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# An Approach to Lessen the Stresses in Flat Slab for Earthquake Zone IV

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***Abstract—*** *It has been examine from various findings that the stresses generated in the flat slab analysis, its intensity should lessen in order to provide stability to the structure. For this, four cases have been taken viz., simple flat slab providing shear wall at lift area, simple flat slab providing shear wall at lift area and at maximum stress location, flat slab with drop providing shear wall at lift area and flat slab with drop providing shear wall at lift area and at maximum stress location on G+11 multistoried residential building located at seismic Zone 4. Using response spectrum method with the help of analysis and design tool STAAD Pro V8i, to evaluate analysis parameters such as nodal displacement, shear forces in column, compressive and tensile stresses, storey drift, von mis stress along with principle stress values. The prime case is obtained in this work is Building Case B2 in terms of reducing the stress.*

***Keywords—*** **Drop Panel, Equivalent Frame Method, Flat Slab, Response Spectrum Analysis, Shear Wall, Storey Drift.**

## I. INTRODUCTION

The demand of residential houses increased drastically day by day in constructional sector. The multistoried building should be economical and should have less building components for archi-structural point of view. For that flat slab construction would be preferred. The Flat Slab is a slab which does not have beam component and it directly transfers its load to the soil through vertical columns. Slabs are generally of two types which are R.C.C slab and Flat slab. If beam is present with slab then it is called R.C.C slab and if beam is not present then it called as flat slab. To need more headroom, flat slab is used in multistoried building to decrease the overall cost of building construction. Also, the construction process of flat slab is almost unsophisticated as compare to R.C.C slab. In flat slab the loading patterns is almost same as R.C.C slab but distribution of load is different in both slab. Generally Flat slab is distinguished on the basis of drop panel and column capital. The construction of flat slab is generally used with drop panel or column head and vice versa depends upon the loading condition. If loading is less, then simple flat slab is used, otherwise rest of three types of flat slab will be taken into account. If loading is much higher at the junction of column and slab, a shear phenomenon is occurred is called punching shear that will develop near the support due to occurrence of higher end moment.

The flat slab is mainly of four types:

1. Simple flat slab
2. Flat slab attached with drop
3. Flat slab attached with column capital
4. Flat slab attached with drop and column capital

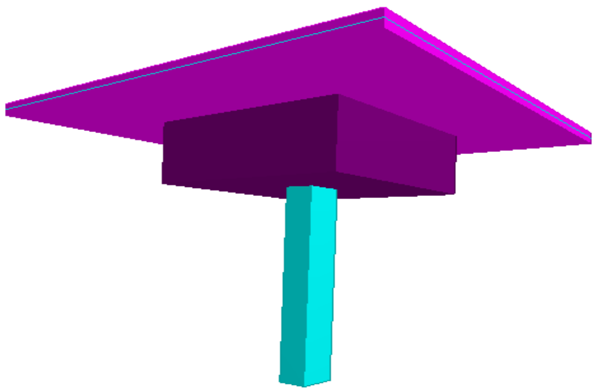

*Fig. 1: Flat Slab*

**Drop -** The Drop panel is supportive structural member of a flat slab which has provided with some thickness to the slab. It is attached at the junction of slab and column, it is always provided on bottom surface of the slab. The main purpose of providing drop in flat slab is to overcome the magnitude of moment near the support. The shape of drop should be in proper geometry i.e. rectangular or square according to the IS Code provisions.

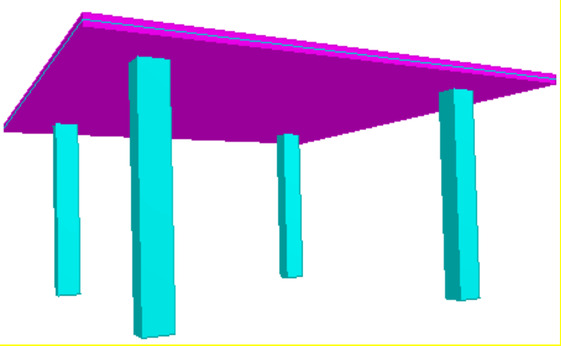

*Fig. 2: Flat Slab with drop*

**Column head -** Column head is the most important structural member of the flat slab, it reduces the punching shear effect on the critical section. It is monolithically constructed with column; also the diameter of the column capital is greater on the upper side of column. Various shape of column capital may be used in construction for architectural point of view.

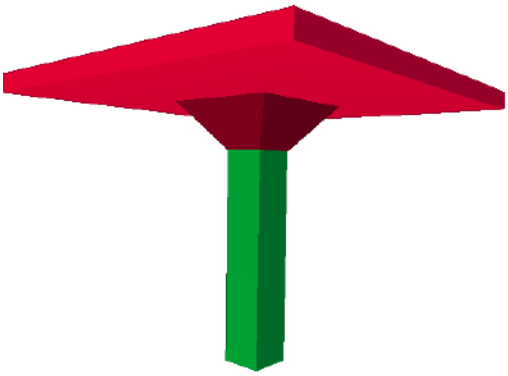

*Fig. 3: Flat Slab with column capital*

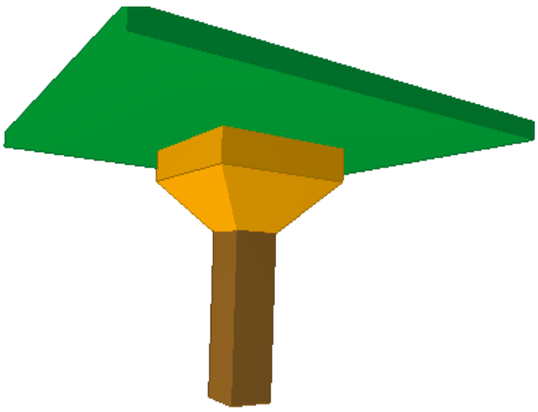

*Fig. 4: Flat Slab with column capital and drop*

## II. OBJECTIVE

In this paper the main purpose is to find out the optimum Building Case of flat slab against lateral loading condition such as seismic loading. The structure is analyzed with response spectrum for seismic loading in STAAD Pro software. After analyzing the different building plan and comparing all the result parameters which are as follows:

1. To find maximum nodal displacement in X and Z direction.
2. To evaluate the maximum value of axial force in column.
3. To find out maximum shear force in column in Sy and Sz direction.
4. To compare maximum compressive stress in column.
5. To evaluate maximum tensile stress in column.
6. To find maximum base shear in X and Z direction.
7. To compare storey drift in X and Z direction.

## III. STRUCTURAL CONFIGURATION AND METHODOLOGY

In this research work the configuration used are as follows:

*Table 1: Structural Parameters*

| Structural Parameters | Value |
|---|---|
| Plan area | 25 m x 35 m |
| Building configuration | G+11 |
| Over all height of building | 45.72 m |
| Foundation depth | 3 m |
| Height of each storey | 3.81 m |
| Grade of concrete | M 30 |
| Grade of steel | Fe-415 |
| Diameter of bar | 10 mm |
| Clear cover | 20 mm |
| Unit weight of brick | 19 $KN/m^2$ |
| Thickness of external wall | 0.203m |
| Thickness of internal wall | 0.102 m |
| Plaster thickness | 0.024 m |
| Unit weight of plaster | 20 $KN/m^2$ |
| Height of parapet | 0.75 m |
| Unit weight of mortar | 0.21 $KN/m^2$ |
| Unit weight of clay tile | 0.1 $KN/m^2$ |
| Size of Column | (500x550) mm |
| Live load for roof | 1.5 KN |
| Live load for floor | 2.5 KN |

## IV. DESIGN OF FLAT SLAB

*Table 2: Data considered*

| Given Parameters | Values |
|---|---|
| Panel size | (4x8) m |
| Drop depth | 50 mm |
| Drop size | (1x2 ) m |
| Column size | (5x5.5) m |
| Column height | 3.81m |
| Grade of concrete | M 30 |
| Grade of steel | Fe-415 |

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**STEP 1- THICKNESS OF FLAT SLAB**

Modification Factor (M.F) = 33.8

Overall Depth (D) = Span / Ratio = 8000 /33.8 =236 mm, D with drop = 343 mm

Effective Depth (d) = D - (Dia. of Bar / 2) - Clear Cover = 343 - (10 / 2) - 20

In Longer Direction ($d_l$) = 318 mm or .318 m

In Shorter direction ($d_s$) = $D_l$ – Dia. of Bar = 318 – 10 = 308 mm or .308 m

**STEP 2- LOAD CALCULATION**

**Dead Load**

**Self load of slab** = D x unit weight of concrete = .343 x 25 = 8.6 KN/$m^2$

**Plate area load** = (thickness x height x unit weight of brick) / plate area

EWL = [(.203x19+.024x20) x 3.81] / (8x4) = .51 KN/$m^2$

**for 10mm mortar both side of roof and floor** = .42 KN/$m^2$

**Clay floor tiles load** =12mm thick = .1 KN/$m^2$

**Total Dead Load = for floor level dead load =** 8.6+.51+.42+.1 = 9.62 KN/$m^2$

**Live load**

For floor = 2.5 KN/$m^2$

**Total Load**=for floor level = 9.62+2.5 = 12.12 KN/$m^2$

**Total Factored Load**=for floor level = 1.5x12.12= 18.19 KN/$m^2$

**STEP 3- CALCULATION OF STIFFNESS AND ALPHA C (AC)**

**Along Longer Direction**

**For Slab**

Ks = (4 x E x I) / LL = (4 x E x 1353117199) / 8000 = 6766058 x E

$\sum$ks = 2 x 6766058 =13532117

**For Column**

Kc = (4 x E x I) / CH = (4 x E x 2657812500) / 3810 = 2790354 x E

$\sum$kc = 2 x 2790354 = 5580709

Ac = $\sum$kc / $\sum$k = (5580709E /13532117 x E) = 0.41

**Along Shorter Direction**

**For Slab**

Ks = (4 x E x I) / LL = (4 x E x 27064234398) / 4000 = 27064234 x E

$\sum$ks = 2 x 27064234 x E =54128469

**For Column**

Kc = (4 x E x I) / CH = (4 x E x 1607812500) / 3810 = 1687992 x E

$\sum$kc = 2 x 1687992 = 3375984

Ac = $\sum$kc / $\sum$ks = 3375984 / 54128469= .06

**STEP 4- CHECK FOR CORRECTION DUE TO PATTERN LOADING**

If Ratio Of Live Load And Dead Load Is Greater Then .5, Then Pattern Loading Required. Live Load /Dead Load < = .5

At Floor Level = live load / dead load = 2.5 / 9.62 = .25 (not required)

**STEP 5- TOTAL MOMENT CALCULATION**

**In Longer Direction**

Ln = 7.55 m, $L_2$ = 4m, $Ln^2$ = 57.0025 m

Mo = (W x Ln x $L_2$) / 8 or (w x $L_2$ x $Ln^2$) / 8= (18.19 x 57.0025 x 4) / 8 = 518 KNm

**In Shorter Direction**

Ln = 3.65m, L2 = 8m, $Ln^2$ = 13.32 m

Mo = (W x Ln x $L_1$) / 8 or (w x $L_1$ x $Ln^2$) / 8 = (18.19 x 13.32 x 8) / 8 = 242 KNm

**STEP 6- COLUMN STRIP AND MIDDLE STRIPS**

**In Longer Direction**

**Column Strips**

2 (.25 x $L_2$) = 2 (.25 x 4000) = 2000 mm

2 (.25 x $L_1$) = 2 (.25 x 8000) = 4000 mm

Lesser Value Will Be Taken (A or B) Column Strip = 2000 mm

Middle Strips = L2 - Column Strips = 4000 - 2000 = 2000 mm

In Shorter Direction

Column Strips

2 (.25 x $L_1$) = 2 x (.25 x 8000) = 4000 mm

2 (.25 x $L_2$) = 2 x (.25 x 4000) = 2000 mm

Lesser Value Will Be Taken (A or B) Column Strip = 2000 mm

Middle Strips = L1 - Column Strip = 8000-2000 = 6000 mm

**STEP 7- REINFORCEMENT**

**Along Longer Direction**

Moment in Longer Direction

$$Pt\ \% = [50 * (fck/fy)] * 1 - \sqrt{1 - \left(\frac{4.6Mu}{fckbd^2}\right)}$$

*Table 3: Reinforcement along Longer Direction*

| Mu | $Mu_{cn}$ = .65 x .75 x Mo= .65 x .75 x 518 = 252 | $Mu_{cp}$ = .35 x .6 x Mo =.35 x .6 x 518 = 108 | $Mu_{mn}$ = .65 x Mo - $Mu_{cn}$ = .65 x 518 - 252= 84 | $Mu_{mp}$ = .35 x $M_o$ x $Mu_{cp}$ = .35 x 518 - 108 = 72 |
|---|---|---|---|---|
| Pt | .37 % | .15 % | .07 % but take .12 | .06 % but |

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| | | | | |
|---|---|---|---|---|
| | | | % | take .12 % |
| Total Ast | (Pt x b x d) / 100 = (.37 x 318 x 2000) / 100 = 2360 | (Pt x b x d) / 100 = (.15 x 318 x 2000) / 100 = 960 | (Pt x b x d) / 100 = (.12 x 318 x 2000) / 100 = 770 | (Pt x b x d) / 100 (.12 x 318 x 2000) / 100 = 770 |
| Ast/m | 1180 | 480 | 382 | 382 |

**STEP 8- REINFORCEMENT ALONG SHORTER DIRECTION**

**For Roof**

*Table 4: Reinforcement along Shorter Direction*

| Mu | $Mu_{cn}$ = .65 x .75 x Mo = .65 x .75 x 242 = 118 | $Mu_{cp}$ = .35 x .6 x Mo = .35 x .6 x 242 = 51 | $Mu_{mn}$ = .65 x Mo - $Mu_{cn}$ = .65 x 242 – 118 = 40 | $Mu_{mp}$ = .35 x Mo x $Mu_{cp}$= .35 x 242 – 51 = 34 |
|---|---|---|---|---|
| Pt | .17 % | .048 % but taken .12 % | .012 % but take .12 % | .010 % but take .12 % |
| Total Ast | (Pt x b x d) / 100 = (.17 x 308 x 2000) / 100 = 1050 | (Pt x b x d) /100 = (.12 x 308 x 2000) / 100 = 740 | (Pt x b x d) /100 = (.12 x 6000 x 308) / 100 = 2222 | (Pt x b x d) /100 (.12 x 6000 x 308) / 100 = 2222 |
| Ast/m | 524 | 370 | 370 | 370 |

**STEP 9- CHECK FOR TWO WAY SHEAR OR PUNCHING SHEAR**

**Shear Force Calculation**

Vu = ($L_1$ x $L_2$ - critical section area) x factored load

= (8 x 4 - .758 x .658) 18.19 = 574 KN

Bo= 2 x critical section area = (658 + 758) x 2 = 28

Bo x d = 2834 x 308 = 875047

TAU c = Vu / Bo x d= (574 / 875047) x 1000 = .65 N/mm$^2$

From is code 456 -2000 page no. 58 (cl. 31.6.3.1)

Ks = 1.25

tauc = .25 x (fck)$^{.5}$ = 1.118

tauc' = 1.118033989, For Roof - TAU c =.65 N/mm$^2$.

## V. SEISMIC LOADING DETAIL

For analysis of structure in seismic loading the provisions of IS code 1893 (2000) part 1, is preferred. The seismic parameters are listed in table below:

Table 5: Seismic Definitions

| | |
|---|---|
| Zone factor | 4 |
| Response reduction factor | 4 with SMRF with ordinary shear wall |
| Important factor | 1 i.e. General Structure |
| Rock/soil types | Medium Soil |
| Types of structure | Flat Slab |
| Damping ratio | 5 % |
| Fundamental natural period of vibration | .09 x h / (d)$^{0.5}$ |

**Load Combinations**- The load combinations are used to analyze G+11 multistoried building which are followed by IS-1893. The main thirteen load combinations used in this work are as follows:

Table 6: Possible Load Combinations

| S. No. | Load combination |
|---|---|
| 1 | 1.5(DL + LL) |
| 2 | 1.2(DL + LL + EQX) |
| 3 | 1.2(DL + LL - EQX) |
| 4 | 1.2(DL + LL + EQZ) |
| 5 | 1.2(DL + LL - EQZ) |
| 6 | 1.5(DL + EQX) |
| 7 | 1.5(DL - EQX) |
| 8 | 1.5(DL + EQZ) |
| 9 | 1.5(DL - EQZ) |
| 10 | 0.9DL + 1.5EQX |
| 11 | 0.9DL - 1.5EQX |
| 12 | 0.9DL + 1.5EQZ |
| 13 | 0.9DL - 1.5EQZ |

## VI. CASES USED IN FLAT SLAB

In this work, there are four types of Building Cases that are considered after the review of literature and to be analyzed with STAAD Pro, the cases are follows:

*Table 7: Building Case Description*

| | |
|---|---|
| Building Case B1 | G+11 Flat Slab building providing shear wall at lift location. |
| Building Case B2 | G+11 Flat Slab building providing shear wall at lift and maximum stress location. |
| Building Case B3 | G+11 Flat Slab added drop building providing shear wall at lift location. |
| Building Case B4 | G+11 Flat Slab added drop building providing shear wall at lift and maximum stress location. |

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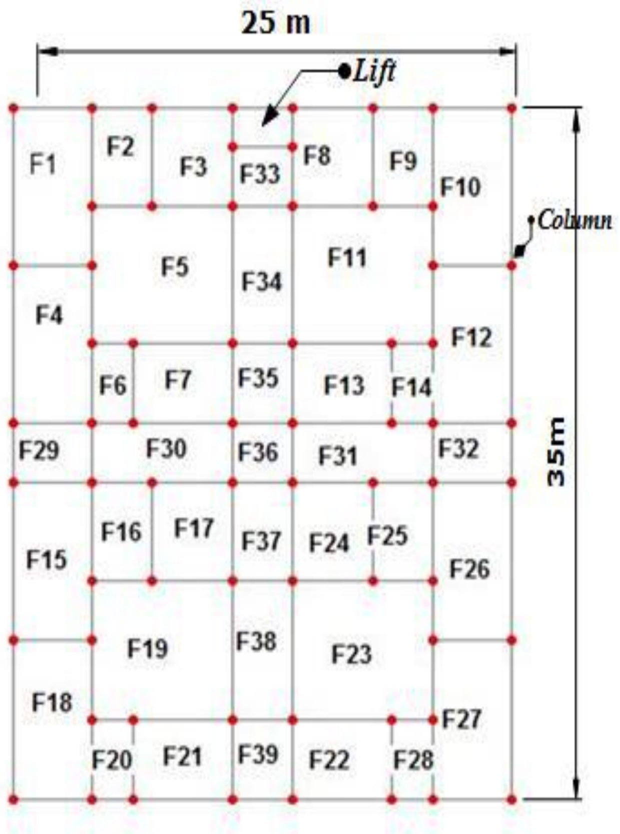


*Fig. 5: Panel Layout in G+11 building*

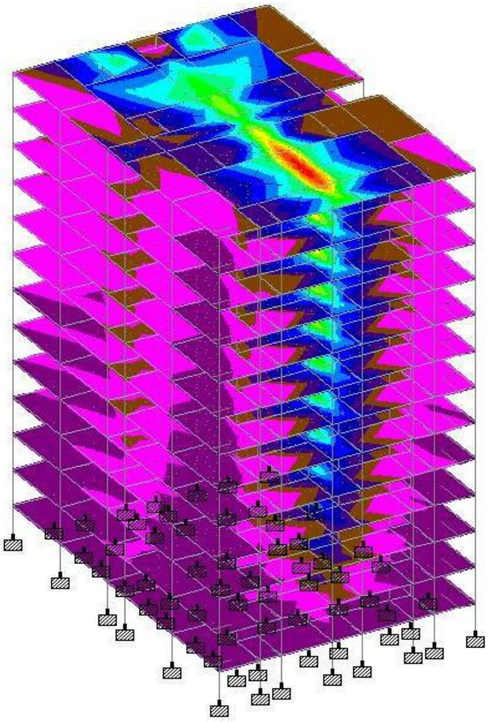

*Fig. 7: Location of Maximum Stresses on plate*

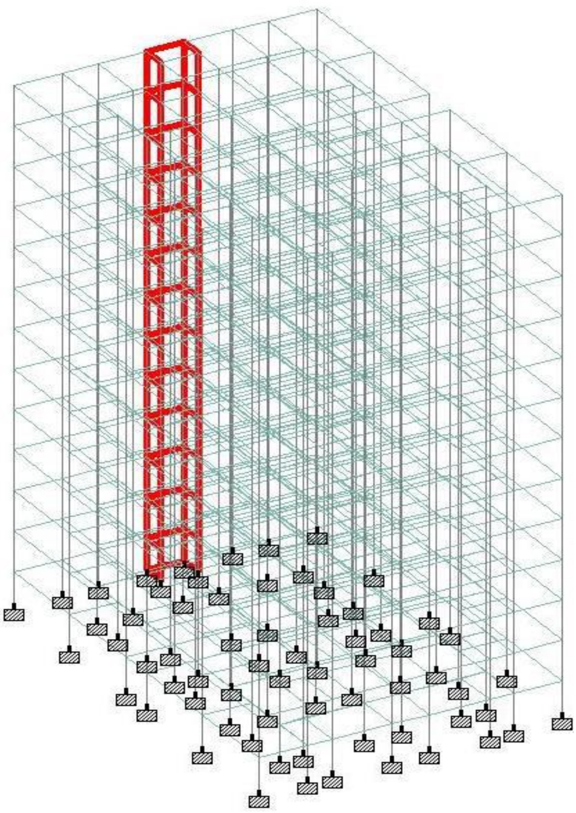

*Fig. 6: 3D Wireframe view of Shear Wall provided at Lift Location*

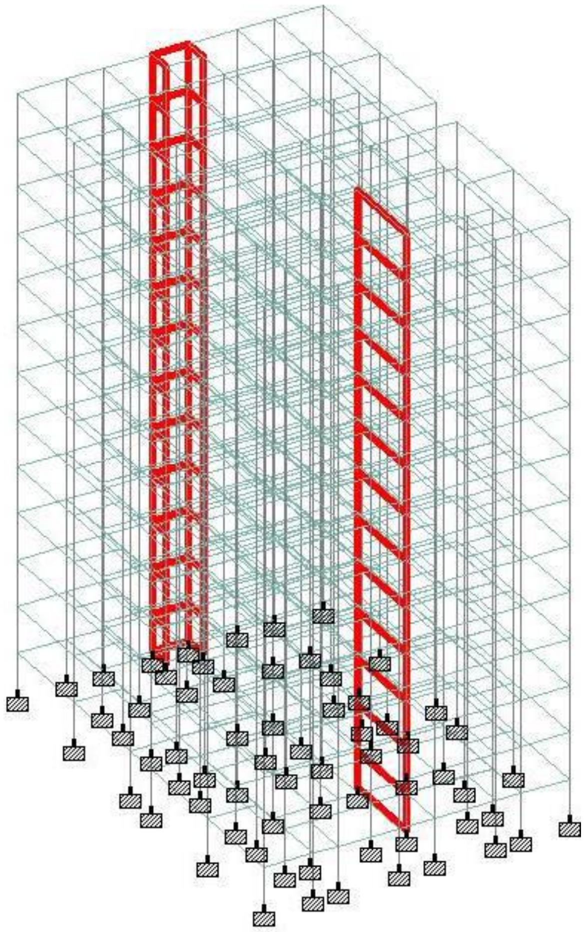

*Fig. 8: Shear Wall provided over the maximum stressed location*

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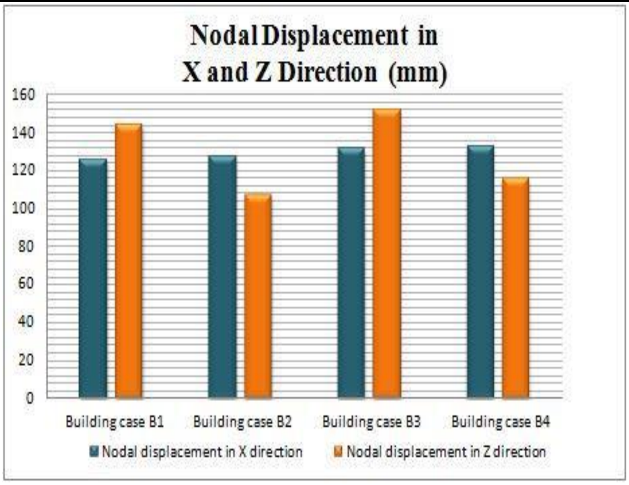
## VII. RESULTS AND DISCUSSION

In this work, the four Building Cases in STAAD Pro are analyzed and compared. All parametric results to find out optimum Building Case are as follows:-

**Nodal displacement in X and Z Direction**

*Table 8: Nodal displacement in X and Z Direction*

| Cases | Maximum Displacement In X and Z Direction (mm) | | | |
|---|---|---|---|---|
| | Building Case B1 | Building Case B2 | Building Case B3 | Building Case B4 |
| X Direction | 125.959 | 127.686 | 131.601 | 133.058 |
| Z Direction | 144.473 | 107.322 | 152.065 | 115.89 |



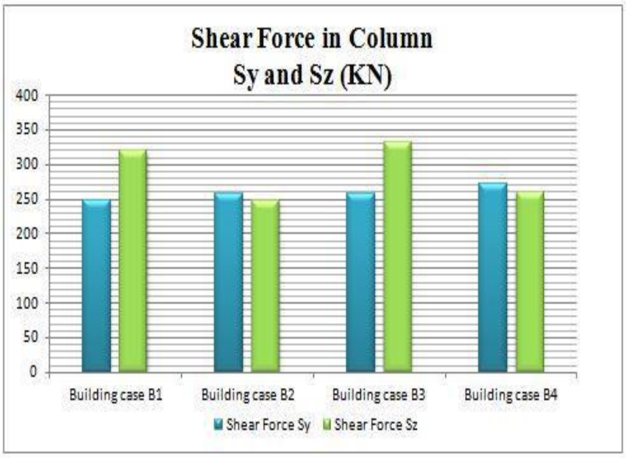

*Graph 1: Nodal Displacement in X and Z Direction*

The value of Nodal Displacement is minimum in Building Case B2 when observing the least values in both the directions. After comparing all the model cases, model case B2 shows the least values among all.

**Shear Force in Column Sy and Sz**

*Table 9: Shear Force Sy and Sz in Column*

| Cases | Shear Force Sy and Sz in Column (KN) | | | |
|---|---|---|---|---|
| | Building Case B1 | Building Case B2 | Building Case B3 | Building Case B4 |
| Sy | 248.685 | 257.545 | 258.512 | 270.955 |
| Sz | 319.728 | 249.878 | 333.374 | 260.203 |



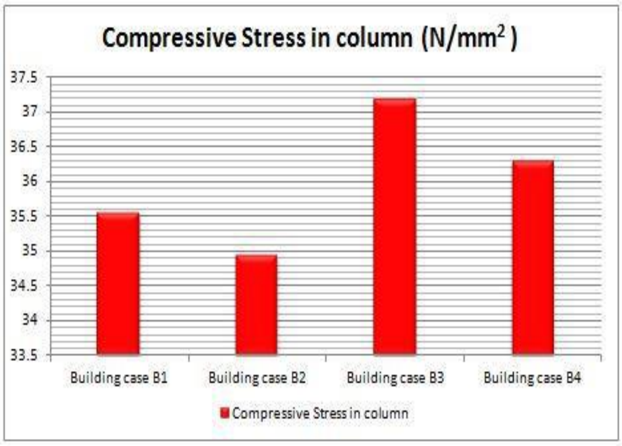

*Graph 2: Shear Force in Column*

On comparing the shear force values in column, for Y direction Building Case B1 shows the least value and for Z direction, Building Case B2 shows least value among all the considered cases. Since deciding the least value case, for this building plan for both the directions, Building Case B2 should be considered as least one.

**Maximum Compressive Stress in Column**

*Table 10: Maximum Compressive Stress in Column*

| Cases | Maximum Compressive Stress in column ($N/mm^2$) | | | |
|---|---|---|---|---|
| | Building Case B1 | Building Case B2 | Building Case B3 | Building Case B4 |
| | 35.54 | 34.945 | 37.171 | 36.293 |




*Graph 3: Maximum Compressive Stress in Column*

Compressive Stress in Column is lesser among all Building Cases with a minimum value of 34.945 $N/mm^2$. So that Building Case B2 is optimum case.

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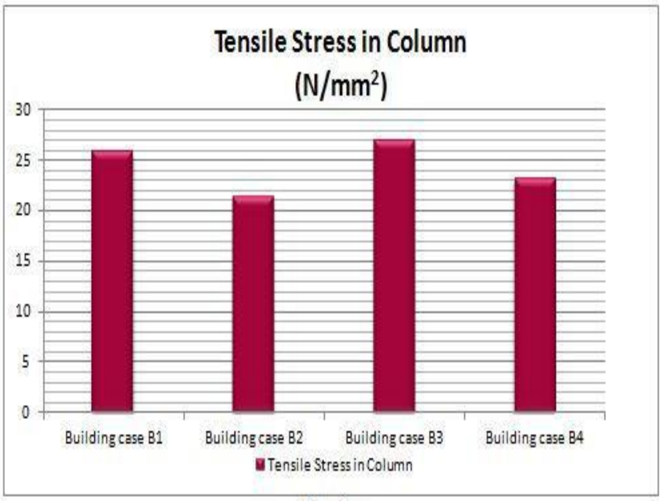
**Maximum Tensile Stress in Column**

Table 11: Maximum Tensile Stress in Column

| Cases | Maximum Tensile stress in column ($N/mm^2$) | | | |
|---|---|---|---|---|
| | Building Case B1 | Building Case B2 | Building Case B3 | Building Case B4 |
| | 25.777 | 21.429 | 26.889 | 23.23 |



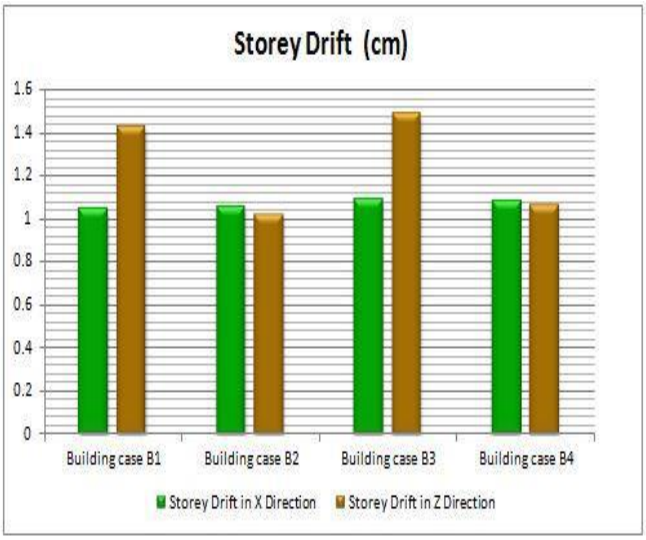

*Graph 4: Maximum Tensile Stress in Column*

To check and compare the maximum values of tensile stresses in four Building Cases, optimum Building Case obtained is B2 with a minimum value of 21.429 $N/mm^2$. Hence for this parameter, Building Case B2 should be considered.

**Storey Drift in X and Z Direction**

*Table 12: Storey Drift in X and Z Direction*

| Cases | Storey Drift in X and Z Direction (cm) | | | |
|---|---|---|---|---|
| | Building Case B1 | Building Case B2 | Building Case B3 | Building Case B4 |
| X Direction | 1.0458 | 1.0548 | 1.0909 | 1.0872 |
| Z Direction | 1.4294 | 1.0247 | 1.4894 | 1.0688 |



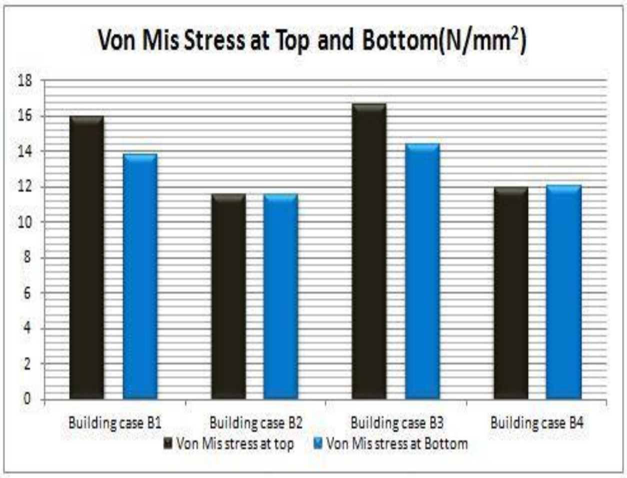

*Graph 5: Storey Drift in X and Z Direction*

Observing the Storey Drift parameter for X direction there is a minute difference in Building Case B1 and B2. But in Z direction, the observation clearly state that the Building Case B2 is an optimum case with a minimum value of 1.0247 cm. Hence the efficient case will be Building Case B2.

**Von Mis Stress at Top and Bottom**

*Table 13: Von Mis Stress at Top and Bottom*

| Cases | Von Mis Stress at Top and Bottom ($N/mm^2$) | | | |
|---|---|---|---|---|
| | Building Case B1 | Building Case B2 | Building Case B3 | Building Case B4 |
| Top | 15.955 | 11.548 | 16.603 | 11.976 |
| Bottom | 13.836 | 11.559 | 14.401 | 12.070 |




*Graph 6: Von Mis Stress at Top and Bottom*

Building Case B2, on observing the graphical representation of the obtained values seems to be minimum among all Building Cases. Hence the efficient Building Case is Building Case B2 with a minimum

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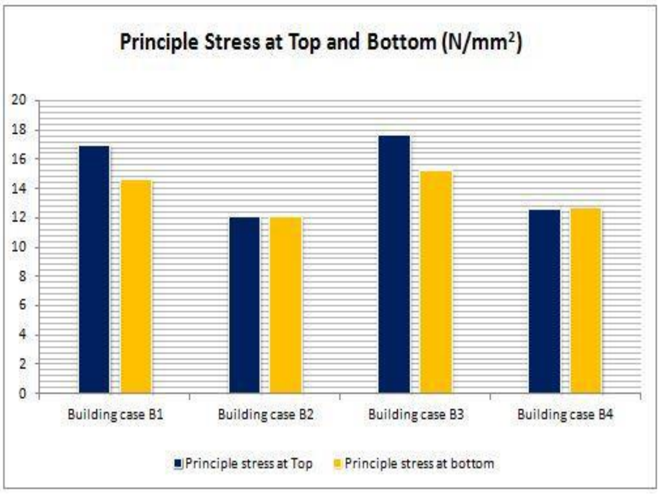
values of 11.548 N/mm$^2$ and 11.559 N/mm$^2$ for von mis top and bottom values.

**Principle Stress at Top and Bottom**

*Table 14: Principle Stress at Top and Bottom*

| Cases | Principle Stress at Top and Bottom (N/mm$^2$) | | | |
|---|---|---|---|---|
| | Building Case B1 | Building Case B2 | Building Case B3 | Building Case B4 |
| Top | 16.942 | 12.057 | 17.633 | 12.506 |
| Bottom | 14.620 | 12.070 | 15.219 | 12.599 |




*Graph 7: Principle Stress at Top and Bottom*

It is clearly observed that for multistory building situated in Seismic Zone IV, the Building Case B2 seems to be minimum for principle stresses top and bottom and proves to be an efficient case.

## VIII. CONCLUSION

After analysis of various parameters that are evolved for four different Building Cases, the conclusion obtained by summarizing result parameters are as follows:-

1. Building Case B2 is an optimum Building Case in terms of nodal displacement in X and Z direction showing its minimum value of 127.686 mm and 107.322 mm respectively.
2. Finding and Examine the Compressive stress in column seems to be less among all Building Cases with a minimum value of 34.945 N/mm$^2$. So that Building Case B2 is optimum Building Case.
3. After checking and comparing the maximum values of tensile stresses in four Building Cases, optimum Building Case obtained is B2 with a minimum value of 21.429 N/mm$^2$. Hence for this parameter, Building Case B2 should be considered.
4. Observing the storey drift parameter, for X direction there is a minute difference in Building Case B1 and B2. But in Z direction, the observation clearly state that the Building Case B2 is an optimum case with a minimum value of 1.0247 cm. Hence the efficient case will be Building Case B2.
5. On examine the Building Case B2, on observing the graphical representation of the obtained values seems to be minimum among all Building Cases. Hence the efficient Building Case is Building Case B2 with a minimum values of 11.548 N/mm$^2$ and 11.559 N/mm$^2$ for von mis top and bottom values.
6. To explore the possibilities for multistory building situated in seismic zone 4, the Building Case B2 seems to be minimum for principle stresses top and bottom and proves to be an efficient case.
7. Concluding the research work, Building Case B2 should be preferred in terms of comparative results of various parameters.

## IX. ACKNOWLEDGEMENT

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