FINITE ELEMENT ANALYSIS OF FLAT SLAB WITH DROP PANEL FOR APARTMENT BUILDING USING ETABS

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Abstract- *The aim of this project is analysis of flat slab with drop panel using etabs software. The design of flat slab is carried out as per IS 456:2000. The flat slab system of construction is the one in which the slab is directly rest on the column and load from the slab is directly transferred to the columns and then to the foundation. The analysis and design are carried out by equivalent frame method with staggered column and without staggered column as mention in the IS code 456:2000. We get result that flat slab with drop is developing construction in India even in the seismic prone areas for better stability and life span of the building. Compared to the conventional concrete, flat slab has a very good storey drift and it is lies within the permissible limit. Hence the design construction will be safe. Flat slab with drops is used to avoid the beams by this we can say that it is economical way of construction. The initial cost of the flat slab is high and also results shows that the ductility of building and stiffness of the building is within the codal provision.*

Key Words: **Flat slab1, Multistorey building2, Storey drift3,Punching Shear4,Crack width5, Seismic analysis6, Earth quake7, FEA8.**

1. INTRODUCTION

Reinforced concrete slabs, also called beamless slabs, directly supported by columns. The part of the floor is defined by the centerline of the column on each of the four sides is called the panel. The slab is usually thickened near the support, column to provide sufficient shear strength and negotiate the amount of negative reinforcement in the support area. The thickened part that is the protruding part under the floor, is called the drop. The flat slab system is a beam system that uses traditional construction methods. The direct support in the column is eliminated, and the load on the slab is straightly transmitted to the column and foundation. Drops or columns are usually marked with column headings or capital letters. The lattice floor system is composed of beams equally spaced in the vertical direction and integrated with the floor slab. They are usually used for aesthetics reasons of large rooms, such as auditoriums, corridors, theaters, boutique lounges, where column-free space is usually the main requirement.

1.1 Types of flat slabs

1. Typical flat slab
2. Slab without drop and column with column head.
3. Slab with drop and column without column head.
4. Slab with drop and column with column head.

1.2 Comparison b/w Flat & Conventional Slab

1. Building structures can also be constructed using columns with negotiating beams. These kind of slabs are referred as flat slabs.
2. The conventional floor slab system consists of thin beams spaced at regular intervals in the vertical direction, which coincide with the floor slab.
3. The seismic performance of conventional slab and flat slab is analogous but conventional slab performs good in seismic prone areas.
4. No beams are present in flat slab type of system it only consists of walls, slabs.
5. In flat slab construction the slab thickness will be kept more whereas in normal construction beam depth will be increased for strength of the building.
6. Drop will be provided above the column hence costing will be high in flat slab but it's less in normal construction.
7. Floor to floor height can be reduced by providing the flat slab in construction and more number of stories can be built on site conditions.
8. Installation of pipelines and other material utilities are very simple and easy compared to normal buildings.

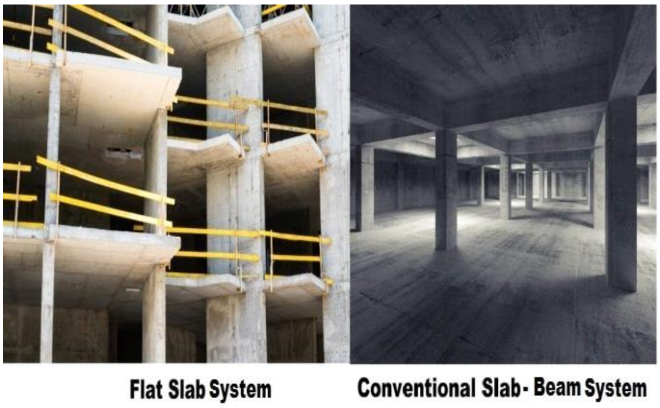

Fig 1.1: Shows the flat slab system and conventional slab-beam system

1.3 Advantages of Flat Slab

- Improve the construction speed, due to the simplified formwork, it is easy to lay reinforcement bars, and the construction is simple and economic.
- Simple ceilings give a charming and pleasant appearance; without beams, acoustic treatment is easy. Reduce the overall height of the building
- Allow additional floors to be integrated into a certain height building.

1.4 Objectives

1. To understand the basic principles of structural building configuration and its behavior in ETABS.
2. To design structural components like flat slab, normal slab, column manually as per IS 456-2000.
3. To compare the flat slab with normal slab sections manually as per IS 456-2000.
4. To determine the flexural designs and crack width for flat slab in E-tabs.

2. LITERATURE SURVEY

Sumit Sharma et.al., (2018) [1]: In construction projects, flat slabs are often used, cheiflyin public buildings. Due to several advantages of flat slab systems over traditional panel systems, flat panels are often used in construction. A slab is best realized as a slab without beams, which directly rests on the support due to the bending moment and shear stress generated near the column. The intention of this article is to introduce the advantages and disadvantages of flat slab in construction.

M. Jeelani et.al., (2018) [2]: The advent of flat panels provides features such as increased rigidity, increased load-bearing capacity, safety, and at the same time economy. In this article, seismic analysis was carried out to verify that commercial buildings with slabs are suitable for different areas without any failure. We analyze and design G-2 and G+7 commercial buildings with flat panels in the ETABS program.

Kolapuri Akshita et.al., (2018) [3]: Flat slab systems are widely used in professional buildings and residential buildings, hospitals, schools and hotels. They can be formed and constructed quickly and easily. The negotiation of beams can reduce the height of floors, thereby saving the cost of vertical envelopes, partitions, mechanical installation, pipes and a large number of other structural elements, especially for buildings and mid-to-high-rise buildings. Provides the flexibility of partition placement and allows easy switching and maintenance. SAP is evolving into a structural analysis program. SAP 2000 is the most advanced and easy-to-use version of the SAP software suite. It is the first SAP version to be fully merged with Microsoft Windows. It has a well built graphical user interface and is second to none in terms of ease of use and performance. SAP 2000 is object-based, which means that models are created using elements that represent physical reality. A beam with multiple frame members is created as a single body because it exists in the real world, and the grid required to connect to other members is processed internally by the program.

Priya M P et.al., (2018) [4]: This article introduces the experimental study of the puncture behavior of the flat slab under various supporting conditions. Today, slabs are widely used in various concrete structures due to their many advantages. For testing, six slab column samples with four, three, and two rigid support side flat plates were cast and tested. These tests are conducted to study the penetration ability and crack mode at the connection between the plate and the column. It has been observed that compared to three and two supporting sides, the slab columns connected and supported on the four sides of the plate have improved punching shear resistance.

Lalit Balhar et.al., (2019) [5]: Use STAAD.PRO V8i software for analysis. The seismic characteristics of traditional reinforced concrete frame buildings and slab buildings mean that additional measures need to be taken to guide the origination and design of these structures in earthquake areas and improve the construction efficiency of traditional reinforced concrete buildings. Flat plate under seismic load. The purpose of this research is to study the ways of multi-storey buildings with traditional RC slab buildings and slabs, and to study the behavior of such buildings under the influence of earthquake forces. The current research includes information on parameters such as displacement, lateral displacement, subsoil seismic shear and storey shear.

3. MATERIALS AND METHODOLOGY

3.1 Finite Element Method

Before we continue to discrete FE and numerical solutions, we study model problems for analysis. This step is used to determine which elements are important to the goal, so you can skip unnecessary details and which theory or math formula describes the behavior. Degrees of freedom are independent quantities that govern the spatial variation of a field. It denotes the number of independent restraints necessary to determine the geometric stability of the member as a whole, relative to system of co-ordinates. For example, a member freely movable in a plane, has 3 degrees of freedom or 3 possible movements, thereby requiring 3 Co-ordinates or restraints in the plane to fix it in a stable manner.

Fig 3.1: Degree of freedom for 2 noded beam element

3.2 Building Specifications

1. Materials

Table 3.1: Material Properties

Sl.no	Description	Value
1	Grade of concrete for columns	M30
2	Grade of concrete for drop panel	M30
3	Grade of steel	HYSD415
4	Density of concrete	25KN/m³

2. Building details

Table 3.2: Geometrical Properties of Building

Sl No	Descriptions	Values
1.	Typical storey height	3.2m
2.	Area of Plan	247.75 sq.mt
3.	No. of stories	G+8
4.	Type of building	Apartment
5.	Wall thickness	0.23m
6.	Drop panel size	1200x1200mm
7.	Drop thickness	350mm
8.	Slab thickness	150mm
9.	Size of column	230x400mm
10.	Floor load	3.125KN/m²
11.	Live load	5 KN/m²
12.	Dead load	3.125 KN/m²

3. Seismic Details

Table 3.3: Seismic details

Sl.no	Description	Value
1	Seismic Zone	**Zone II**
2	Zone factor	**0.10**
3	Response reduction, R	SMRF-5
4	Type of soil	TYPE II
5	Importance factor, I	1.5

4. Wind Load Details

Table 3.4: Wind load details

Sl no	Description	Value
1	Wind speed, Vb (m/s)	33
2	Terrain category	3
3	Structure class	A
4	Risk coefficient factor (K1)	1.05
5	Terrain & height factor (K2)	1.0
6	Topography (K3)	1.0

5. Loads Combinations

Combinations of loads considered based on earthquake Codal provisions IS 1893-2002 and wind load IS 875-1987(Part 3) are as follows

1.5(DL+LL)
1..2(DL+LL±ELx)
1..2(DL+LL±ELy)
1.5(DL±ELx)
1.5(DL±ELy)
0.9DL±1.5ELx
0.9DL±1.5Ely
1.5(DL±WLx)
1.5(DL±WLy)
1.2(DL+LL±WLx)
1.2(DL+LL±WLy)
0.9DL±1.5 WLx
0.9DL±WLy

3.3 Modelling Analysis

1. Plan

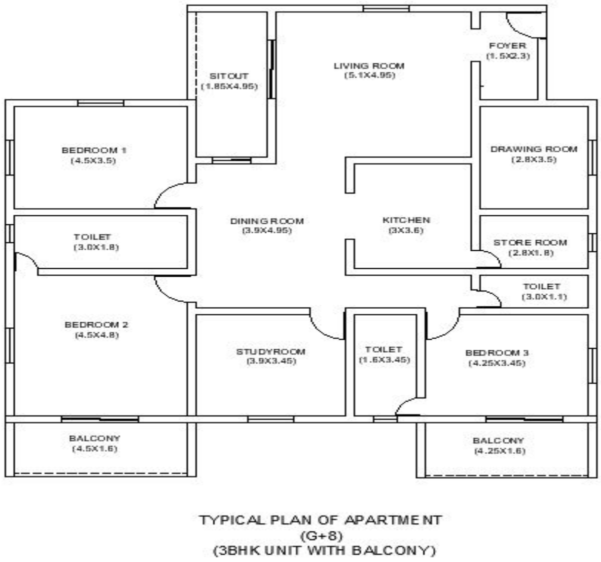

Fig 3.2: Typical Floor plan of Apartment building (G+8)

2. ETABS model

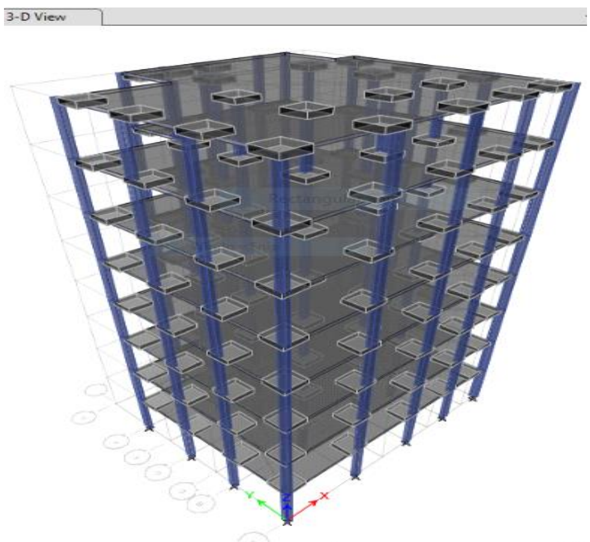

Fig 3.3: Shows the extruded 3D view of a building after assigning column, drop, slab.

4. RESULTS AND DISCUSSION

4.1 Manual Calculations

Methods of designing structure:

There are 3 methods for the design of RC structures.

1. Working stress methodology.
2. Ultimate load method.
3. Limit state method.

1. Column Design Procedure (230 mm x 400 mm)

Design Parameters:

1. Rebar percentage (Pt) = 0.8%
2. bxd = 230*400mm
3. f_{ck}=20 N/mm^2
4. f_y=415N/mm^2

Ast = (Ptxbxd)/100
= (0.8x230x400)/100
= 730mm^2

Adopt 12mm dia bars

No. of bars = 730/113.1
= 6.45

Take 8 no's Lateral ties

$[A_{sv}/(300*S_v)]=[0.4/(0.87*f_y)]$

Take 8mm dia bars

$[(2*50.2)/(300*S_v)]=[0.4/(0.87*415)]$

S_v=302mm

Take S_v=300mm

Provide 2L 8mm dia @ 300mm c/c.

2. Conventional Slab design S1 (150mm)

Design Parameters:

1. Room size = 4.5m × 3.5m
2. Thickness of wall = 0.23m
3. Density of concrete = 25 KN/m^3
4. Thickness of slab = 150 mm

Load Calculation

Self-weight = 0.15×25 = 3.75 KN/m^2
Live Load = 4 KN/ m^2
Floor Finish = 1 KN/ m^2
Total load = 8.75 KN/m^2
Factored load = 1.5 × 8.75 = 13.125 KN/ m^2

Calculation of moments

l_y/l_x = 4.5/3.5= 1.2 < 2

Hence, design the slab as 2 way slab.

Slab condition: Two Adjacent Edges Discontinuous.

We got these below α values from IS 456:2000 (Table 26.pg.num.91)

α_{x-ve} =0.0470

α_{x+ve} =0.0350

α_{y-ve} =0.0470

α_{y+ve} =0.0350

Mux-ve=13.125x0.047x3.5^2 =7.59 KN-m

Mux+ve=13.125x0.035x3.5^2 =5.6 KN-m

Muy-ve=13.125x0.047x3.5^2 =7.59 KN-m

Muy+ve=13.125x0.035x3.5^2 =5.6 KN-m

Mu_{max}= 7.59 KN-m

Check for depth

$Mu_{max} = Mu_{lim}$

$7.59\times 10^6 = 0.138 \times f_{ck} \times b \times d^2$

$d_{reqd} = 46.9 < d_{prov}$ (150 mm)

Hence safe

Calculation of reinforcement:

Main reinforcement:

M_u=7.59 KN-m

b=1000 mm

d=150 mm

$k=Mu/bd^2 = 7.59x10^6/(1000x150^2) = 0.33$

From SP 16, Pt=0.82%

A_{st} = 102.75 mm^2

Ast_{min}= (0.12/100) x1000x150=180mm^2

Take 8mm dia bar

Spacing = (50.25/180) x1000 =279mm

Provide 8mm dia @ 300mm c/c

Distribution reinforcement:

$A_{st} = (0.12 \times b \times d)/100 = (0.12 \times 1000 \times 150)/100$

A_{st} =180 mm^2

Provide 8mm dia @ 300mm c/c.

4.2 Flat Slab Design with Drop Panel

1. **Division into column and middle strip along:**
   1. **Longer span**

      L_1 = 4.5 m, L_2 =3.5 m

      a. Column strip = 0.25 L_2 = 0.25x3.5 = 0.875 m

not > than 0.25 L_1 = 0.250 x 4.50 = 1.125 m

      b. Middle strip = 3.5- (0.875+0.875) = 3.5-1.75 = 1.75 m
   2. **Shorter span**

      L_1 =3.5 m , L_2 =4.5 m

   a. Column strip = 0.25 xL_2 = 0.25 x 4.5 = 1.125 m

      i. But not > than 0.25 L_1 = 0.25 x 3.5 = 0.875 m

   b. Middle strip = 4.5-(0.875+0.875) = 2.9m

2. **Drop dimensions along:**
   1. **Longer span**

      L_1 = 4.5 m, L_2 =3.5 m

      Not < than $L_1/3$ = 4.5/3 = 1.5 m
   2. **Shorter span**

      L_1 =3.5 m, L_2 =4.5 m

      Not< than $L_1/3$ = 3.5/3 = 1.16 m

      .'. provide a drop of size 1.5 x 1.5 m i.e., in column strip width.

3. **Column head dimension along:**
   1. **Longer span**

      L_1 = 4.5 m, L_2 =3.5 m

      Not > than $L_1/4$ = 4.5/4 = 1.125 m
   2. **Shorter span**

      L_1 =3.5 m, L_2 =4.5 m

      Not > than $L_1/4$ = 3.5/4 = 0.875 m

      Adopting the diameter of column head = 1 m =1000 mm

4. **Depth of flat slab:**

It will have a minimum plate thickness of 125 mm.

L/D= 26 , D = L/ 26

Depth along:

1. **Longer span**

   L_1 = 4.5 m, L_2 =3.5 m

   a. D=L/26= 4500/26 = 173.07 say 180 mm
2. **Shorter span**

   L_1 =3.5 meter, L_2 =4.5 meter

   a. D=L/26= 3500/26 = 134.61 say 140 mm

      Take effective depth of 25mm

   b. Overall Depth D = 180 +25 =205 mm

      125 mm (min slab thickness as per IS: 456)

   Therefore, safe to provide depth of 200 mm.

5. **Calculation of load acting on the slab:**
   a. Dead load acting on the slab (Wd_1) = 0.2 x 25 = 5 KN/m^2
   b. Floor finishes load on slab (Wd_2) = 1.45 KN /m^2
   c. Live Load on Slab (W_l) = 5 + 1.45 = 6.45 KN /m^2
   d. Total Dead load (W_d) = $Wd_1 + Wd_2$ = 5 + 1.45 = 6.45 KN /m^2

Thus, the design LL shall not exceed 3 times the design DL.

Check: W_l/ W_d =6.45/6.45 = 1 < 3 ok

Total design load (W) = $W_d + W_l$ = 6.45 + 6.45 = 12.95 KN /m^2

6. **Total Design Moment for a span:**
   1. $M_o = Wl_n/8$ (From IS 456:2000,Pg.no.55)
   2. A= π/4 x d^2 = 0.785 (d=1m, diameter of column head)
   3. Clear Span along longer span (l_n) = 4.5 - 1/2(0.785) – 1/2(0.785) = 3.72 m
   4. Should not be less than 0.65 x l_1 = 0.65 x 4.5 = 2.928m

      3.72 > 2.92m , hence ok
   5. Clear Span along shorter span (l_n) = 3.5 – 1/2(0.785)-1/2(0.785) = 2.72 m
   6. Should not be less than 0.65 x l_1 = 0.65 x 3.5 = 2.27m

      2.72 > 2.27 m , hence ok

7. Total Design Load along:

1. **Longer Span**

L_n=3.72 m, L_2 = 3.5 m

W = W x L_n x L_2 = 12.95 x 3.72 x 3.5 = 168.60 KN

2. **Shorter Span**

L_n= 2.72 m, L_2 = 4.5 m

W = W x L_n x L_2 = 12.95 x 2.72 x 4.5 = 157.34 KN

8. The absolute sum of -ve and +ve moment in a panel along:

1. **Longer Span**

L_n=3.72 m, L_2 = 3.5 m

M_o = Wl_n/8 = 168.60 x 3.72 / 8 = 78.399 KN-m

2. **Shorter Span**

L_n= 2.72 m, L_2 = 4.5 m

M_o = Wl_n/8 = 157.34 x 2.72 / 8 = 53.49 KN-m

9. Stiffness calculation

1. Height of floor = 3.2 m
2. Clear height of the column = height of floor - depth of drop- thickness of slab -thickness of column head
3. Clear height of the column of head = 3200 –140 – 200 – 300 = 2560 mm
4. Effective height of column = 0.8 x 2560 = 2048 mm

10. Distribution of bending moment across the panel width:

1. **Longer span**

a. **Column strip**

M_o = 78.39 KN-m

-ve B.M at exterior support = $\frac{-0.65\ x\ Mo}{1+(\frac{1}{\alpha c})}$ x 1 = -29.64 KN-m

+ve span BM =$0.63 - \frac{0.28}{1+(\frac{1}{\alpha c})}$ x M_o x 0.60 = 21.974 KN-m

-ve span BM at interior support = - [0.75 - $\frac{0.10}{1+(\frac{1}{\alpha c})}$] x M_o x 0.75 = - 40.67 KN-m

b. **Middle Strip**

+ve Mid span BM = $0.63 - \frac{0.28}{1+(\frac{1}{\alpha c})}$x M_o x 0.40 = 14.69 KN-m

-ve BM at interior support

= - [0.75 -$\frac{0.10}{1+(\frac{1}{\alpha c})}$] x M_o x 0.75 = -13.55 KN-m

2. **Short span**

a. **Column strip**

M_o = 53.49 KN-m

negative moment at exterior support

= $\frac{-0.65\ x\ Mo}{1+(\frac{1}{\alpha c})}$ x 1= - 25.754 KN-m

+ve moment = $0.63 - \frac{0.28}{1+(\frac{1}{\alpha c})}$ x M_o x 0.60 = 13.57 KN-m

-ve Moment at exterior support

= - [0.75 -$\frac{0.10}{1+(\frac{1}{\alpha c})}$] x M_o x 0.75 = - 27.119 KN-m

b. **Middle Strip**

+ve Mid span BM = $0.63 - \frac{0.28}{1+(\frac{1}{\alpha c})}$ x M_o x 0.40 = 29.05 KN-m

-ve BM at interior support = - [0.75-$\frac{0.10}{1+(\frac{1}{\alpha c})}$] x M_o x 0.75 = 27.11 KN-m

11. Shear in Flat Slab:

The critical section for shear is at a distance d/2 from the end of the column/capital/ drop panel, longitudinal to the plane of the slab, where d is the effective depth of the section.

12. Check for shear stress developed in slab

The critical section for shear for the slab will be at a distance d/2 from the face of drop

a. Perimeter of critical section = 4 x 2340 = 9340 mm
b. Total factored shear force
V_0 = 1.5 x 15.45 x (L_1 x L_2 – (2.34 x 2.34)) =1.5 x 15.45 x (4.5 x 3.5 – (2.31 x 2.34) = 238.239 KN
c. Nominal Shear Stress τ_v
= V_u/bd = 238.239/(9340 x 140) = 0.4 N/mm²
d. Shear Strength of concrete τ_c = 0.25 $\sqrt{f_{ck}}$ = 0.25$\sqrt{30}$ = 1.369 N/mm²
e. Permissible shear stress K_s = 0.5 + β_c = 0.5 + 0.848 = 1.348 > 1

$\tau_v < \tau_c$, Hence Safe in Shear

13. Check for shear in drop

a. $b_0 = \pi$ x (D + d_o) = 4.89 m
b. V = 1.5 x 15.45 (3.5 x 4.5 – (π/4)(1.3+0.26)²) = 320.97 KN
c. Nominal Shear Stress τ_v = V_u/bd
d. = 320.97/(4890/260) = 0.683 N/mm²
e. Shear Strength of concrete τ_c = 0.25 $\sqrt{f_{ck}}$ = 0.25$\sqrt{30}$ = 1.369 N/mm²

$\tau_v < \tau_c$, Hence Safe in Shear

14. Reinforcement details

Longer span:

-ve exterior reinforcement:

M_u=0.87$f_y A_{st}$[d-0.42x_u]

$=1.5 \times 40.67 \times 10^6 = 0.87 \times 415 \times A_{st}$ [150-(0.42 x 0.48 x 150)]

$A_{st} = 1410.86\ mm^2$

Use 12mm ϕ bars = 1410.86/113 = 12.48 Numbers

C/C spacing is = 1.4 x 1000 / 12 = 116.66 mm c/c

+ve steel: -

$M_u=0.87f_yA_{st}[d-0.42x_u]$

$1..5 \times 27 \times 10^6 = 43239.3 \times A_{st}$

$A_{st} = 93.66\ mm^2$

Use 12mm ϕ bars = 93.66/113 = 32 Numbers

C/C spacing is = 3.8 x 1000 / 32 = 118.75 mm c/c

15. Reinforcement along shorter span:

a. **Column strip:**

$M_u=0.87f_yA_{st}[d-0.42x_u]$

$1.5 \times 40.67 \times 10^6 = 0.87 \times 415 \times A_{st}$ [140-(0.42 x 0.48 x 140)]

$A_{st} = 1547.86\ mm^2$

Use 12mm ϕ bars = 1547.86/ $\pi(12)^2$ /4 = 25 No's

C/C spacing is = 1.4x 1000 / 25 = 56 mm c/c

b. **Middle Strip:**

$M_u=0.87f_yA_{st}[d-0.42x_u]$

$1.5 \times 27 \times 10^6 = 0.87 \times 415 \times A_{st}$ [280-(0.42 x 0.48 x 140)]

$A_{st} = 1082\ mm^2$

Use 12mm ϕ bars = 1082/ $\pi(12)^2$ /4 = 6 No's

C/C spacing is = 2.8 x 1000 / 10 = 280 mm c/c

4.2 Static Analysis of Seismic Parameters by Manual Calculation

Seismic Weights Calculations:

1.Self-Weight of Floor

Dead load due to self-weight of Slab

= (15.4 x 16.1 x 0.15) x25 = 929.775 KN

Assuming Floor finish factor =0.8

Floor Self weight +Floor finish

= 929.775 + (15.4x16.1x0.8) = 929.775 + 198.35

Total Floor weight = 1128.12 KN

water proofing = 1.5 KN /m²

Total Roof Slab = 15.4x16.1x 1.5 = **371.91 KN**

Total Weight of Floor

= 929.775 + 198.35 + 371.91 = 1500.03 KN

2. Self-Weight of Wall

Self-weight of wall = Thickness of wall x Density of Masonry = 0.23 x 20 = **4.6 KN /m**

Longitudinal Wall = 4.5 x 4.1 x 15 = 282.9 KN /m

Transverse Wall = 4.6 x 3.27 x 21 = 315.882 KN /m

3. Self-Weight of Column

Self-wg of Column = 0.23 x 0.4 x 25x 24 = 55.2 KN /m

4.Live Load

The live load class is 5 KN/m² only 50% of the live load is consolidated at the floors.

Live Load on floor = 0.5 x 5 = 2.5 KN /m²

At roof, no live load is to be lumped.

Hence, the Live Load on the floors

= 15.4 x 16.1 x 2.5 = 619.85 KN

5.Total Weight of Roof for Storey

Roof Slabs + Columns + Walls

= 1500.03 + 55.2 + 315.882 (2.8/2) + 282.9(2.8/2)

= 2846.16 KN

Floor Slab + Columns+ Walls

= 929.775 + 55.2 + 282.9(3.2-0.4) + 315.882 (3.2-0.4)

= 3566.844 KN

Total Seismic weight of stories = 3566.844 x 5 + 2846.16

= 31380.91 KN

6. Time Period

T = 0.09h / √d= 0.09(25.6)/ √15.4

T= 0.58 sec

The building is located on Type II (medium soil).

Sa/g=0.87

$A_h= \frac{Z}{2}\frac{I}{R}\frac{Sa}{g} = \frac{0.1 \times 1.5 \times 0.87}{2 \times 5}$ 0.01305 (Clause 6.4.2 of IS: 1893 Part 1)

Design base shear $V_B = A_h x w$ = 0.01305 x 31380.91 = 409.52 KN (Clause 7.5.3 of IS: 1893 Part 1)

Thus, for this building the design seismic force in X and Y direction is similar as that in the Direction.

7. Lateral Load Distribution with Height by the Static Method

Q=Design Lateral Force at floor

W= Seismic Weight (KN)

h= Height of floor I measured from base (m)

N= No of levels at which masses are located

V_B=Design Base Shear (KN)

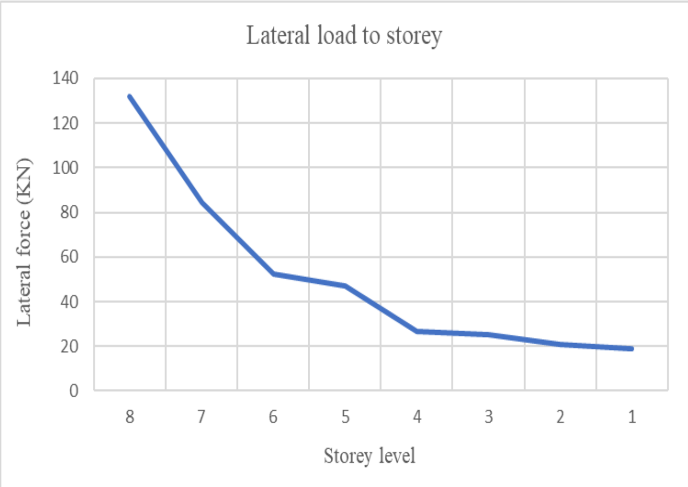

Fig 4.1: Lateral force distribution up to 8 storey

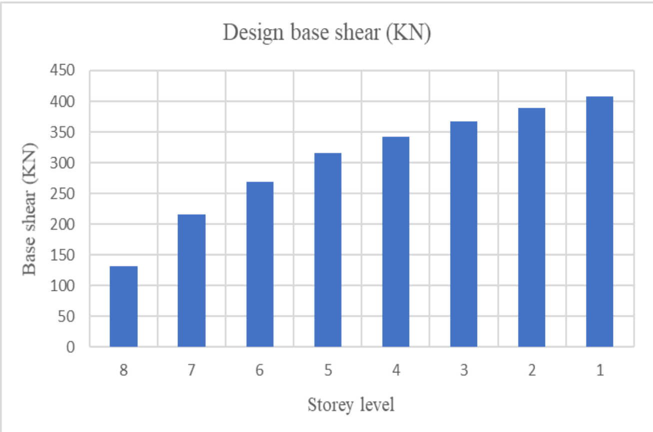

Figure 4.2: Storey Shear up to 8 storey

4.3 Static Analysis of Wind Load by Manual Calculation IS-875 (Part 3-1987)

Step 1 : Design Wind Speed (Vz)

V_b=Basic wind speed (m/s) Appendix A IS 875-1987 (Part – 3) V_b = 33 m/s

Step 2: Design Wind Pressure (Pz)

Table 4.1: Design Wind Pressure (Pz)

Height	Vz (m/sec)	Pz=0.6 Vz²
10	31.53	596.484
15	33.61	677.77
20	34.99	734.58
30	36.729	809.411

Step 3: Design Wind Load (F) $F = C_f \times A_e \times P_z$

Where, C_f = Force Coefficient of building

A_e = Effective frontal area

P_z= Design Wind load

a = 16.1 m

b = 15.4 m

h=25.6 m

a/b = 16.1/15.4 = 1.04

h/b = 25.6/15.4 = 1.66

C_f = 1

A_e= 4.5 x 1 = 4.5 m²

Step 4 : Force at each storey level

Table 4.2: Force at each storey level

Storey Number	Loading Level	Height of each storey	Design force (KN/m)	Force at each storey evel (KN)
8	22.4-25.6	25.6	3.6	92.16
7	19.2-22.4	22.4	3.28	73.47
6	16-19.2	19.2	3.28	62.97
5	12.8-16	16	3.015	48.24
4	9.6-12.8	12.8	2.655	33.984
3	6.4-9.6	9.6	2.655	25.488
2	3.2-6.4	6.4	2.655	16.992
1	0-3.2	3.2	2.655	8.496

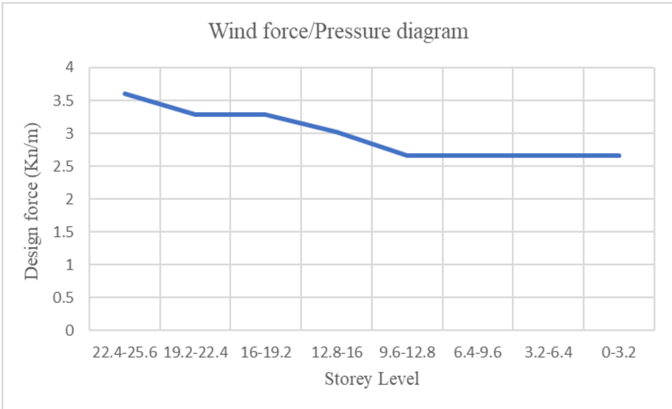

Fig 4.3: Wind force/pressure diagram for 0-25m

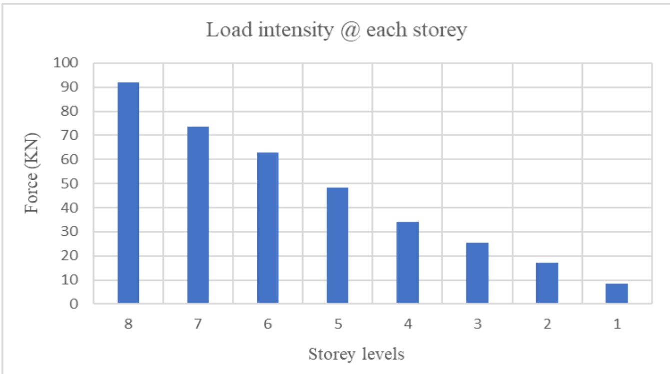

Fig 4.4: Load intensity at each storey level (KN)

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4.4 Comparitive Results from Manual Calculation and ETABS

1. **Comparison of manual calculations of Normal slab to Flat slab**

From manual calculations of flat slab and conventional slab design, we obtain design load of flat slab is 12.95 KN/ m^2 and conventional slab is 13.125 KN/ m^2, hence we can conclude that the Compared with convention slab, flat slab has a lower design load, resulting in a lower self-weight, which also has a positive effect on the column and foundation.

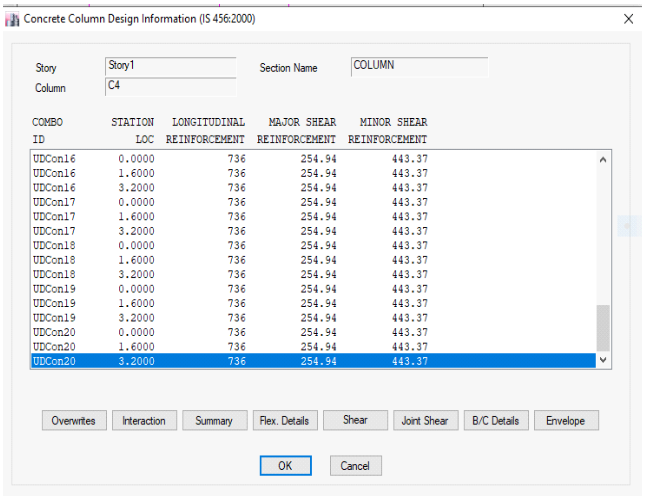
In normal slab thin beams are considered at regular intervals but in flat slab beam are avoided indirectly the cost of whole building's will be decreases at some point, but when compare to earthquake prone areas normal slab gives good results when compare to flat slab

The area of floor-to-floor height will increase in flat slab which gives aesthetic appearance when compare to normal slab.

The reinforcement details obtained from manual calculations of both parameters can be simply concluded that the cost of flat slab structure construction can be reduced up to overall 16% compared to conventional slab structure.

Thus, Flat slab can be used as a best solution for high rise building constructions like malls, storage structures, apartments etc., A good flexibility design layout can be obtained in construction of flat slab

2. Comparison of manual calculations of Column with E-tabs (Area of reinforcement (mm^2)


Concrete Column Design Information (IS 456:2000)

Story: Story1 | Section Name: COLUMN | Column: C4

COMBO ID	STATION LOC	LONGITUDINAL REINFORCEMENT	MAJOR SHEAR REINFORCEMENT	MINOR SHEAR REINFORCEMENT
UDCon16	0.0000	736	254.94	443.37
UDCon16	1.6000	736	254.94	443.37
UDCon16	3.2000	736	254.94	443.37
UDCon17	0.0000	736	254.94	443.37
UDCon17	1.6000	736	254.94	443.37
UDCon17	3.2000	736	254.94	443.37
UDCon18	0.0000	736	254.94	443.37
UDCon18	1.6000	736	254.94	443.37
UDCon18	3.2000	736	254.94	443.37
UDCon19	0.0000	736	254.94	443.37
UDCon19	1.6000	736	254.94	443.37
UDCon19	3.2000	736	254.94	443.37
UDCon20	0.0000	736	254.94	443.37
UDCon20	1.6000	736	254.94	443.37
UDCon20	3.2000	736	254.94	443.37

Overwrites | Interaction | Summary | Flex. Details | Shear | Joint Shear | B/C Details | Envelope
OK | Cancel

Fig 4.5: Concrete Column Design information of column

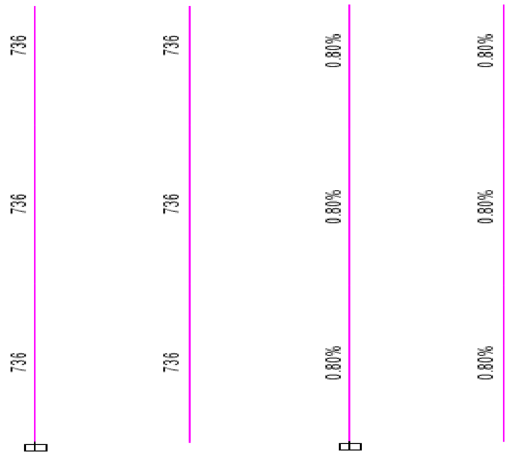


Fig 4.6: Elevation view of column having longitudinal reinforcement (mm^2) and P_t (%) value

From manual calculations of Column, we have obtained A_{st} of 730mm^2 and rebar percentage of 0.8%. Similarly, from Etabs analysis results we have obtained A_{st} of 736mm^2 and rebar percentage of 0.8%.

From the obtained results we can conclude that manual and software validation of column results are very approximate and thus it's a good indication of the work done and thus it showing a good steel reinforcement parameter which can be used in site for construction.

This building is apartment section of storey 8 with flat slab with drop panel so the important section is column and from both manual and software validation the A_{st} value is very accurate and indirectly give good strength in life span of building.

4.4 Comparison of manual calculations of Drop with E-tabs

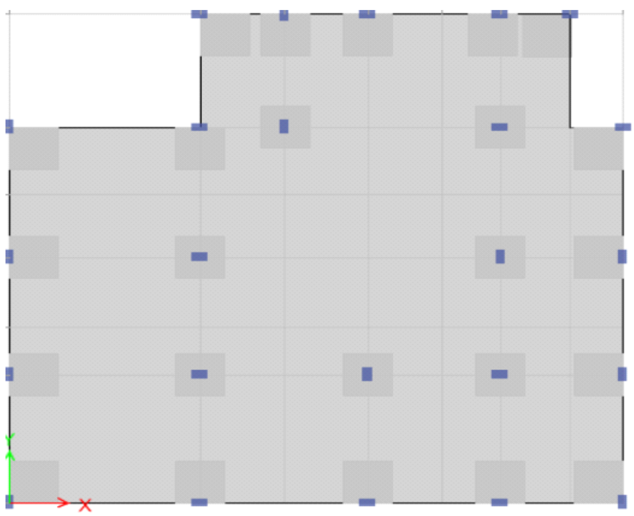


Fig 4.7: Top view of Drop Panel in Etabs

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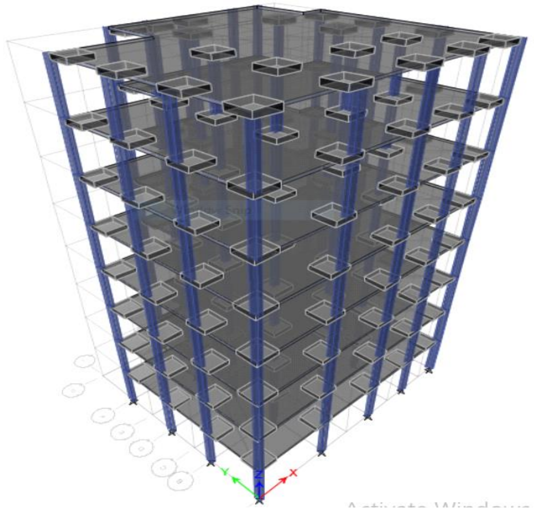

Fig 4.8: 3 D view of Drop Panel

From Manual calculation we can provide 1.5x1.5m for considering the longer and shorter side span by using different type of strips in middle and center for flexural strength of flat slab.

In Etabs validation the drop size is kept 1.2x1.2m that is nearly 4 feet as the basic requirement mentioned in Codal provision of Indian.

Since its apartment building of storey 8 the drop size is totally important parameter for handling the load distributing from slab to column and column to footing and thus the shear strength of slab will be increased and also increases the contact surface area between the column and slab thus the better distribution of load will take place between the elements.

4.5 Comparison of Manual Calculations of Seismic in Etabs

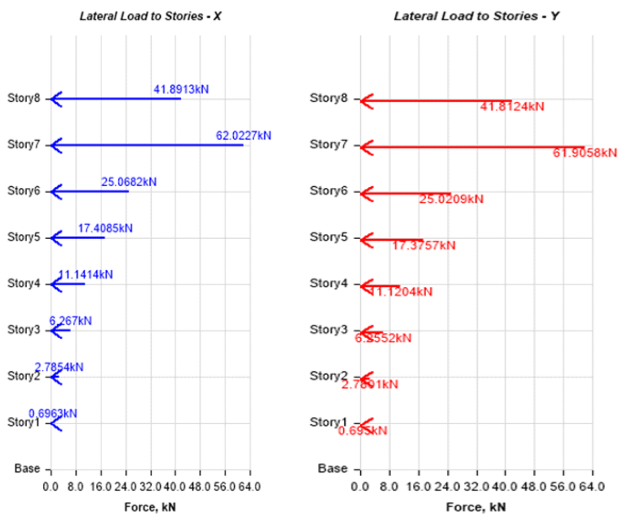

Fig 4.9: Lateral load results for seismic in E-tabs

From the above graph, we can conclude that from Etabs results the seismic parameter obtained from the flat slab building is very less and from figure no manual calculation we can conclude that for highest storey the value of lateral load is obtained as 131.36KN and from Etabs results we got 62.58KN the difference is a lot as in Etabs validation we have considered the dead, live and floor load of column and wall ,but in manual calculation we have included the roof level also so that value is getting varied.

Damping ratios is kept to 1% in manual calculation part because the storey is up to 8 floor and the zone and soil condition is within the applicable limit and moderate zone.

The seismic weight from manual calculation is 31380.91KN and from Etabs results we got the value of seismic weight is 12757.0414 KN. From this we can conclude that the variation is high and its due to mass source entered in Etabs for dead and live load condition of 50% as the live load is exceeding above 3KN/m^2

4.6 Comparison of manual calculations of wind with E-tabs

Table 4.3: Results of Force of each storey from wind analysis

Storey	Elevation (m)	Force, KN
Storey8	25.6	90.6608
Storey7	22.4	80.7048
Storey6	19.2	75.1272
Storey5	16	44.245
Storey4	12.8	35.8434
Storey3	9.6	28.659
Storey2	6.4	17.6855
Storey1	3.2	7.6855

Table 6.8: Force at each storey level calculated manually

Storey Number	Loading Level	Height of each storey	Design force (KN/m)	Force at each storey level (KN)
8	22.4-25.6	25.6	3.6	92.16
7	19.2-22.4	22.4	3.28	73.47
6	16-19.2	19.2	3.28	62.97
5	12.8-16	16	3.015	48.24
4	9.6-12.8	12.8	2.655	33.984
3	6.4-9.6	9.6	2.655	25.488

2	3.2-6.4	6.4	2.655	16.992
1	0-3.2	3.2	2.655	8.496

From above two tables we can observed the force load acting for wind lad condition in a flat slab apartment building of storey 8. From both manual and software validation force is obtained at the top most level at storey 8 and value observed is 92.16KN and 90.66KN respectively.

From above values we can conclude that the values are within the permissible limit and further its hold good in stability of the life span of the structure. In Etabs analysis the wind coefficient is considered by applying the building to claddings by applying wind pressure coefficients and also by applied diaphragms and meshing of floor slab parameters we have obtained these values. Thus, the variation is observed much in earthquake when compared to wind parameters.

4.7 Explanation of graphical results obtained from E-tabs

1. **Displacement in X and Y Direction**

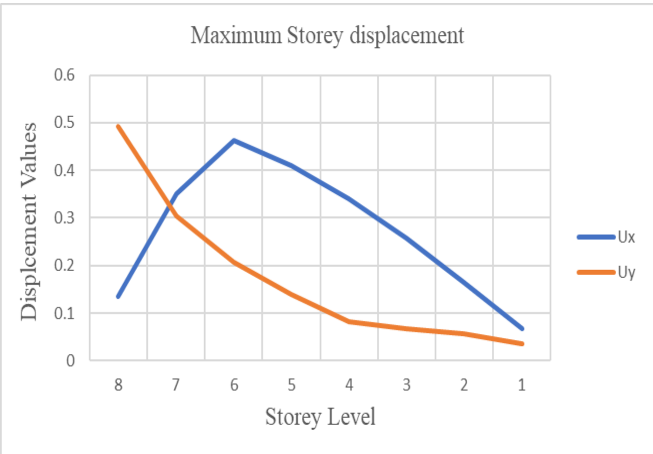

Fig 4.10: Graph representing the maximum storey displacement in X and Y direction

2. **Storey Drift in X and Y Direction**

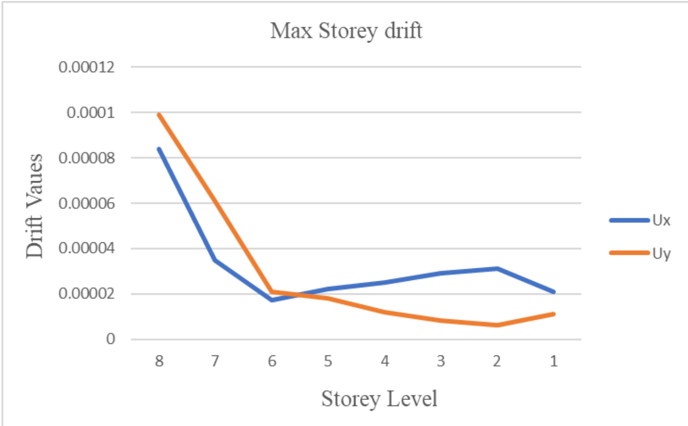

Fig 4.11: Graph representing the maximum storey drift in X and Y direction

3. **Storey Shear in x and Y Direction**

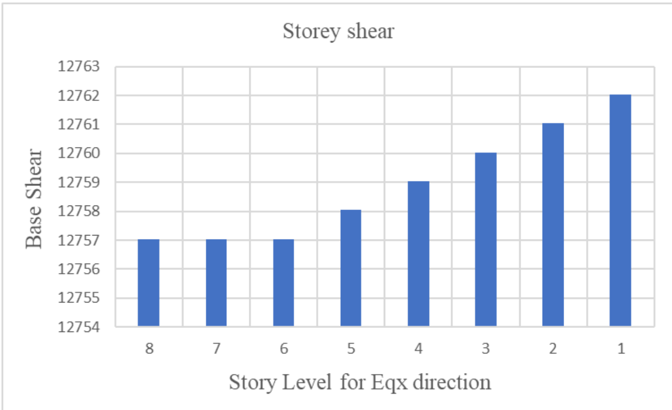

Fig 4.12.: Graph representing the maximum storey shear in Eqx direction

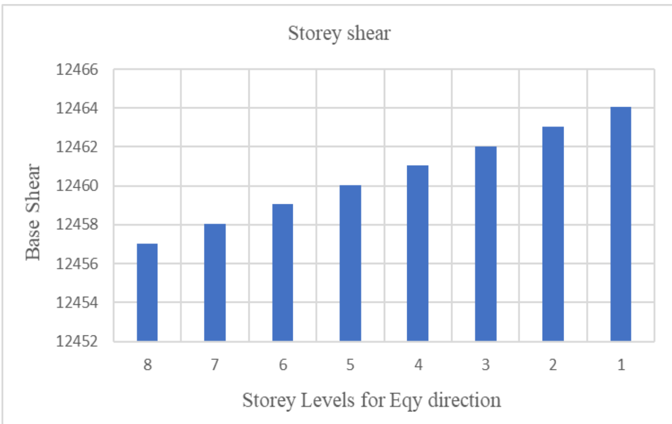

Fig 4.13: Graph representing the maximum storey shear in Eq_y direction

4. Time Period

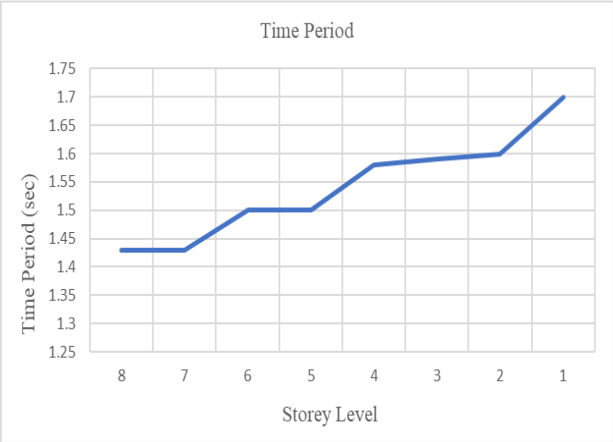

Fig 4.14: Graph representing the Time period (sec)

5. CONCLUSIONS

1. The four side supported slab can increase the stiffness of the slabs and enhance concrete ductility and integrity of domain of slab-column connections.
2. Flat Slab with drop construction is developing construction in India and can be implemented for Apartment buildings even in the seismic prone areas for better stability and life span of the building.
3. Compare to conventional concrete, flat slab has a very good storey drifts and its lies within the permissible limit and hence the design and construction will be safe.
4. Maximum displacement is seen at higher stories and to improvise the strength and stability of the building we can increase the supporting drop panel thickness or the overall slab thickness can be increased.
5. The equivalent static method analyzed can get more accurate results in Etabs when compare to manual calculations as it is a big procedure to carry out.
6. Flat Slab with drops is used avoiding the beams in this apartment building system by this we can conclude that its economical way of construction and only the initial cost will be high.
7. The results obtained above shows that the ductility of building and stiffness of building is withing the codal provision by comparing with manual to software output.
8. From the above graphical observation displacement increases with the increases in the height of the building.
9. Flat slab for this apartment building can provide a good aesthetic view.
10. For seismic parameters, when we consider flat slab, we can get reduced weight of the structures.

6. FUTURE SCOPE

1. The obtained results can be compared with dynamic analysis method.
2. The Apartment building can be constructed with X bracing type at the four corners of the building to avoid the displacement factor.
3. With the different type of Bracings, the model can be further analyzed.
4. The Variations of different seismic zones can be compared with this type of buildings.
5. Flat slab with drop panels can be further continued and can be analyzed with waffle slab structure of buildings, which gives a good aesthetic appearance of the building.
6. The construction cost of normal conventional slab and flat slab with drop panels can be manually compared.

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