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Performance of High-Rise Steel Building With and Without Bracings

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Abstract A comparative study on performance of high-rise steel building with and without bracings, carried out on a residential building by considering the gravity loads and lateral loads in the form of Earth quake loads and Wind loads incorporating the Bracings to reduce lateral loads on structural elements. In this study, a 20 storey steel frame structure has been selected to be idealized as multi storey steel building model. The model is analyzed by using STAAD.Pro 2008 structural analysis software with the consideration of wind *and earthquake loads. At the same time the influence of X-bracing pattern has been investigated*.The building proposed in designed by Limit State Method according to steel code IS: 800-2007, the Wind load analysis according to IS: 875-(part-3)1987 and seismic/Earth quake loads according to IS: 1893 (Part-1)-2002. In this study the node displacements of buildings having with and without bracings of wind and earthquake effect of Zone II and Zone V, and the axial force of the members of the buildings having with and without bracings of wind and earthquake effect of Zone II and Zone V.

Keywords: *Wind load, Displacement, Axial force, Bracings.*

I. INTRODUCTION

The tallness of a building is relative and cannot be defined in absolute terms either in relation to height or the number of stories. But, from a structural engineer's point of view the tall building or multi-storeyed building can be defined as one that, by virtue of its height, is affected by lateral forces due to wind or earthquake or both to an extent that they play an important role in the structural design. Buildings and structures are considered stable with lateral supports by using either bracing systems or shear system or both such as wall to ensure the stability of the building. Moreover, the important thing to consider are the software to be used for the analysis of tall building structure and wind speed at construction area to avoid any problems in future.

One of the problems is affected from wind load. Wind creates inward and outward pressures acting on building surfaces, depending on the orientation of the surface such as flat. This pressure increases uplift on parts of the building, forcing the building apart if it is too weak to resist the wind loads. Therefore, the most important thing to overcome this problem is the connection between beam and column in a frame such as rigid or pin ended should be considered for a realistic design it will become instable structure which means loss of some situation and come close to a failure such as buckling and sway if the structure cannot sustain for a certain load whether from dead load, imposed load, wind load and also natural phenomena like earthquake.

II. LITRATURE REVIEW

Previous Studies

Suresh P, Panduranga Rao B, kalyana Rama J.S, presented a Structures are classified as rigid and flexible. The present investigation deals with the calculation of wind loads using static and gust factor method for a sixteen storey high rise building and results are compared with respect to drift. Structure is analyzed in STAAD Pro, with wind loads calculated by gust factor as per IS 875-Part III with and without X- bracings at all the four corners from bottom to top.

Present Study

In the present problem the 20 storey building with steel elements as columns and beams, those building outside panels are provided with X - bracings and the interior panels of the building are without bracings are modeled of this problem. The model is prepared using STAAD Pro analysis software. All features like dead load, live load, wind load and seismic load. The loads on various structural components like vertical, horizontal and inclined members are evaluated and the members are designed as per the IS specifications. In Chapter 5 prescribed the node displacements of buildings having with and without bracings of earthquake effect of Zone II and Zone V.

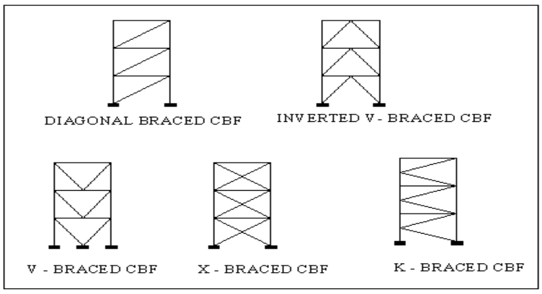
Braced Frames

Application on braced frames is typically used in which the beam and column are designed resist vertical loads only . Horizontal loads are resisted by bracing element to achieve lateral stability of the structures. The braced framing system able to achieve material savings with respect to moment resisting frame and control of frame drift due to lateral forces. Wind bracing system can be installed as longitudinal bracing or transverse bracing. A building also can be designed for combination of both longitudinal and transverse bracing. There are two types of braced frames which are concentrically braced frames and eccentrically braced frames

Concentrically braced frames (CBF)

Factors affecting the inelastic cyclic response of a concentrically braced frame including the following

- The slenderness and compactness of the bracing member.
- The relative axial strength of the brace in compression and tension.
- The strength of the brace connections to the beam and columns.
- The degree of lateral restraint provided to the brace to beam connection.
- The stiffness, strength, and compactness of the beam into which the brace frames.



Design of Wind Pressure:

The design wind pressure at any height above mean ground level shall be obtained by the following relationship between wind pressure and wind velocity:

$$Pz = 0.6\ Vz^2$$

Where Pz is design wind pressure in N/m^2 at height z, and Vz is design wind velocity in m/s at height z,

Design of wind speed (Vz)

The basic wind speed (Vb) for any site shall be obtained from below figure and shall be modified to include the following effects to get design wind velocity at any height (Vz) for the chosen structure.

a. Risk level;
b. Terrain roughness height and size of structure; and
c. Local topography

It can be mathematically expressed as follows;

$$V_z = V_h \times K_1 \times K_2 \times K_3$$

Where V_z = design wind speed at any height z in m/s;

K_1 is Probability factor (risk coefficient)
K_2 is terrain, height and structure size factor
K_3 is topography factor

Note: design wind speed up to 10m height from mean ground level shall be considered constant

Design Approach for Braced frames

A braced frame is one in which resistance to lateral force and frame instability is provided by a specially designed bracing system. The bracing system in a building frame is designed to serve the following important functions.

- Resisting lateral loads
- Counteraction the over turning moment (p-Δ moment) due to gravity loads
- Preventing Frame buckling and
- Improving sway behavior.

Earthquake Zone Intensity

- **Zone 5**

Zone 5 covers the areas with the highest risks zone that suffers earthquakes of intensity MSK IX or greater. The IS code assigns zone factor of 0.36 for Zone 5.

- **Zone 4**

This zone is called the High Damage Risk Zone and covers areas liable to MSK VIII. The IS code assigns zone factor of 0.24 for Zone 4.

- **Zone 3**

This zone is classified as Moderate Damage Risk Zone which is liable to MSK VII. and also 7.8 The IS code assigns zone factor of 0.16 for Zone 3.

- **Zone 2**

This region is liable to MSK VI or less and is classified as the Low Damage Risk Zone. The IS code assigns zone factor of 0.10 for Zone 2.

- **Load Calculations**

Loads and load combinations are given as per Indian standards. (IS 875:1984, IS 1893:2002 and IS 800:2007)

- **Gravity Loading**

Floor load and Dead loads are calculated as per general considerations as per IS 875 part1. (ref Appendix 3&4)

Live load – 2.5kN/m2

- **Wind Loading**

Static wind load is given as per IS 875-Part

III According to IS CODE (875 PART 3),

$$V_z = V_b \times K_1 \times K_2 \times K_3$$

P_z is Design wind pressure at a height z meter.

$$P_z = 0.6 V_z^2$$

The following assumptions are taken for the wind load calculation

- ¬ Location – Visakhapatnam
- ¬ Wind speed – 50m/s (ref Appendix 5)
- ¬ Terrain category – 3 and Class – C
- ¬ K_1 – 1.08 (life- 100 years)
- ¬ K_2 – depending upon the variation of height
- ¬ K_3 – 1.00 (flat topography)

Dynamic wind load also calculated by using gust factor approach

ANALYSIS FOR G+20 BUILDING:

- **Along X – Direction:**

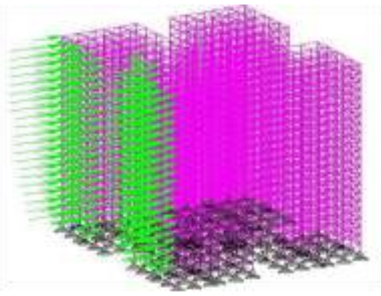
Regional wind speed (V_b) = 50 m/sec
Risk coefficient factor (K_1) = 1.08 (ref. sec 3.3.3)
Topography factor (K_3) = 1 (ref. sec 3.3.3)
Design wind speed (Vz) = k1*k2*k3*V_b = 54*k2
Width of the building along wind (a)=X(a) = 48 m
Width of the building normal wind(b)=Y(b)=44 m
Height (h) above G.L = 77 m
a/b = 1.09
h/b = 1.75
C_f = 1.2 (ref fig.2 in Appendix)

For Wind force at level 10 m for G+20 building at node 1 along X-direction is

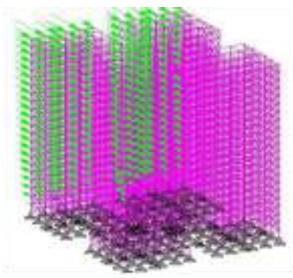
Area (A)= 3.5 m^2

Pressure (P_z)= 0.6 Vz^2 = 0.6 X 50 K_2
= 0.6 X 50 X 0.99
= 1.72 kN/m^2

Wind Force (F)=A* C_f* P_z= 3.5x1.2x1.72
= 7.22 kN



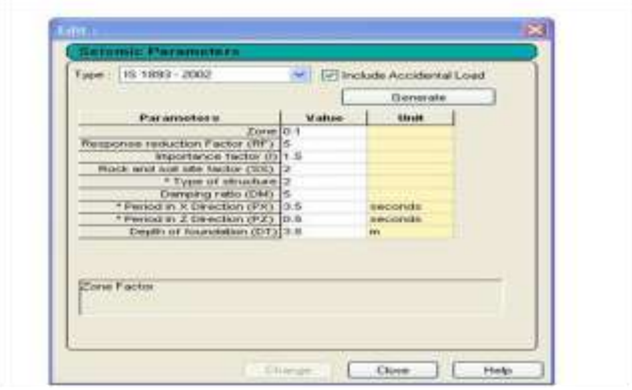
G+20 steel building wind in X- direction



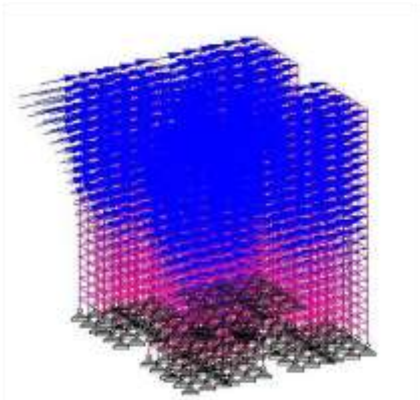
G+20 steel building wind in Z- direction

Seismic loading: - Seismic load is given as per IS 1893- 2002. Following assumptions are used for the calculation.

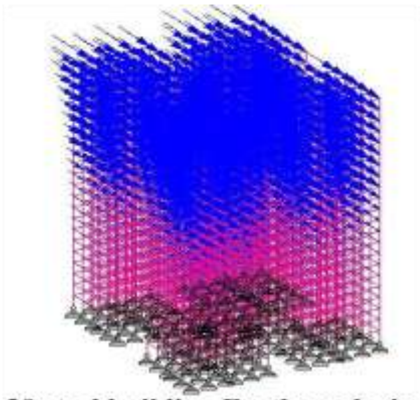
Zone factor – 0.1 (Zone-2)
– 0.36(Zone-5)
Importance Factor – 1.5
Soil type – 2 (medium Soil)
Structure type –Steel Frame Building
Damping co-efficient – 5%
Response reduction – 4 (for concentric brace)
5 (for eccentric brace)
5(Special Moment Resisting Frame (SMRF)



Seismic parameters Stadd Pro



G+20 steel building Earth quake in X- direction



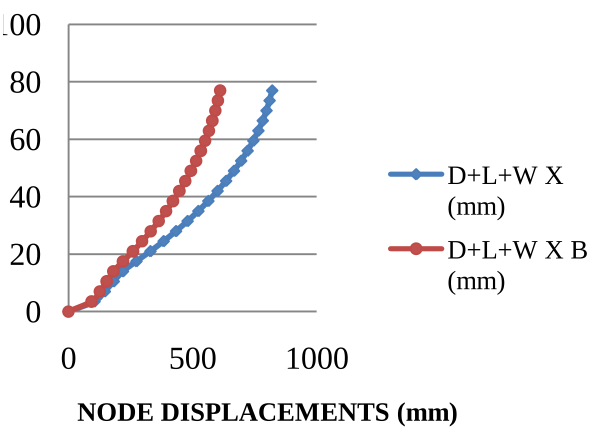
G+20 steel building Earth quake in Z- direction

NODAL DISPLACEMENTS IN WITHOUT AND WITH BRACINGS

Zone ii variation of node displacements and heights for external column in x- direction (without and with bracings wind load)

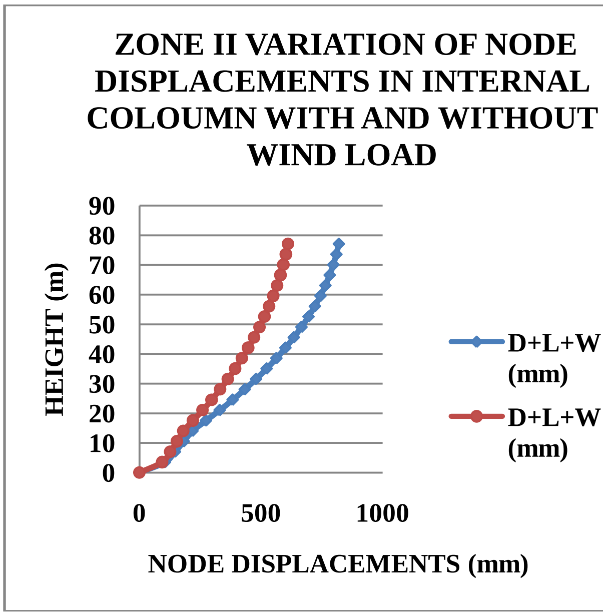
Nodal Displacements			
Loading (Dead + Live + wind)			
Node	Height	Without Bracings	With Bracings
No.	(m)	(mm)	(mm)
0008	0.0	0.000	0.000
1008	3.5	104.859	92.817
2008	7.0	146.242	126.187
3008	10.5	182.294	153.600
4008	14.0	219.413	180.078
5008	17.5	273.626	219.513
6008	21.0	330.023	259.413
7008	24.5	383.237	296.570
8008	28.0	433.070	331.108
9008	31.5	479.705	363.294
10008	35.0	523.029	393.155
11008	38.5	563.214	420.894
12008	42.0	600.418	446.705
13008	45.5	634.772	470.74
14008	49.0	666.384	493.124
15008	52.5	695.327	513.916
16008	56.0	721.339	532.915
17008	59.5	744.476	550.144
18008	63.0	764.816	565.653
19008	66.5	782.442	579.466
20008	70.0	797.460	591.566
21008	73.5	809.922	601.938
22008	77.0	820.552	-610.212

Figure 5.1.1 ZONE II VARIATION OF NODE DISPLACEMENTS IN EXTERNAL COLUMN WITH AND WITHOUT WIND LOAD



Zone ii variation of node displacements and heights for interior column in x- direction (without and with bracings wind load

Nodal Displacements			
Loading (Dead + Live + wind)			
Node	Height	Without Bracings	With Bracings
No.	(m)	(mm)	(mm)
0008	0.0	0.000	0.000
1008	3.5	104.859	92.817
2008	7.0	146.242	126.187
3008	10.5	182.294	153.600
4008	14.0	219.413	180.078
5008	17.5	273.626	219.513
6008	21.0	330.023	259.413
7008	24.5	383.237	296.570
8008	28.0	433.070	331.108
9008	31.5	479.705	363.294
10008	35.0	523.029	393.155
11008	38.5	563.214	420.894
12008	42.0	600.418	446.705
13008	45.5	634.772	470.74
14008	49.0	666.384	493.124
15008	52.5	695.327	513.916
16008	56.0	721.339	532.915
17008	59.5	744.476	550.144
18008	63.0	764.816	565.653
19008	66.5	782.442	579.466
20008	70.0	797.460	591.566
21008	73.5	809.922	601.938
22008	77.0	820.552	-610.212

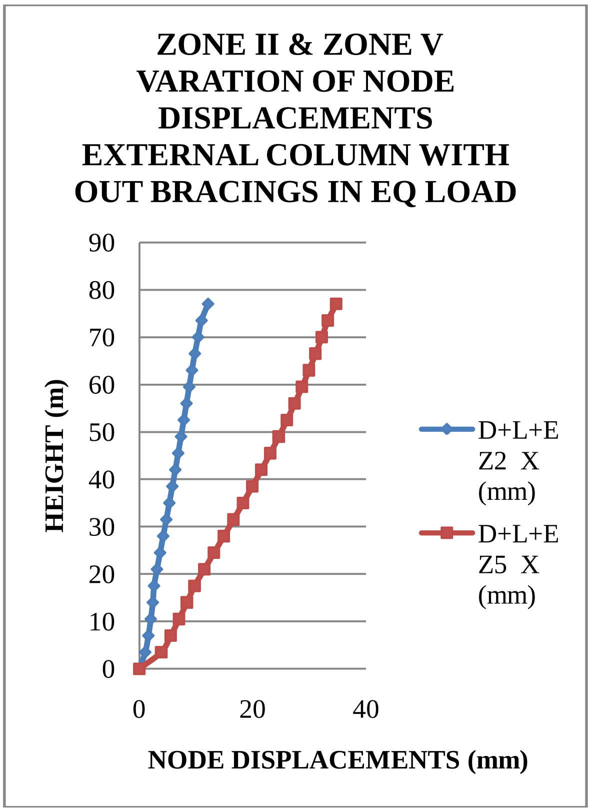


PERFORMANCE OF WIND EFFECT BUILDING ON NODAL DISPLACEMENTS IN FIGURES

the wind effect that nodal displacements in the exterior columns in X-direction braced structure and un braced structure are almost same up to 14 m height, from this point the braced structure nodal displacement is varied, the un braced structure the displacement is more compared with braced structure at top of building 25.52% and peak displacement at 56m height of building noted. No significant variation in interior column also.

Zone ii and zone v variation of node displacements and heights for external column in x- direction (without bracings)

Nodal Displacements			
Loading (Dead + Live + EQ)			
Node	Height	Without Bracings Zone II	Without Bracings Zone V
No.	(m)	(mm)	(mm)
0008	0.0	0.000	0.000
1008	3.5	1.029	3.853
2008	7.0	1.589	5.540
3008	10.5	2.006	6.983
4008	14.0	2.370	8.376
5008	17.5	2.583	9.731
6008	21.0	3.106	11.438
7008	24.5	3.654	13.167
8008	28.0	4.202	14.887
9008	31.5	4.747	16.591
10008	35.0	5.286	18.270
11008	38.5	5.816	19.917
12008	42.0	6.338	21.523
13008	45.5	6.848	23.081
14008	49.0	7.346	24.581
15008	52.5	7.834	26.017
16008	56.0	8.314	27.384
17008	59.5	8.791	28.677
18008	63.0	9.276	29.899
19008	66.5	9.786	31.057
20008	70.0	10.359	32.180
21008	73.5	10.973	33.236
22008	77.0	12.114	34.709



Zone ii and zone v variation of node displacements and heights for internal column in x- direction (without bracings)

Nodal Displacements			
Loading (Dead + Live + EQ)			
Node	Height	Without Bracings Zone II	Without Bracings Zone V
No.	(m)	(mm)	(mm)
0008	0.0	0.000	0.000
1008	3.5	1.029	3.853
2008	7.0	1.589	5.540
3008	10.5	2.006	6.983
4008	14.0	2.370	8.376
5008	17.5	2.583	9.731
6008	21.0	3.106	11.438

7008	24.5	3.654	13.167
8008	28.0	4.202	14.887
9008	31.5	4.747	16.591
10008	35.0	5.286	18.270
11008	38.5	5.816	19.917
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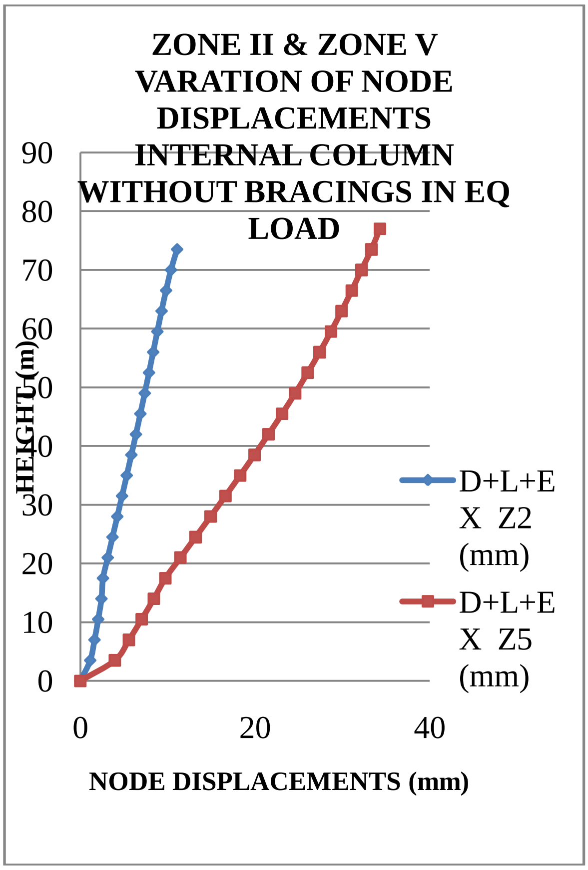


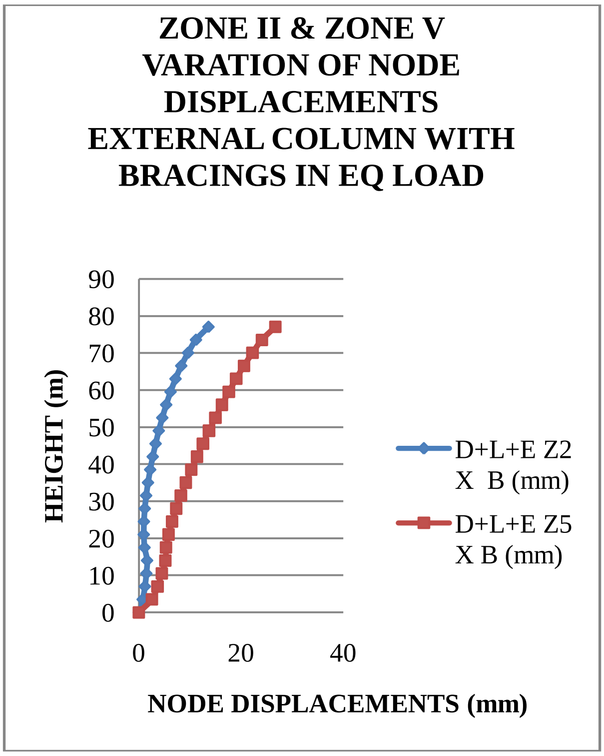
PERFORMANCE OF EQ EFFECT BUILDING ON NODAL DISPLACEMENTS IN WITHOUT BRACING FIGURES

The Earth quake effect that nodal displacements in the **exterior columns** in X-direction un braced structure are Zone II is low when compared with Zone V. The variation is linearly from bottom to top level for both earth quake zones, at the bottom and top variation is 73.29% and 65% and for both conditions the peak variation is at 21m height.

The Earth quake effect that nodal displacements in the **interior columns** in X-direction un braced structure are Zone II is low when compared with Zone V. The variation is linearly from bottom to top level for both earth quake zones at the bottom and top variation is 71.52% and 65.91% and for both conditions the peak variation is at 21m height

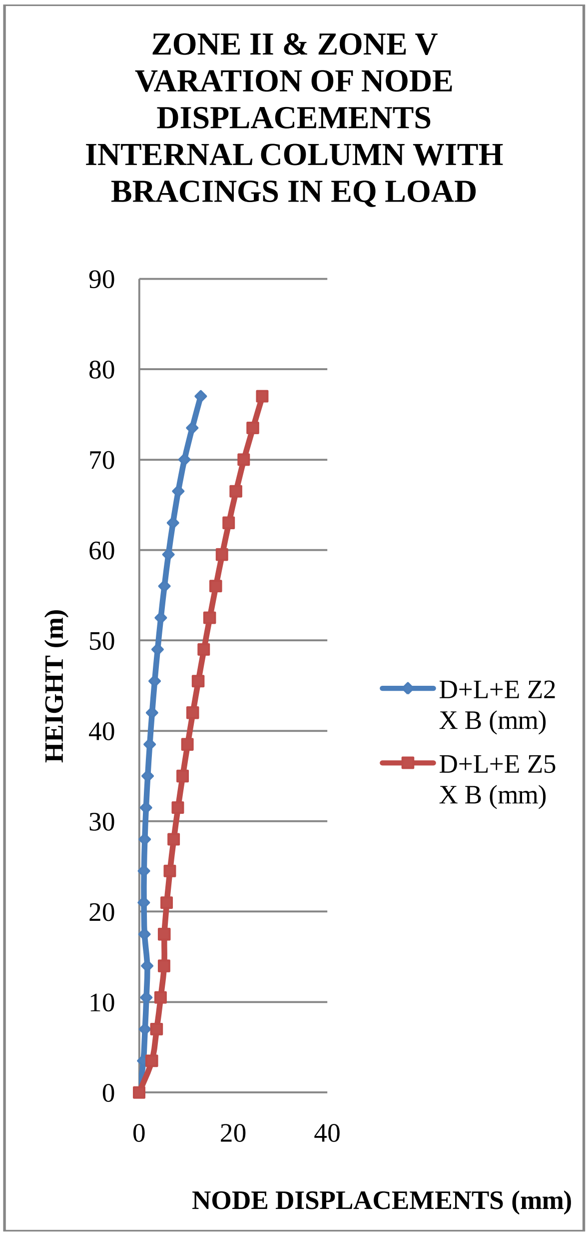
Zone ii and zone v variation of node displacements and heights for external column in x- direction (with bracings)

Nodal Displacements			
Loading (Dead + Live + EQ)			
Node	Height	Without Bracings Zone II	Without Bracings Zone V
No.	(m)	(mm)	(mm)
0008	0.0	0.000	0.000
1008	3.5	1.029	3.853
2008	7.0	1.589	5.540
3008	10.5	2.006	6.983
4008	14.0	2.370	8.376
5008	17.5	2.583	9.731
6008	21.0	3.106	11.438
7008	24.5	3.654	13.167
8008	28.0	4.202	14.887
9008	31.5	4.747	16.591
10008	35.0	5.286	18.270
11008	38.5	5.816	19.917
12008	42.0	6.338	21.523
13008	45.5	6.848	23.081
14008	49.0	7.346	24.581
15008	52.5	7.834	26.017
16008	56.0	8.314	27.384
17008	59.5	8.791	28.677
18008	63.0	9.276	29.899
19008	66.5	9.786	31.057
20008	70.0	10.359	32.180
21008	73.5	10.973	33.236
22008	77.0	12.114	34.709



Zone ii and zone v variation of node displacements and heights for internal column in x- direction (with bracings)

Nodal Displacements			
Loading (Dead + Live + EQ)			
Node	Height	With Bracings Zone II	With Bracings Zone V
No.	(m)	(mm)	(mm)
62	0.0	0.000	0.000
1062	3.5	0.862	2.679
2062	7.0	1.219	3.697
3062	10.5	1.507	4.549
4062	14.0	1.695	5.291
5062	17.5	1.118	5.338
6062	21.0	0.980	5.849
7062	24.5	1.007	6.523
8062	28.0	1.171	7.330
9062	31.5	1.442	8.239
10062	35.0	1.798	9.228
11062	38.5	2.228	10.283
12062	42.0	2.724	11.391
13062	45.5	3.281	12.547
14062	49.0	3.901	13.746
15062	52.5	4.588	14.989
16062	56.0	5.350	16.279
17062	59.5	6.204	17.627
18062	63.0	7.172	19.049
19062	66.5	8.291	20.574
20062	70.0	9.613	22.243
21062	73.5	11.262	24.170
22062	77.0	13.072	26.171



PERFORMANCE OF EQ EFFECT BUILDING ON NODAL DISPLACEMENTS IN WITH BRACING FIGURES

The Earth quake effect that node displacements in the **exterior columns** in X-direction braced structure are Zone II is low when compared with Zone V. The variation is parabolic from bottom to top level, at bottom and top variation is 70.83% and 65.91% and for both conditions the peak variation is at 24.5m height.

The Earth quake effect that node displacements in the **interior columns** in X-direction braced structure are Zone II is low when compared with Zone V. The variation is parabolic from bottom to top level, at bottom and top variation is 67.80% and 50.05% and for both conditions the peak variation is at 24.5m height.

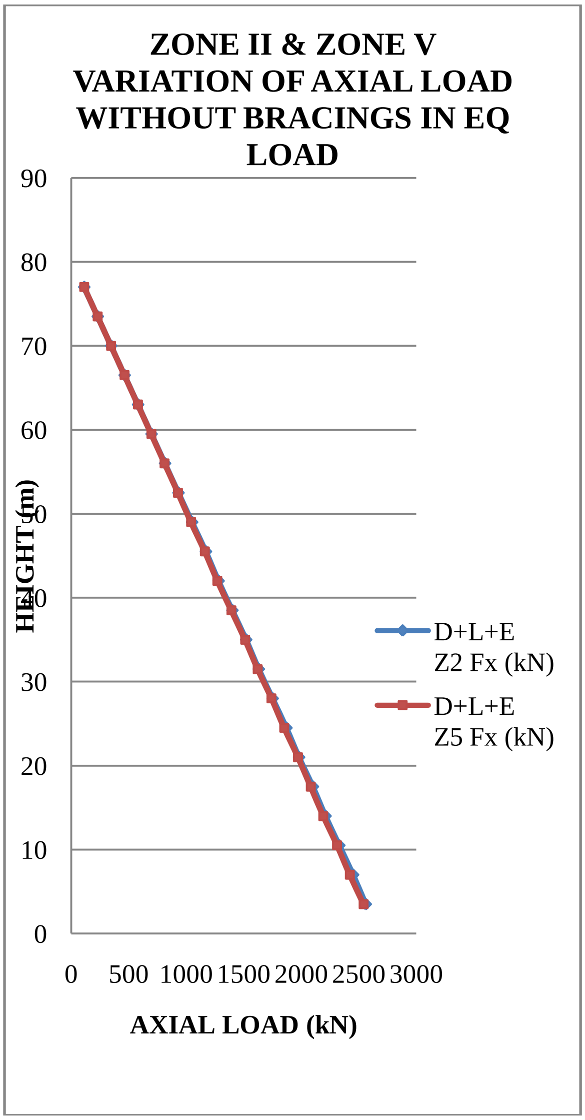
PERFORMANCE OF EQ EFFECT BUILDING ON AXIAL FORCE IN FIGURES

Zone II the earth quake effect that Axial Force the exterior and interior columns in X-direction braced structure and un braced structure is varied from bottom to top level .The un braced structure axial force is more compared with braced structure. The exterior column axial force at top of building 5.96% and bottom of building 14.84% and peak axial force at 24.5m height of building noted and the interior column axial force at top to bottom level of building almost same and peak axial force at 38.5m height of building noted.

Zone V the earth quake effect that Axial Force the exterior and interior columns in X-direction braced structure and un braced structure is varied from bottom to top level .The un braced structure axial force is more compared with braced structure. The exterior column axial force at top of building 5.89% and bottom of building 14.96% and peak axial force at 3.5m height of building noted and the interior column axial force at top to bottom level of building almost same and peak axial force at 28m height of building noted.

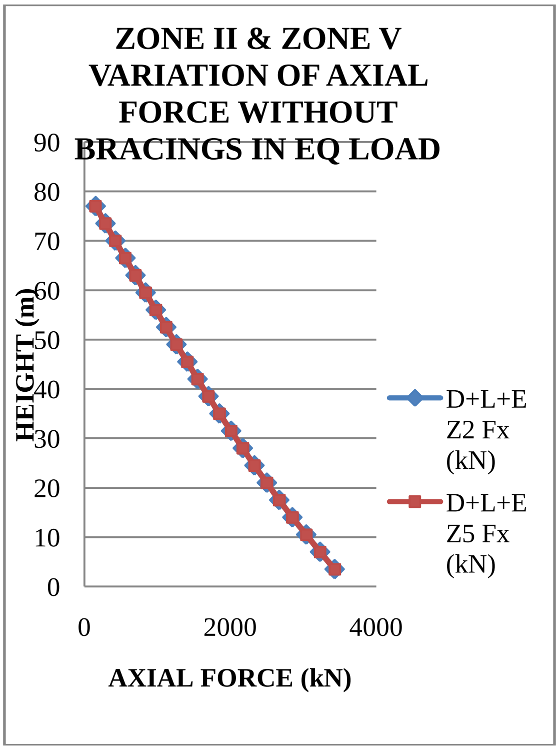
Zone ii and zone v variation of axial force and heights for external column in x- direction (with out bracings)

Axial Force			
	Loading (Dead + Live + EQ)		
Beam No.	Height (m)	Without Bracings (KN)	With Bracings (KN)
39061	3.5	2540.000	2160.000
40061	7.0	2420.000	2080.000
41061	10.5	2310.000	1990.000
42061	14.0	2190.000	1900.000
43061	17.5	2080.000	1800.000
44061	21.0	1970.000	1710.000
45061	24.5	1850.000	1610.000
46061	28.0	1740.000	1520.000
47061	31.5	1620.000	1420.000
48061	35.0	1510.000	1330.000
49061	38.5	1390.000	1230.000
50061	42.0	1270.000	1130.000
60061	45.5	1160.000	1030.000
70061	49.0	1040.000	926.330
80061	52.5	927.060	824.230
90061	56.0	811.060	721.540
100061	59.5	694.910	618.430
110061	63.0	578.610	515.170
120061	66.5	462.170	412.170
130061	70.0	345.600	310.000
140061	73.5	229.070	209.230
150061	77.0	111.670	105.084



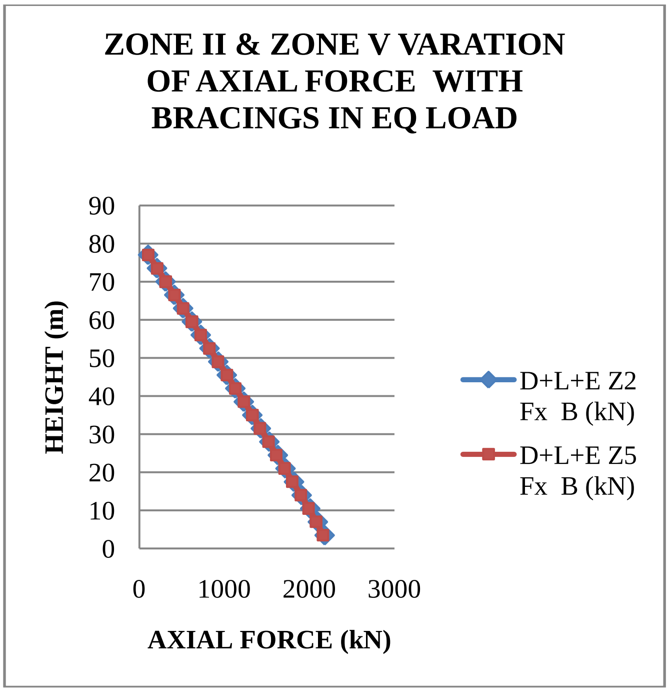
Zone ii and zone v variation of axial force and heights for internal column in x- direction (with out bracings)

Axial Force			
	Loading (Dead + Live + EQ)		
Beam	Height	Without Bracings	With Bracings
No.	(m)	(KN)	(KN)
39061	3.5	2540.000	2160.000
40061	7.0	2420.000	2080.000
41061	10.5	2310.000	1990.000
42061	14.0	2190.000	1900.000
43061	17.5	2080.000	1800.000
44061	21.0	1970.000	1710.000
45061	24.5	1850.000	1610.000
46061	28.0	1740.000	1520.000
47061	31.5	1620.000	1420.000
48061	35.0	1510.000	1330.000
49061	38.5	1390.000	1230.000
50061	42.0	1270.000	1130.000
60061	45.5	1160.000	1030.000
70061	49.0	1040.000	926.330
80061	52.5	927.060	824.230
90061	56.0	811.060	721.540
100061	59.5	694.910	618.430
110061	63.0	578.610	515.170
120061	66.5	462.170	412.170
130061	70.0	345.600	310.000
140061	73.5	229.070	209.230
150061	77.0	111.670	105.084



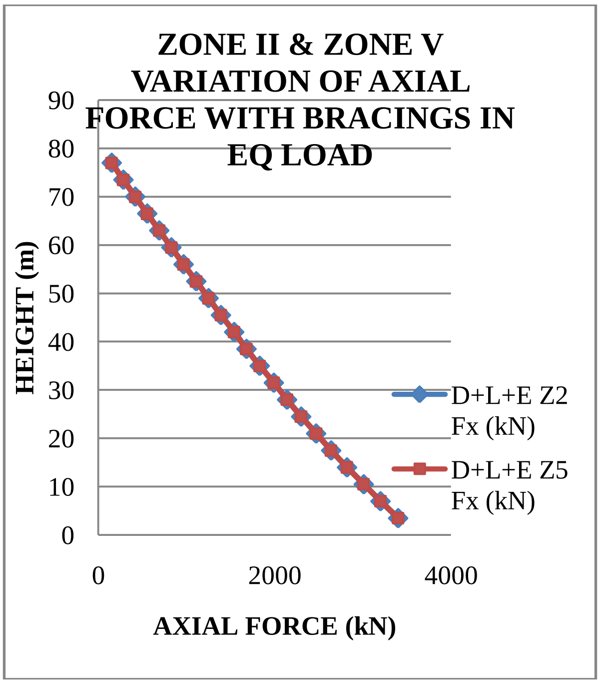
Zone ii and zone v variation of axial force and heights for external column in x- direction (with bracings)

Axial Force			
	Loading (Dead + Live + EQ)		
Beam	Height	Without Bracings	With Bracings
No.	(m)	(KN)	(KN)
39061	3.5	2540.000	2160.000
40061	7.0	2420.000	2080.000
41061	10.5	2310.000	1990.000
42061	14.0	2190.000	1900.000
43061	17.5	2080.000	1800.000
44061	21.0	1970.000	1710.000
45061	24.5	1850.000	1610.000
46061	28.0	1740.000	1520.000
47061	31.5	1620.000	1420.000
48061	35.0	1510.000	1330.000
49061	38.5	1390.000	1230.000
50061	42.0	1270.000	1130.000
60061	45.5	1160.000	1030.000
70061	49.0	1040.000	926.330
80061	52.5	927.060	824.230
90061	56.0	811.060	721.540
100061	59.5	694.910	618.430
110061	63.0	578.610	515.170
120061	66.5	462.170	412.170
130061	70.0	345.600	310.000
140061	73.5	229.070	209.230
150061	77.0	111.670	105.084



Zone ii and zone variation of axial force and heights for internal column in x- direction (with bracings

Axial Force			
Loading (Dead + Live + EQ)			
Beam	Height	Without Bracings Zone II	Without Bracings Zone V
No.	(m)	(KN)	(KN)
39065	3.5	3400.000	3400.000
40065	7.0	3200.000	3200.000
41065	10.5	3010.000	3010.000
42065	14.0	2820.000	2820.000
43065	17.5	2640.000	2640.000
44065	21.0	2470.000	2470.000
45065	24.5	2300.000	2300.000
46065	28.0	2140.000	2140.000
47065	31.5	1990.000	1990.000
48065	35.0	1830.000	1830.000
49065	38.5	1680.000	1680.000
50065	42.0	1540.000	1540.000
60065	45.5	1390.000	1390.000
70065	49.0	1250.000	1250.000
80065	52.5	1110.000	1110.000
90065	56.0	966.245	966.380
100065	59.5	827.743	827.890
110065	63.0	690.345	690.500
12065	66.5	553.898	554.060
13065	70.0	418.319	418.480
14065	73.5	283.338	283.480
15065	77.0	151.023	151.210



PERFORMANCE OF EQ EFFECT BUILDING ON AXIAL FORCE IN FIGURES

The earth quake effect that Axial Force in the exterior columns in **un braced** structure are Zone II and Zone V are same. No significant variation is found in the interior column.

The earth quake effect that Axial Force in the exterior columns in **braced** structure are Zone II and Zone V are same. No significant variation is found in the interior column.

Conclusions of building on nodal displacements

Zone II the wind effect that nodal displacements in the exterior columns in braced structure and un braced structure nodal displacement is varied, the un braced structure the displacement is more compared with braced structure at top of building 25% No significant variation in interior column also.

Zone II the earth quake effect that nodal displacements in the exterior and interior columns in braced structure and un braced structure nodal displacement is increased gradually up to certain height and then decreased gradually from top level. In the un braced structure the displacement is more compared with braced structure, at top of building almost same braced and un braced structure.

Zone V the earth quake effect that nodal displacements in the exterior and interior columns in braced structure and un braced structure nodal displacement is increased gradually from top level. In the un braced structure the displacement is more compared with braced structure, at top of building varied 23% braced and un braced structure.

The Earth quake effect that nodal displacements in the exterior and interior columns in braced and un braced structure are Zone II is low when compared with Zone V. The variation is linearly from bottom to top level for both earth quake zones, at the bottom to top maximum variation is 75% and for both.

Conclusions of building on axial force

The Wind effect that Axial Force the exterior columns in braced structure are low when compared with un braced structure, from top floor both are same. No significant variation is found in the interior column.

Zone II and Zone V earth quake effect that axial force the exterior columns in braced structure are low when compared with un braced structure, from top floor both are same. In the interior columns almost same in braced and un braced structures

The variation of Zone II and Zone V the earth quake effect that Axial Force in the exterior columns in braced and un braced structure are same. No significant variation is found in the interior column.

Discussions

In high rise buildings the stability can be achieved by suitably adding the dimensions of the external columns with diagonal X-bracings. Provision of X-bracings reduces the amount of displacements in structure.

In case of any reasons Zone provision will be changed the bracings can also be used as a retrofitting technique to strengthen the existing structure as X-bracings will act more like shear wall.

The braced building of the storey displacement decreases as compared to the un braced building which indicates that the overall response of the building decreases.

The displacement of the building decreases depending upon the different bracing system employed and the bracing sizes, about the whole of performance of X braced building better than the other braced building.

Scope for Further Work

The present work is an approach to carry out initial study the response of very large complicated tall structures. The work may be extended to aspects like condition monitoring of these structures due to moments and time period of earth quake motions. The following challenging case studies can be taken up with recent developments in finite element analysis and sap software.

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