab by Response Spectrum Method

2.1 Introduction to Problem

2.2 Modeling of flat slab for Response Spectrum

- Column size (500x500)mm
- Slab thickness 200 mm without drop
- Live load on all floors 6 kN/m² (50% for earthquake)
- Grade of concrete M25 & steel Fe 415N/mm²
- Brick wall external & internal 230 mm
- Density of brick wall including plaster 20kN/m³
- Density of brick wall including plaster 20kN/m³
- Drop size external (1100x1000)mm
- Drop size internal (2200x2000)mm
- Depth of Head 400mm
- Head at bottom (500x500)mm
- Head at top (1200x1200)mm

2.2.1 Mathematical Model

<table>
<thead>
<tr>
<th>Sr.No</th>
<th>Particulars</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The mathematical model includes five storey building with 30 column in each floor and 20 slab section</td>
</tr>
<tr>
<td>2</td>
<td>All columns are modeled as beam element and slab is modeled as plate element having area type shell</td>
</tr>
<tr>
<td>3</td>
<td>Each plate is subdivided into 9*8 =72 plate element</td>
</tr>
<tr>
<td>4</td>
<td>For dynamic analysis of structure response spectrum method was used</td>
</tr>
</tbody>
</table>

2.2.2 Soil Strata

It is assumed that the footing is resting at 1.5m from GL

Medium soil
2.2.3 Seismic Force Calculation

Zone II for Nagpur city Z=0.1
Hence spectra for medium soil
Importance factor =1.5
Sa/g=1+15T0.00 ≤ T ≤ 0.101
Damping 5%
= 2.5 0.1 ≤ T ≤ 0.55
Soil type medium
= 1.36/T 0.55 ≤ T ≤ 4.0
R for SMRF=5 & OMRF=3

1. Time period in long direction Tx =0.09H/√d
=0.09x21/√28 =0.357sec
2. Time period in short direction Ty=0.09H/√d
=0.09x21/√26.4 =0.368sec
Take Sa/g for both direction = 2.5

2.2.4 Scale Factor

\[ f = \frac{1}{2} x \frac{I}{R} = 0.15 \]

Where, I= Importance factor =1.5
R=Response reduction factor=5

2.2.5 Response Spectrum for Zone II:-Soil Type II (Medium Soil)

Table No. 2.2 Time Period Vs Acceleration

<table>
<thead>
<tr>
<th>Period (Sec)</th>
<th>Acceleration</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.1</td>
</tr>
<tr>
<td>0.1</td>
<td>0.25</td>
</tr>
<tr>
<td>0.55</td>
<td>0.25</td>
</tr>
<tr>
<td>0.8</td>
<td>0.17</td>
</tr>
<tr>
<td>1</td>
<td>0.136</td>
</tr>
<tr>
<td>1.2</td>
<td>0.1133</td>
</tr>
<tr>
<td>1.4</td>
<td>0.0971</td>
</tr>
<tr>
<td>1.6</td>
<td>0.085</td>
</tr>
</tbody>
</table>

![RESPONSE SPECTRA](image)

Figure 2.6 Response Spectra for Zone II
2.3 Results and Discussion

2.3.1 Comparison of Time Period (sec)

<table>
<thead>
<tr>
<th>TYPE</th>
<th>FLAT SLAB</th>
<th>DROP</th>
<th>WITH HEAD</th>
<th>DROP WITH HEAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>593</td>
<td>573</td>
<td>581</td>
<td>569</td>
</tr>
<tr>
<td>C2</td>
<td>728</td>
<td>708</td>
<td>716</td>
<td>699</td>
</tr>
<tr>
<td>C3</td>
<td>708</td>
<td>689</td>
<td>695</td>
<td>681</td>
</tr>
<tr>
<td>C4</td>
<td>722</td>
<td>703</td>
<td>712</td>
<td>693</td>
</tr>
<tr>
<td>C5</td>
<td>836</td>
<td>819</td>
<td>825</td>
<td>809</td>
</tr>
<tr>
<td>C6</td>
<td>833</td>
<td>810</td>
<td>821</td>
<td>799</td>
</tr>
<tr>
<td>C7</td>
<td>715</td>
<td>695</td>
<td>708</td>
<td>689</td>
</tr>
<tr>
<td>C8</td>
<td>838</td>
<td>815</td>
<td>827</td>
<td>806</td>
</tr>
<tr>
<td>C9</td>
<td>869</td>
<td>879</td>
<td>888</td>
<td>876</td>
</tr>
</tbody>
</table>

Table 2.3: Comparison of Time Period (sec)

As we go from fifth story to the first story we can see the time period of flat slab without head & drop seems to be low due to which Sa/g will be less and lateral forces will also be less.

![Comparison of Axial Force (kN) First Storey](image)

**Description & Interaction (Axial Force)**

As we go from fifth Story to the first story we can see the first story have long column and we have maximum axial force to be developed in the column of first story with drop and head.

![Comparison of Shear Force (kN) First Storey](image)

**Description & Interaction (Shear Force)**

From SAP Result it is seen that due to lateral forces developed are in decreasing order from flat to drop with head & there is not much differences in the models with only drop & only head.

![Comparison of Time Period (sec)](image)

**Description & Interaction (Time Period)**

As it is seen from SAP-Results there are many modes out of which if we consider the first two modes it has been seen that the time period of flat slab without Head & Drop...
Description & Interaction (Moments)

From the graph it is found that the moments are directly proportional to the stiffness. Since the stiffness is going to increase from flat to drop with head & if we compare Slab with the head & Slab with the drop. The stiffness will not very much there fore the moment variation are not much.

Fig 2.10 Comparison of Moment in X- Direction (kN-m)

4. DESIGN OF FLAT SLAB BY IS 456:2000

<table>
<thead>
<tr>
<th>TYPE</th>
<th>FLAT SLAB</th>
<th>DROP</th>
<th>WITH HEAD</th>
<th>DROP WITH HEAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>76 107</td>
<td>80 120</td>
<td>84 110</td>
<td>112 101</td>
</tr>
<tr>
<td>C2</td>
<td>335 38</td>
<td>300 30</td>
<td>285 30</td>
<td>261 35</td>
</tr>
<tr>
<td>C3</td>
<td>295 31</td>
<td>357 32</td>
<td>306 32</td>
<td>330 32</td>
</tr>
<tr>
<td>C4</td>
<td>22 196</td>
<td>25 231</td>
<td>32 221</td>
<td>21 231</td>
</tr>
<tr>
<td>C5</td>
<td>23 30</td>
<td>45 41</td>
<td>40 41</td>
<td>27 35</td>
</tr>
<tr>
<td>C6</td>
<td>24 32</td>
<td>40 41</td>
<td>40 41</td>
<td>28 51</td>
</tr>
<tr>
<td>C7</td>
<td>21 298</td>
<td>46 328</td>
<td>25 307</td>
<td>34 293</td>
</tr>
<tr>
<td>C8</td>
<td>31 32</td>
<td>25 31</td>
<td>62 37</td>
<td>36 41</td>
</tr>
<tr>
<td>C9</td>
<td>31 32</td>
<td>26 32</td>
<td>45 42</td>
<td>40 48</td>
</tr>
</tbody>
</table>

The term flat slab means a reinforced concrete slab with or without drops, supported generally without beams, by columns with or without flared column heads. A flat slab may be solid slab or may have recesses formed on the soffit so that the soffit comprises a series of ribs in two directions. The recesses may be formed by removable or permanent filler blocks.

4.1 Components of flat slab design

4.1.1 Column Strip

Column strip means a design strip having a width of 0.25 I₁, but not greater than 0.25 I₂, on each side of the column centre-line, where I₁ is the span in the direction moments are being determined, measured centre to centre of supports and I₂ is the -span transverse to I₂, measured centre to centre of supports.

4.1.2 Middle Strip

Middle strip means a design strip bounded on each of its opposite sides by the column strip.
4.1.3 Panel

Panel means that part of a slab bounded on-each of its four sides by the centre line of Column or centre-lines of adjacent spans.

Division into column and middle strip along:

<table>
<thead>
<tr>
<th>Type</th>
<th>Main R/F IS 456-2000</th>
<th>Main R/F IS 13920-1993</th>
<th>Stirrups IS 456-2000</th>
<th>Stirrups IS 13920-1993</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>6-25Φ+2-16Φ</td>
<td>6-25Φ+2-16Φ</td>
<td>8mmDia. 2L@180mm</td>
<td>1)8mmDia. 2L@250mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2)8mmDia. 3L@80mm</td>
</tr>
</tbody>
</table>

Table 4.1 Span Calculations

<table>
<thead>
<tr>
<th>Panel</th>
<th>Longer span</th>
<th>Shorter span</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column strip</td>
<td>-956 kN-m</td>
<td>-568 kN-m</td>
</tr>
<tr>
<td>Middle strip</td>
<td>+134 kN-m</td>
<td>+104 kN-m</td>
</tr>
<tr>
<td>Column strip</td>
<td>-956 kN-m</td>
<td>-956 kN-m</td>
</tr>
<tr>
<td>Reinforcement</td>
<td>4664 mm²</td>
<td>3512 mm²</td>
</tr>
<tr>
<td>−ve steel</td>
<td>1938 mm²</td>
<td>1508 mm²</td>
</tr>
<tr>
<td>Reinforcement</td>
<td>20 mm Φ @ 130c/c</td>
<td>20 mm Φ @ 130c/c</td>
</tr>
<tr>
<td>+ve steel</td>
<td>16 mm Φ @ 100c/c</td>
<td>16 mm Φ @ 130c/c</td>
</tr>
</tbody>
</table>

4.1.4 Drop

When provided shall be rectangular in plan, and have a

Drop dimensions along:

Table 4.6 Steel Calculation

4.7 Design Of column by IS-456-2000 and IS-13920

Detailing of C3 Column for First Storey

Figure 4.2 Detailing of C3 column as per IS 13920:1993

Figure 4.3 Detailing of C1 column as per IS 13920:1993
5. Conclusions

1. Drops are important criteria in increasing the shear strength of the slab.
2. By incorporating heads in slab, we are increasing rigidity of slab.
3. The dynamic analysis results indicate that the lowest mode of vibration i.e. third mode was the torsional mode. This seems to be a typical of flat-slab building with a central core of shear walls.
4. Modeling of flat plate slab with diaphragm and without diaphragm in case of response spectrum method there is no variation in axial force, shear force and moment as moment of inertia of slab is very high it acts as rigid.
5. 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.
6. Enhance resistance to punching failure at the junction of concrete slab & column by providing drop with head.
7. Drop with head & Flat slab head is very good combination to reduce the moment with less thickness of slab.
8. In earthquake zone we shall provide only flat slab drop with head & ductile detailing for all structure.

References

[9] Ductile Detailing of Reinforced Concrete Structures to Seismic Forces IS 13920:1993