Effect of Sensitive Analysis on Multistorey Building with Different Configuration of Structural Element

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Abstract— **The preference for the mixed-use of buildings has led to a paradigm shift in the way buildings are designed, and their geometries are determined. A podium-tower building configuration that caters for both commercial and residential functionalities has become a popular form of building construction in many metropolitan cities around the world. Horizontal offset buildings constitute a class of structures that are particularly prone to in-plane floor deformation and torsion occurring simultaneously. It is found from previous studies that podium can impose significant differential restraint on coupled tower walls, these walls displace under lateral loads contributing to the generation of in-plane strutting forces in podium floors leading to its un-conservative design. So, the scope of this study is to understand the realistic behaviour of such structures under lateral loads considering the backstay effect as per IS: 16700(2017). Also, study of behaviour of structure in modified modifier of upper bound.**

The present work focus on the effect of podium structure of single tower structure connected by a common podium at the interface level under seismic load. For this purpose, the simulation model with different arrangement of wall and beam/slab at podium level is created in the ETABs and it is analysed for the response spectrum method. In this study, the effect on the top displacement of the tower connected with podium structure under response spectrum method of analysis is observed. The backstay forces that are developed to resist the lateral overturning actions at the interface when the lateral horizontal forces are transferred from the tower to the podium are studied. The unfavorable effect of podium on the shear force distribution at and above the interface level of the structural wall is observed.

Index Terms— **Damage, earthquake engineering, Performance Based Design, Safety.**

I. INTRODUCTION

Considering the increasing populations in major cities and the limitation of spaces available, construction of tall building structures has become inevitable. Hence, there is a spurt in construction of tall buildings in major metros in India such as Mumbai, Delhi, Pune, Hyderabad and others. Due to the complexity of the structures, the most advanced engineering design techniques are needed in tall structures and to satisfy demand of larger commercial space near road level and make the building compliant with minimum parking space requirements for such mixed-use development according to prevailing bye-laws, Architects and Developers have come up with the unique idea of Podium type Buildings.

A podium is the lowest level of tall building construction with a larger floor plan area and significantly higher seismic force resistance than the tower above. As compared to low and mid-rise buildings, the design criteria for high-rise buildings are different. Shear walls (lateral systems) have traditionally been viewed as simple cantilever beams fixed at the base. This analogy is reasonably correct for the above-grade structure, but for (podium + tower) type building, a more realistic and justifiable analogy would be a cantilever with a back span to take into account the effects of the relatively large lateral stiffness of the podium.

Backstay effects are the transfer of lateral forces from the tower's seismic-force-resisting components to additional elements within the podium, usually via one or more floor diaphragms. A tall building's lateral force resistance and force transfer through floor diaphragms at these levels help it resist seismic overturning forces. Based on its similarity to the back span of a cantilever beam, this component of overturning resistance is referred to as the backstay effect. Sometimes it is also referred to as “Shear

Reversal", because the shear in seismic load resisting elements can change its direction within the podium levels.

►Importance of sensitive analysis:

A podium is a term used to describe the base of a tall building. Podium in architecture is any of various elements that form the foot or base of a structure and have a low wall supporting columns, or the structurally or decoratively emphasized the lowest portion of a wall. A building's basement story is sometimes used as a podium. In many multi-functional tall buildings, this type of configuration is seen. Podiums are augmented floor area at the lower level of a high-rise building surrounding it as shown in (Fig. 1.1).

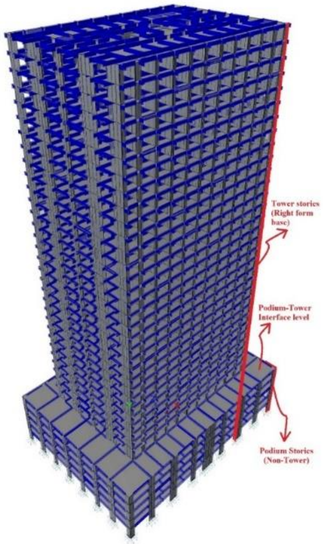


Figure 1.1 Podiums are augmented floor area at the lower level of a high rise building surrounding.

At the podium-tower interface, horizontal forces are transferred from the tower to the podium. Reactive forces are developed at the podium-tower interface to resist the overturning actions (Fig. 1.2). This reacting mechanism is similar to the backstay phenomena. It can induce high intensity shear force in the structural (tower) wall within the podium. The amplitude of the induced shear force is dependent on the in-plane flexibility of the floor structure connecting the pair of walls.

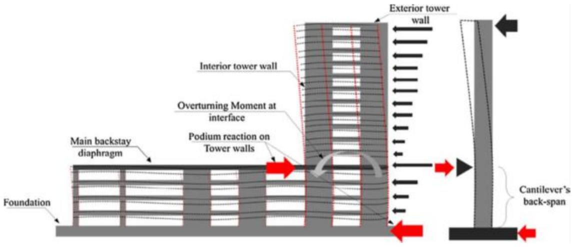


Figure 1.2 Podium-tower interface developed forces.

►Stiffness

Stiffness in civil engineering refers to the ability of a structure or material to resist deformation when subjected to external forces. It is an important concept in construction and design, as it determines the stability and integrity of a structure. Stiffness is the ability to attract moments, shear, axial force etc., stiffer an element, more force it attracts and more reinforcement it is designed for.

►Types of Stiffness in ETABS Software:

In ETABS, shell or area element has two types of stiffnesses i.e., in plane stiffness refers as f11, f22 and f12 and out-of-plane stiffness refers as m11, m22 and m12.

Where, F11 – Membrane direct force in local direction 1
F22 – Membrane direct force in local direction 2
F12 – Membrane in-plane shear force
M11 – Plate bending moment in local direction 1
M22 – Plate bending moment in local direction 2
M12 – Plate twisting moment

Figure 1.3 shows the direction of local axes and their corresponding stiffnesses

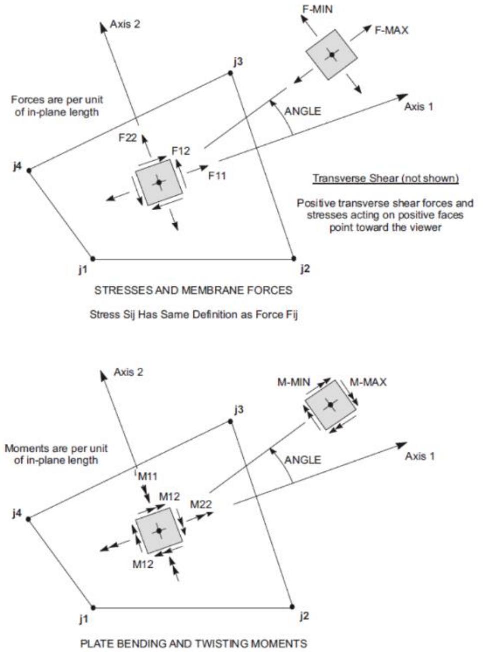


Figure 1.3 Shell Element Internal Resultant Forces and Moments

►Stiffness modifiers

The stiffness modifiers are used to take into consideration the cracking of RCC sections in analysis of structure. The intention for introducing the stiffness modifier is to account for reduced moment of inertia of different members due to cracking.

In IS 16700, stiffness modifier values/ cracked section properties are specified for serviceability and ultimate conditions.

Table 1.1 Service Stiffness Values

Elements stiffness modifier	Structural Walls	Retaining Walls	Spandrel beam	Slab	Frames stiffness modifier	Columns		Beam
						Frame	Gravity	
F11	1	1	0.7	0.35	Area	1	1	1
F22	0.9	0.9	0.7	0.35	As2	1	1	1
F12	1	1	0.7	0.35	As3	1	1	1
M11	0.9	0.9	0.7	0.35	T	0.001	0.001	0.001
M22	0.9	0.9	0.7	0.35	I22	0.9	0.1	0.7
M12	0.9	0.9	0.7	0.35	I33	0.9	0.1	0.7
V13	1	1	1	1				
V23	1	1	1	1				

Table 1.2 Strength Stiffness Values

Elements stiffness modifier	Structural Walls	Retaining Walls	Spandrel beam	Slab	Frames stiffness modifier	Columns		Beam
						Frame	Gravity	
F11	1	1	0.35	0.25	Area	1	1	1
F22	0.7	0.7	0.35	0.25	As2	1	1	1
F12	1	1	0.35	0.25	As3	1	1	1
M11	0.7	0.7	0.35	0.1	T	0.001	0.001	0.001
M22	0.7	0.7	0.35	0.1	I22	0.7	0.1	0.35
M12	0.7	0.7	0.35	0.1	I33	0.7	0.1	0.35
V13	1	1	1	1				
V23	1	1	1	1				

►Sensitivity analyses

As part of collapse pretension evaluation, two sets of backstay sensitivity analyses shall be carried out using upper-bound and lower-bound cracked section properties of floor diaphragms and the stiffness parameters for those diaphragms and perimeter walls of podium and below the level of the backstay are given in below table. These analyses shall be in addition to those required to be carried out using other cracked section properties described.

Besides that of the floor diaphragms, flexibility of following structural elements in the structural analysis shall be considered with appropriate modification to their stiffness:

1) Perimeter walls and their foundation supports; and

2) Foundation supports under the tower lateral load resisting system

Table 1.3 Strength Stiffness Values for Upper Bound model

Elements stiffness modifier	Structural Walls	Retaining Walls	Spandrel beam	Slab		Frames stiffness modifier	Columns		Beam		
				Tower	NTA		Frame	Gravity	Tower beam above NTA	Tower beam upto NTA	NTA
F11	1	0.5	0.35	0.25	0.5	Area	1	1	1	0.5	0.5
F22	0.7	0.5	0.35	0.25	0.5	As2	1	1	1	1	1
F12	1	0.5	0.35	0.25	0.5	As3	1	1	1	1	1
M11	0.7	0.5	0.35	0.1	0.1	T	0.001	0.001	0.001	0.001	0.001
M22	0.7	0.5	0.35	0.1	0.1	I22	0.7	0.1	0.35	0.5	0.5
M12	0.7	0.5	0.35	0.1	0.1	I33	0.7	0.1	0.35	0.35	0.35
V13	1	1	1	1	1						
V23	1	1	1	1	1						

Table 1.4 Strength Stiffness Values for Upper Bound model (Modified)

Elements stiffness modifier	Structural Walls	Retaining Walls	Spandrel beam	Slab		Frames stiffness modifier	Columns		Beam		
				Tower	NTA		Frame	Gravity	Tower beam above NTA	Tower beam upto NTA	NTA
F11	1	0.875	0.35	0.25	0.875	Area	1	1	1	0.875	0.875
F22	0.7	0.875	0.35	0.25	0.875	As2	1	1	1	1	1
F12	1	0.875	0.35	0.25	0.875	As3	1	1	1	1	1
M11	0.7	0.875	0.35	0.1	0.1	T	0.001	0.001	0.001	0.001	0.001
M22	0.7	0.875	0.35	0.1	0.1	I22	0.7	0.1	0.35	0.875	0.875
M12	0.7	0.875	0.35	0.1	0.1	I33	0.7	0.1	0.35	0.35	0.35
V13	1	1	1	1	1						
V23	1	1	1	1	1						

Table 1.5 Strength Stiffness Values for Lower Bound model

Elements stiffness modifier	Structural Walls	Retaining Walls	Spandrel beam	Slab		Frames stiffness modifier	Columns		Beam		
				Tower	NTA		Frame	Gravity	Tower beam above NTA	Tower beam upto NTA	NTA
F11	1	0.15	0.35	0.25	0.15	Area	1	1	1	0.15	0.15
F22	0.7	0.15	0.35	0.25	0.15	As2	1	1	1	1	1
F12	1	0.15	0.35	0.25	0.15	As3	1	1	1	1	1
M11	0.7	0.15	0.35	0.1	0.1	T	0.001	0.001	0.001	0.001	0.001
M22	0.7	0.15	0.35	0.1	0.1	I22	0.7	0.1	0.35	0.15	0.15
M12	0.7	0.15	0.35	0.1	0.1	I33	0.7	0.1	0.35	0.35	0.35
V13	1	1	1	1	1						
V23	1	1	1	1	1						

Diaphragm have been modelled as Semi-Rigid because they transfer the loads acting on it (transverse & in plane) through out of plane and in plane bending both and to study the Backstay Effect these factors are to be considered and understood. In a building the floor may consist of a very stiff concrete slab; despite that, a rigid diaphragm analysis would probably not be appropriate. In a rigid diaphragm analysis, the far ends would be constrained to translate and rotate together. A semirigid diaphragm analysis would more correctly allow to displace independently of each other, tied together only by the stiffness of the diaphragm where the wings meet at the core (Refer figure 1.4).

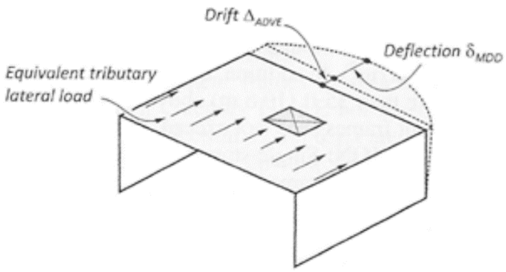


Figure 1.4 Semi rigid Diaphragm

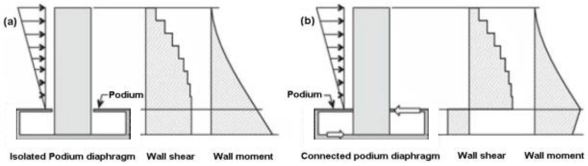


Figure 1.5 Backstay effect: (a) wall and podium diaphragm not connected;
(b) wall and podium diaphragm connected

II. OBJECTIVE OF THESIS

- To understand the concepts and codal provisions (IS 16700: 2017) regarding the Backstay Effect / Shear Reversals observed in the Podium type structures. And study the impact / effect on lateral force distribution amongst various lateral load resisting elements by performing Sensitivity Analysis.
- To analyze RCC building model with different stiffness modifiers for Service & Strength model (3D, Direct load path, Upper bound, Lower Bound) by using ETABS software.
- With above parameter different models will be prepared and Compare

1) Tower only
2) Tower with NTA (Flat Slab arrangement)
3) Tower with NTA (Flat Slab arrangement) + Retaining wall at Periphery
4) Tower with NTA (Beam Slab arrangement)
5) Tower with NTA (Beam Slab arrangement) + Retaining wall at Periphery

The respective models are compare with following parameters such as Mode shapes, lateral deflection, drift, bending moment, axial force, shear force, concrete quantity and reinforcement/steel quantity.

III. THESIS DENITION

The main aim of the project is to conduct the sensitive analysis on multistorey Building with different configuration of structural element and to find out the key behaviour of it.

► Model Details and Configuration

No. of model with Description and detail name of model is mentioned in Table 3.1. Floor layout contain beams, slabs, walls and retaining walls and detail about floor and its layout is specified in Figure 3.1 to 3.5.

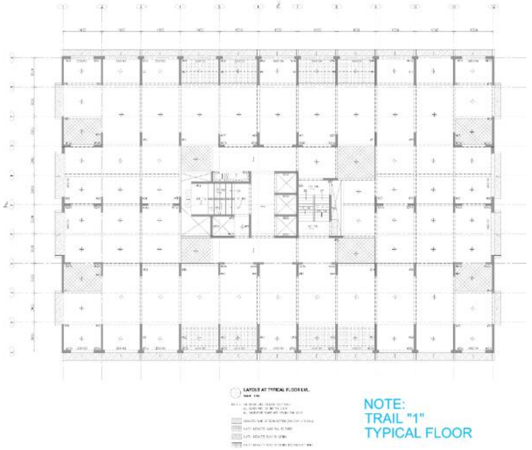


Figure 3.1 Typical floor plan (Trail:01)

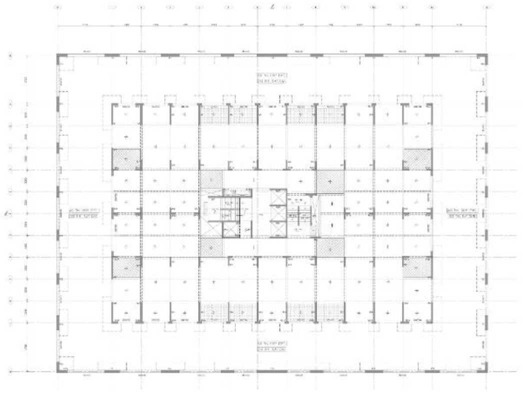


Figure 3.2 Lower floor with flat slab (Trail:02)

Table 3.1 Model Description

SR NO.	MODEL TYPE	DESCRIPTION	UNIQUE ID	REMARK	
1	Service	Tower Only	MB_SE_T		Direct load path
2	Strength	Tower Only	MB_ST_T		Direct load path
3	Service	Tower+NTA	MB_SE_T_N+F	NTA with Flat Slab arrangement	
4	Strength	Tower+NTA	MB_ST_T_N+F		
5	Strength	Tower+NTA	MB_ST_T_N+F_U		Upper Bound
5.1	Strength	Tower+NTA	MB_ST_T_N+F_U		Modified Upper Bound
6	Strength	Tower+NTA	MB_ST_T_N+F_L		Lower Bound
7	Service	Tower+NTA	MB_SE_T_N+F_RW	NTA with Flat Slab but RW Periphery	
8	Strength	Tower+NTA	MB_ST_T_N+F_RW		
9	Strength	Tower+NTA	MB_ST_T_N+F_RW_U		Upper Bound
9.1	Strength	Tower+NTA	MB_ST_T_N+F_RW_U		Modified Upper Bound
10	Strength	Tower+NTA	MB_ST_T_N+F_RW_L		Lower Bound
11	Service	Tower+NTA	MB_SE_T_N+B	NTA with Beam Slab arrangement	
12	Strength	Tower+NTA	MB_ST_T_N+B		
13	Strength	Tower+NTA	MB_ST_T_N+B_U		Upper Bound
13.1	Strength	Tower+NTA	MB_ST_T_N+B_U		Modified Upper Bound
14	Strength	Tower+NTA	MB_ST_T_N+B_L		Lower Bound
15	Service	Tower+NTA	MB_SE_T_N+B_RW	NTA with Beam Slab arrangement but RW Periphery	
16	Strength	Tower+NTA	MB_ST_T_N+B_RW		
17	Strength	Tower+NTA	MB_ST_T_N+B_RW_U		Upper Bound
17.1	Strength	Tower+NTA	MB_ST_T_N+B_RW_U		Modified Upper Bound
18	Strength	Tower+NTA	MB_ST_T_N+B_RW_L		Lower Bound

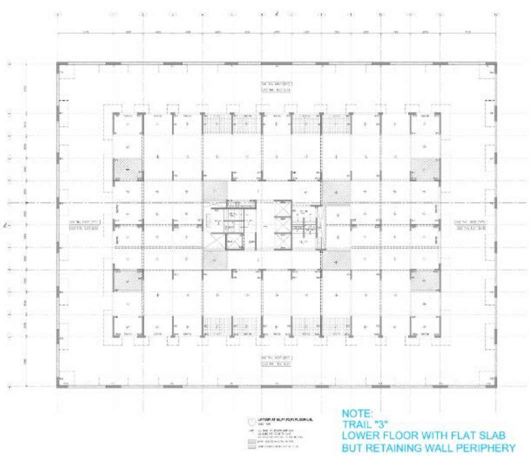


Figure 3.3 Lower floor with flat slab but retaining wall periphery (Trail:03)

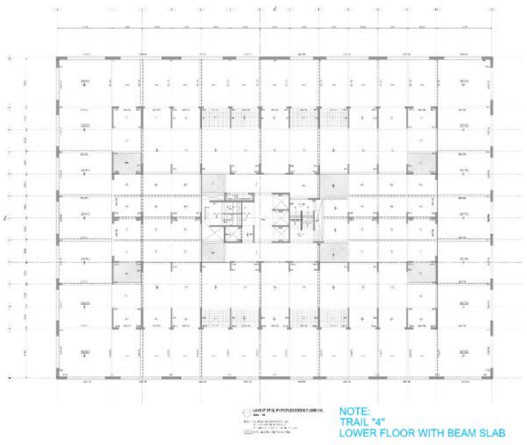


Figure 3.4 Lower floor with beam slab (Trail:04)

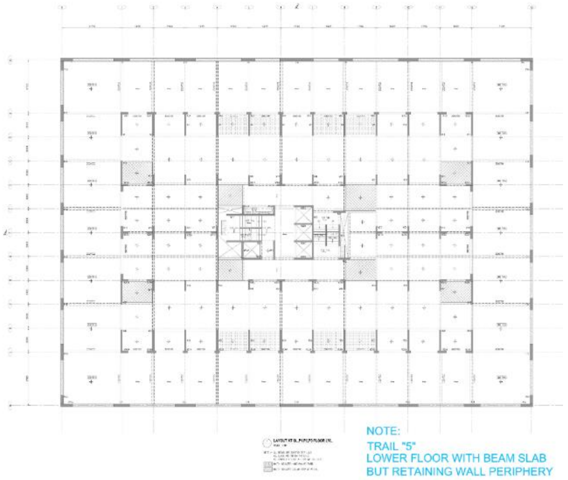


Figure 3.5 Lower floor with beam slab but retaining wall periphery (Trail:05)

Salient Features of building in Table 3.2. Loading is considered as per IS provision. Load combinations is used as per IS provision and description of this is given in Table 3.3.

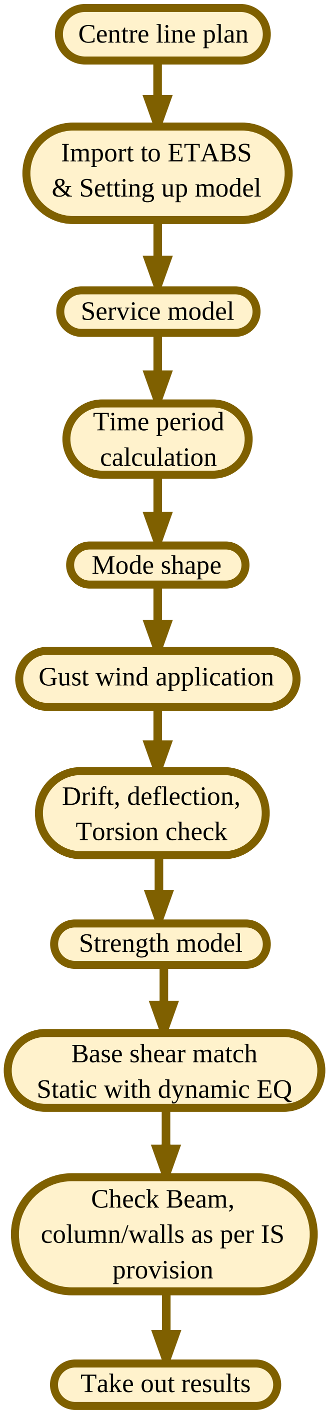
Table 3.2 Salient Features of building

Building description	
Building Type	Residential
Length in X direction (b) (Typical floor)	44 m
Length in Y direction (d) (Typical floor)	30 m
No. of Floors	GL + P1 to P3 + Edeck + 30 Typical + Terrace
Height of Building (Foundation to terrace)	111.6 m
Seismic Data	
Location	Mumbai
Zone Factor	0.16
Importance factor	1.5
Framing type	SMRF
Response Reduction Factor	4
Soil Type	1 (Hard)
Wind Data	
Location	Mumbai
Basic Wind speed	44
Terrain category	3
Structure class	1
Risk coefficient	1
Topography factor	1

Table 3.3 Load combinations

1	D 1.5 DL + 1.5 LL
2	D 1.5 DL + 1.5 LL ± 1.5 TR
3	D 0.8 DL ± 1.5 RSX / RSY
4	D 0.8 DL ± 1.5 RSZX / RSZY
5	D 0.9 DL ± 1.5 RSX / RSY
6	D 0.9 DL ± 1.5 RSZX / RSZY
7	D 1.2 DL + 1.2 LL ± 1.2 RSX / RSY
8	D 1.2 DL + 1.2 LL ± 1.2 RSZX / RSZY
9	D 1.5 DL ± 1.5 RSX / RSY
10	D 1.5 DL ± 1.5 RSZX / RSZY
11	D 0.9 DL ± 1.5 (WSX+0.75WDX-0.75WCX)
12	D 0.9 DL ± 1.5 (WSX+0.75WDX+0.75WCX)
13	D 0.9 DL ± 1.5 (WSX+WCX)
14	D 0.9 DL ± 1.5 (WSX+WDX)
15	D 0.9 DL ± 1.5 (WSX-WCX)
16	D 0.9 DL ± 1.5 (WSY+0.75WDY-0.75WCY)
17	D 0.9 DL ± 1.5 (WSY+0.75WDY+0.75WCY)
18	D 0.9 DL ± 1.5 (WSY+WCY)
19	D 0.9 DL ± 1.5 (WSY+WDY)
20	D 0.9 DL ± 1.5 (WSY-WCY)
21	D 1.2 DL + 1.2 LL ± 1.2 (WSX+0.75WDX-0.75WCX)
22	D 1.2 DL + 1.2 LL ± 1.2 (WSX+0.75WDX+0.75WCX)
23	D 1.2 DL + 1.2 LL ± 1.2 (WSX+WCX)
24	D 1.2 DL + 1.2 LL ± 1.2 (WSX+WDX)
25	D 1.2 DL + 1.2 LL ± 1.2 (WSX-WCX)
26	D 1.2 DL + 1.2 LL ± 1.2 (WSY+0.75WDY-0.75WCY)
27	D 1.2 DL + 1.2 LL ± 1.2 (WSY+0.75WDY+0.75WCY)
28	D 1.2 DL + 1.2 LL ± 1.2 (WSY+WCY)
29	D 1.2 DL + 1.2 LL ± 1.2 (WSY+WDY)
30	D 1.2 DL + 1.2 LL ± 1.2 (WSY-WCY)
31	D 1.5 DL ± 1.5 (WSX+0.75WDX-0.75WCX)
32	D 1.5 DL ± 1.5 (WSX+0.75WDX+0.75WCX)
33	D 1.5 DL ± 1.5 (WSX+WCX)
34	D 1.5 DL ± 1.5 (WSX+WDX)
35	D 1.5 DL ± 1.5 (WSX-WCX)
36	D 1.5 DL ± 1.5 (WSY+0.75WDY-0.75WCY)
37	D 1.5 DL ± 1.5 (WSY+0.75WDY+0.75WCY)
38	D 1.5 DL ± 1.5 (WSY+WCY)
39	D 1.5 DL ± 1.5 (WSY+WDY)
40	D 1.5 DL ± 1.5 (WSY-WCY)

IV. MODELLING AND ANALYSIS



► Time period calculation

h	**111.60 m**
Length (X)	44.00 m
Depth (Y)	30.00 m

Tx		**Tx = 0.075 x (h)^0.75/√Awx**	1.54494		
	MAX			**1.545**	sec
		0.09h/√b	**1.51**		
Ty		**Ty =0.075 x (h) 0.75/√Awy**	1.09		
	MAX			**1.834**	sec
		0.09h/√d	**1.83**		

Response spectrum analysis contains Response parameters, forces and displacements of structure. Figure 4.1 and Figure 4.2 shows 3D representation of ETABS model.

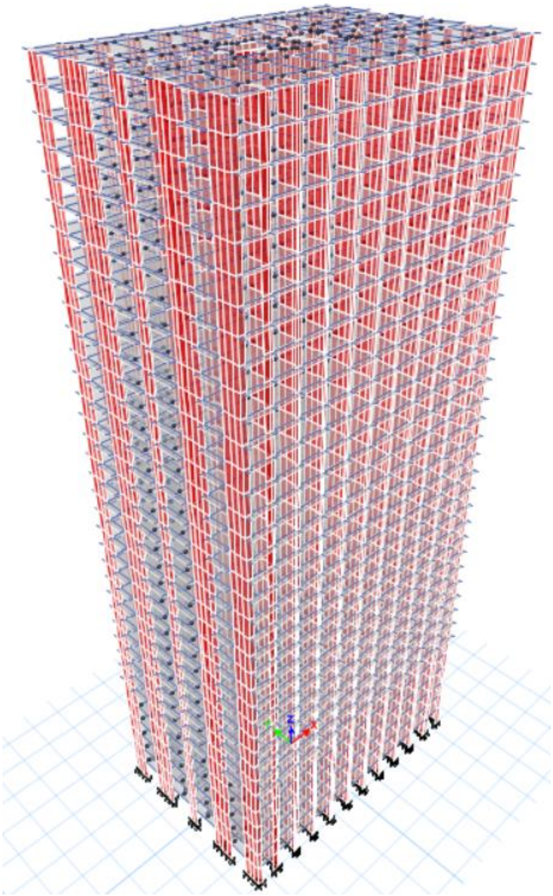


Figure 4.1 Tower only ETABS 3D model

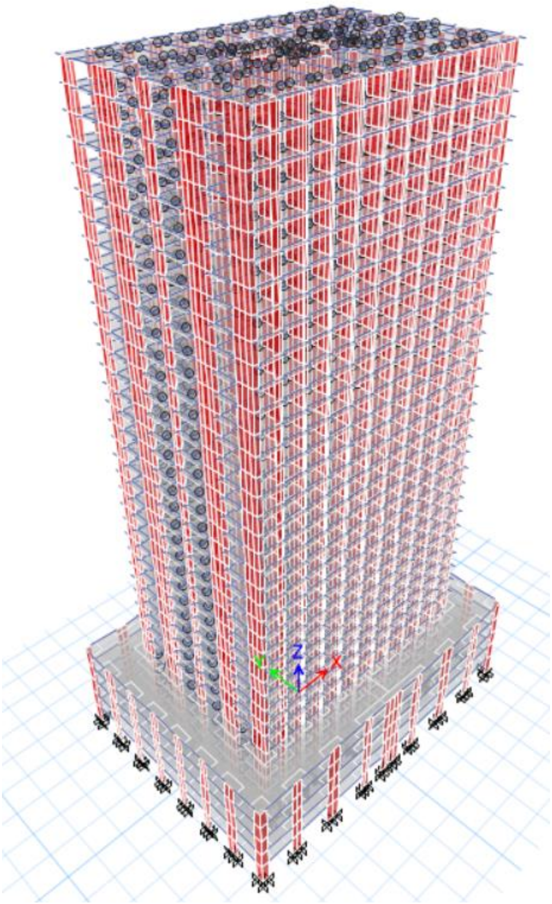


Figure 4.2 Tower + Non tower ETABS 3D model

Base reaction of static earthquake is cross check with hand calculation and it is coming almost same so model is error free. All the paraments are satisfied as per IS provision i.e. Drift, Deflection, Torsion irregularities etc.

V. RESULTS AND DISCUSSION

► Modal participating mass ratio

Model participation mass ratio indicates the percentage of structural mass of the model participating in a given direction and mode.

A summary of the periods and mass participation of the first three modes of the building options are provided in Table 5.1 and Figure 5.1.

Table 5.1 Time Periods and Modal Mass Participation Ratios

Nomenclature	Case	Mode	Period	Mass Participation			% DIFFERENCE
			sec	Ux	Uy	Rz	B/W Two modes
1.) MB_SE_T	Modal	*1*	**3.596**	**74.59**	0.07	0.00	
	Modal	*2*	**3.201**	0.07	**72.35**	0.08	**10.98**
	Modal	*3*	**2.483**	0.00	0.07	**75.57**	**22.43**
3.) MB_SE_T_N+F	Modal	*1*	**3.422**	**64.35**	0.07	0.00	
	Modal	*2*	**3.116**	0.07	**64.02**	0.03	**8.94**
	Modal	*3*	**2.287**	0.00	0.04	**54.83**	**26.60**
7.) MB_SE_T_N+F_RW	Modal	*1*	**3.216**	**57.55**	0.06	0.00	
	Modal	*2*	**2.931**	0.05	**58.06**	0.03	**8.86**
	Modal	*3*	**2.161**	0.00	0.04	**46.92**	**26.27**
11.) MB_SE_T_N+B	Modal	*1*	**3.444**	**65.01**	0.07	0.00	
	Modal	*2*	**3.135**	0.07	**64.59**	0.03	**8.97**
	Modal	*3*	**2.305**	0.00	0.04	**55.86**	**26.48**
15.) MB_SE_T_N+B_RW	Modal	*1*	**3.225**	**57.97**	0.06	0.00	
	Modal	*2*	**2.943**	0.06	**58.56**	0.03	**8.74**
	Modal	*3*	**2.167**	0.00	0.04	**47.56**	**26.37**

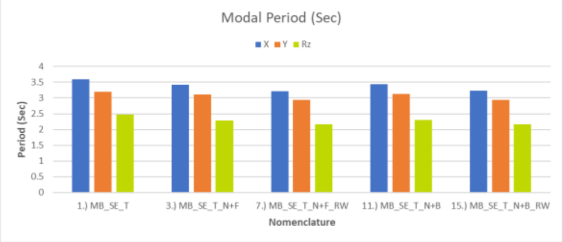


Figure 5.1 Time Period

► Lateral Story drift

Story drift is the lateral displacement of a floor relative to the floor below. Story drift is the horizontal movement of a building or structure due to the action of external forces, such as wind or earthquake.

All the elements comfortably meet the IS acceptance requirements in service and strength model. The drift levels are within the acceptable range (refer Figure 5.2, 5.3, 5.4, 5.5, 5.6, 5.7). As per IS 16700:2017 For earthquake load (factored) combinations the drift shall be limited to hi/250 i.e 0.004. and for wind load (unfactored) combinations the drift shall be limited to hi/400 i.e 0.0025.

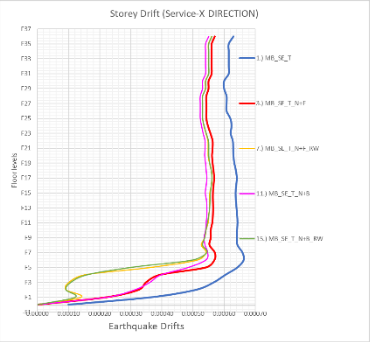


Figure 5. 2 Earthquake story drift in X- Direction

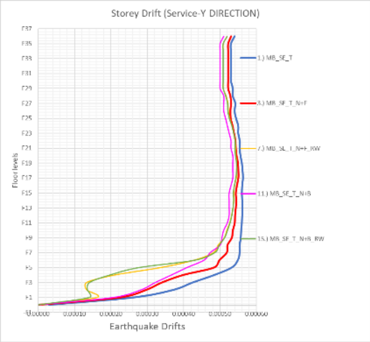


Figure 5. 3 Earthquake story drift in Y- Direction

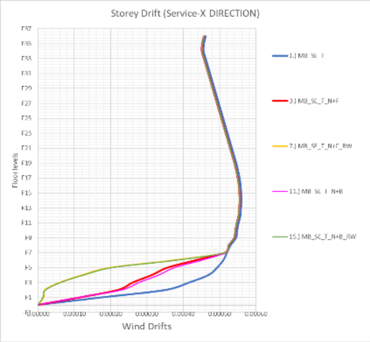


Figure 5. 4 Wind story drift in X- Direction

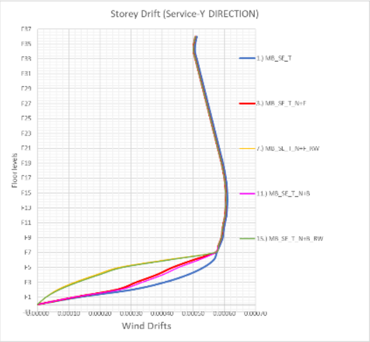


Figure 5. 5 Wind story drift in Y- Direction

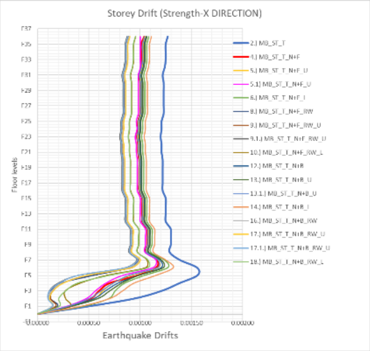


Figure 5. 6 Unscaled earthquake story drift in X-

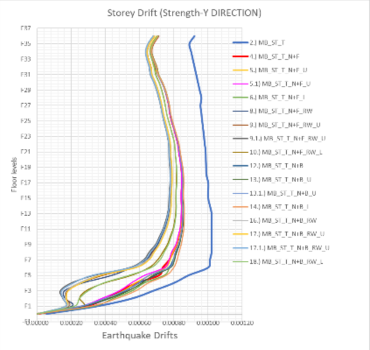


Figure 5. 7 Unscaled earthquake story drift in Y-

► Lateral Story deflection

Story displacement is the deflection of a single-story relative to the base or ground level of the structure. Intuitively, we can expect higher total displacement values as we move up the structure. So, a graph showing the story displacement vs. the height of the structure looks exactly like the deflected shape.

All the elements comfortably meet the IS acceptance requirements in Service and Strength model. The deflection is within the acceptable range (refer Figure 5.8, 5.9, 5.10, 5.11, 5.12, 5.13). As per IS 16700:2017 For earthquake load (factored) combinations the deflection shall be limited to hi/250. and for wind load (unfactored) combinations the deflection shall be limited to hi/500.

► Base shear and base moment

Base shear is an estimate of the maximum expected lateral force on the base of the structure due to seismic activity. It is calculated using the seismic zone, soil material, and building code lateral force equations. The base shear is equal to the sum of all the storey shear forces at different floors. Base moment is an estimate of the maximum expected moment at base of structure. Results are shown in Figure 5. 14 Base shear and Figure 5. 15 Base moment.

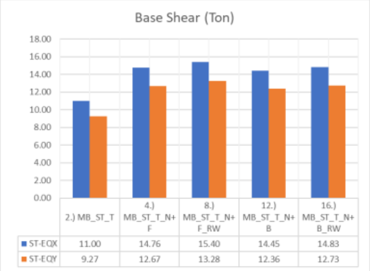


Figure 5. 14 Base shear (Ton)

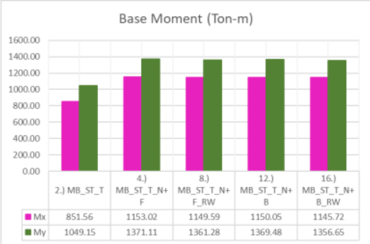


Figure 5. 15 Base moment

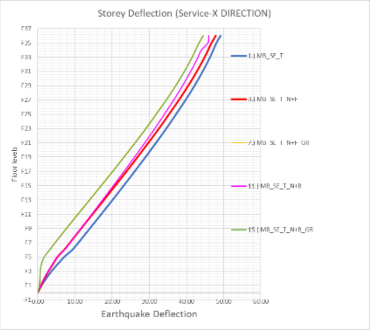


Figure 5. 8 Earthquake story deflection in X- Direction

Figure 5. 9 Earthquake story deflection in Y- Direction

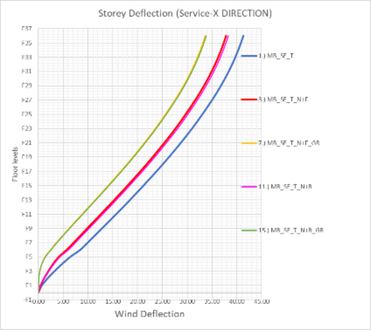


Figure 5. 10 Wind story deflection in X- Direction

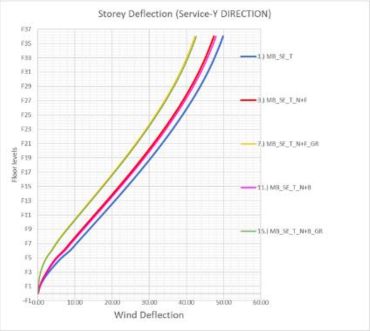


Figure 5. 11 Wind story deflection in Y- Direction

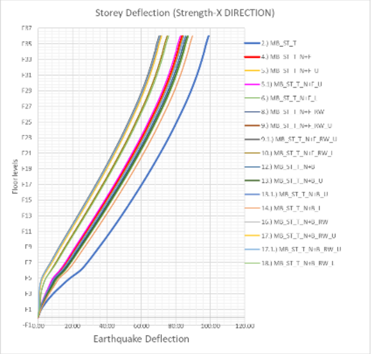


Figure 5. 12 Unscaled earthquake story deflection in

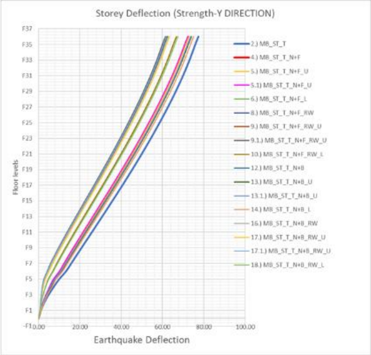
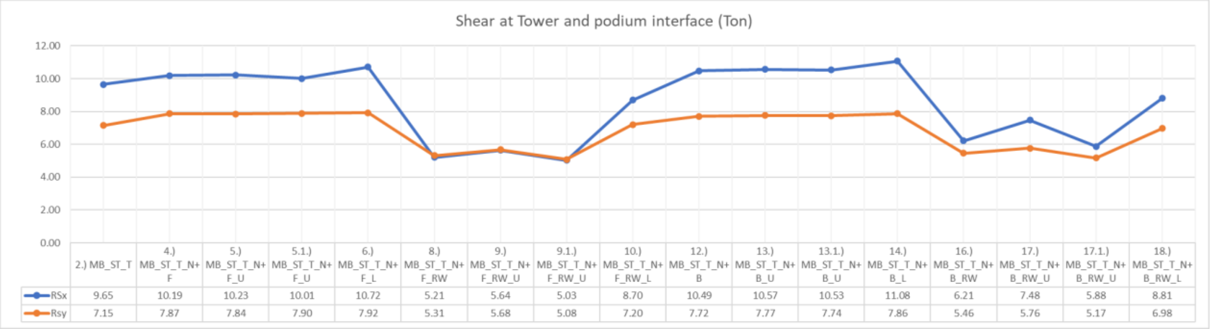
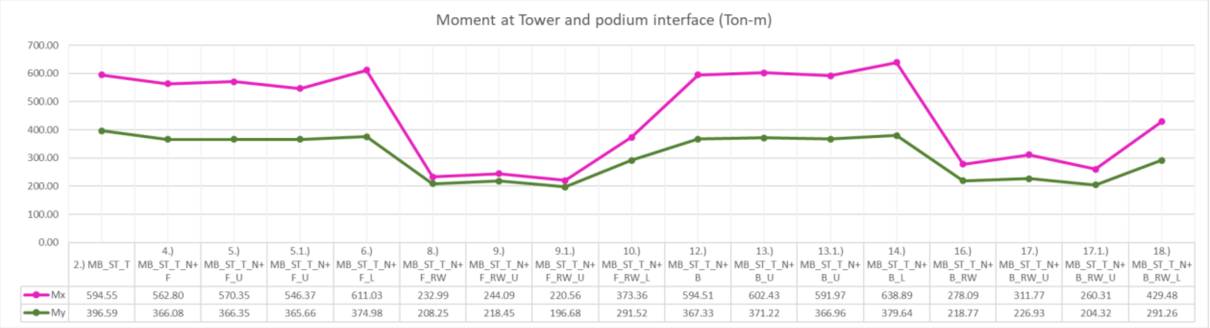


Figure 5. 13 Unscaled earthquake story deflection in



	2.) MB_ST_T	4.) MB_ST_T_N+F	5.) MB_ST_T_N+F_U	5.1.) MB_ST_T_N+F_U	6.) MB_ST_T_N+F_L	8.) MB_ST_T_N+F_RW	9.) MB_ST_T_N+F_RW_U	9.1.) MB_ST_T_N+F_RW_U	10.) MB_ST_T_N+F_RW_L	12.) MB_ST_T_N+B	13.) MB_ST_T_N+B_U	13.1.) MB_ST_T_N+B_U	14.) MB_ST_T_N+B_L	16.) MB_ST_T_N+B_RW	17.) MB_ST_T_N+B_RW_U	17.1.) MB_ST_T_N+B_RW_U	18.) MB_ST_T_N+B_RW_L
RSx	9.65	10.19	10.23	10.01	10.72	5.21	5.64	5.03	8.70	10.49	10.57	10.53	11.08	6.21	7.48	5.88	8.81
Rsy	7.15	7.87	7.84	7.90	7.92	5.31	5.68	5.08	7.20	7.72	7.77	7.74	7.86	5.46	5.76	5.17	6.98

Figure 5. 16 Shear at Tower and podium interface (Ton)



	2.) MB_ST_T	4.) MB_ST_T_N+F	5.) MB_ST_T_N+F_U	5.1.) MB_ST_T_N+F_U	6.) MB_ST_T_N+F_L	8.) MB_ST_T_N+F_RW	9.) MB_ST_T_N+F_RW_U	9.1.) MB_ST_T_N+F_RW_U	10.) MB_ST_T_N+F_RW_L	12.) MB_ST_T_N+B	13.) MB_ST_T_N+B_U	13.1.) MB_ST_T_N+B_U	14.) MB_ST_T_N+B_L	16.) MB_ST_T_N+B_RW	17.) MB_ST_T_N+B_RW_U	17.1.) MB_ST_T_N+B_RW_U	18.) MB_ST_T_N+B_RW_L
Mx	594.55	562.80	570.35	546.37	611.03	232.99	244.09	220.56	373.36	594.51	602.43	591.97	638.89	278.09	311.77	260.31	429.48
My	396.59	366.08	366.35	365.66	374.98	208.25	218.45	196.68	291.52	367.33	371.22	366.96	379.64	218.77	226.93	204.32	291.26

Figure 5. 17 Moment at Tower and podium interface (Ton-m)

►Eco-deck level shear and moment

Storey shear and moment is the horizontal force and moment that is transmitted through a building's walls and floors to resist lateral loads. Result is shown in Figure 5. 16 Shear at Tower and podium interface and Figure 5. 17 Moment at Tower and podium interface.

►Axial force in wall (W18A)

Axial force is the force that acts in the direction of the axis of a body. This force may be tensile or compressive. Axial forces are increasing linearly as goes to lower level as shown in Figure 5. 18 Axial force, Kn (W18A).

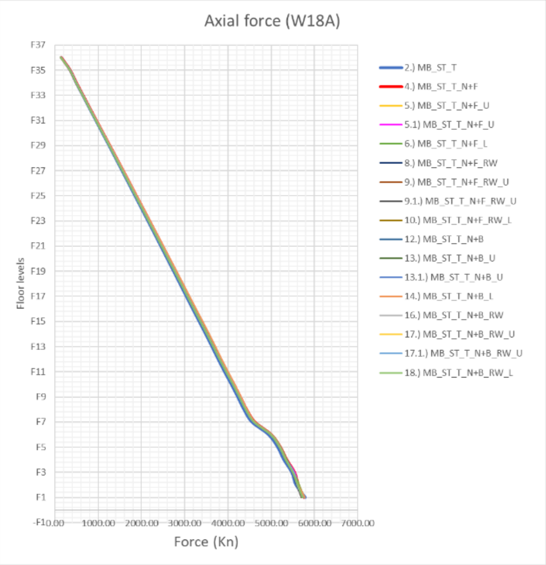


Figure 5. 18 Axial force, Kn (W18A)

► Shear force and bending moment in wall

Shear force refers to the force that acts parallel to the cross-section of a structural element, while bending moment is the moment that occurs when an external force is applied to the element causing it to bend. Refer Figure 5. 19 Shear force, Kn (W18A) and Figure 5. 20 Bending moment, Kn-m (W18A).

►Shear force and bending moment for non-tower area wall P5

Observations compared between tower portion wall (W18A) and NTA portion wall (P5). Refer Figure 5. 19 Shear force, Kn (W18A), Figure 5. 20 Bending moment, Kn-m (W18A), Figure 5. 21 Shear force, Kn (P5) and Figure 5. 22 Bending moment, Kn-m (P5).

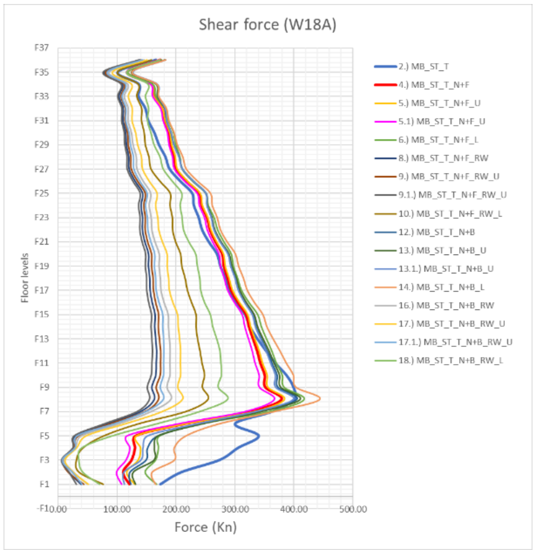


Figure 5. 19 Shear force, Kn (W18A)

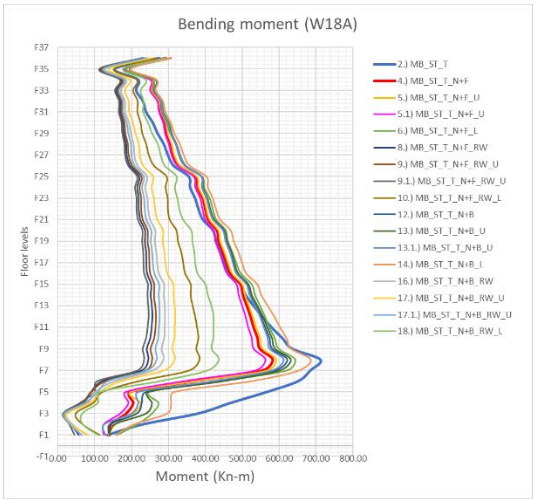


Figure 5. 20 Bending moment, Kn-m (W18A)

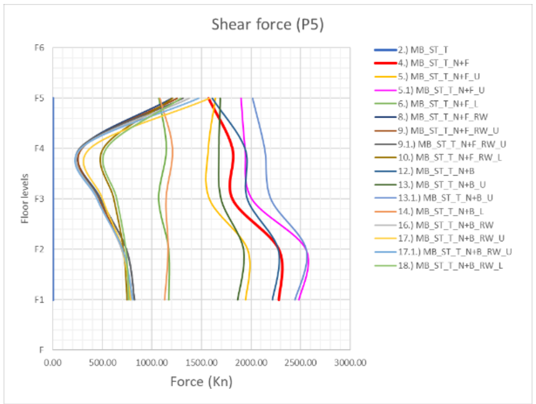


Figure 5. 21 Shear force, Kn (P5)

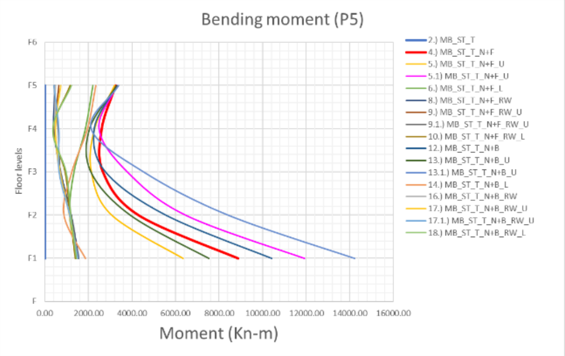


Figure 5. 22 Bending moment, Kn-m (P5)

VI. SUMMARY & CONCLUSION

1. All the models designed as per Indian standard and from result it can be seen that the building drift, deflection is well within permissible limit.

2. From the results it is found that building with retaining wall is stiffer than other models.

As in this model more amount of backstay effect is occur due to this drift and deflection value is less.

But on other side i.e. cost wise it is uneconomical because

i. More concrete quantity (≈ 15% ↑).

ii. Reinforcement quantity will also increase as we have to provide minimum % of steel in all structural element. (As forces produce less because it is shared by retaining wall but in retaining wall itself we have to provide minimum reinforcement of 0.25% of gross concrete area)

iii. Labor cost will be more as we have to do more cocreating and reinforcement.

iv. It is time consuming.

v. Ventilation issue will be there.

vi. Maintenance cost will increase.

3. Other models where basement is not there then we can use tower area with non-tower area as here also backstay effect will occur but it is less than as compared to retaining wall model.

4. Form result it is observed that tower with non-tower area with same moment frame arrangement we can use any structural arrangement for non-tower area portion i.e., beam-slab or flat slab arrangement.

In both type of model building nature is like propped cantilever and drift and deflection value is less for flat slab arrangement but in both the case values are within permissible limits.

Beam-slab arrangement

Pros:

i. Analysis and detailing is easy.

ii. Ductile detailing possible in beams it is act better when earthquake sticks.

Cons:

i. It will reduce clear height of floor.

ii. Larger size of conduit is not possible in beams.

iii. Stiffness of diaphragm is less as compared to flat slab.

Flat slab

Pros:

i. Stiffness of diaphragm is more.

ii. Clear floor height is more.

Cons:

i. When earthquake hit to structure then it will easily crack first because ductile detailing is not possible in slab so generally in higher seismic zone (4 or 5) partially avoid flat slab.

ii. Analysis is complicated.

5. For reinforcement we have check all the model i.e., Direct load path, Tower+NTA, Upper bound and lower bound model and we have to provide maximum of reinforcement from all of above model.

6. From result it is found that modified upper bound modifier has little more impact than standard upper bound modifier.

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