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Seismic Analysis of Twin Tower Structures

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Abstract: In today's world, new concepts for skyscraper construction are required to mitigate the negative effects of seismic and wind forces. Since the world's most populous cities are experiencing land shortage, in this area tall buildings act as very important roles in modern cities. Due to the speedy increase in population and reduction in accessibility of land, vertical accommodation is obtaining a lot of preference which is resulting in vertical town development. Nowadays tall buildings rise higher and higher, with more and more complex and individual plan and elevation, such as multi-tower buildings. The multi-tower buildings refer to two or more towers connected with one large podium or conjunction parts at different levels. It is well known that the podium and conjunction parts shall be designed very carefully to meet the internal force and thedeformation between towers. Nowadays, when building multistory building, height is not the only pursuit. More unique forms are in trend to show the rich connotation and vitality of buildings. Connected twin tower structures conform to these requirements, and many connected structures in different forms have been or are being built in recent years. In present research work considering effects of influencing parameters like the height of the tower, connection with podium and depth of podium with two parallel towers (Twin-Tower). The main objective of this study is to analyze twin tower structure G+4 podium+25 floor building using linear dynamic earthquake analysis. We have considered four models with different combinations of twin tower with podium to achieve desirable results in terms of story drift, displacement and base shear under seismic forces for seismic zone IV and medium type of soil using Response Spectrum Analysis with the help of ETABS v19 software.
Keyword: Twin Tower Structure, Podium, Etabs Software Packages.

I. INTRODUCTION

Structural development in the metro city has rapidly increased as there are many high-rise construction projects that have been carried out. Structural analysis is the fundamental part of the design of the high-rise structure which shad the same height and same geometry. It is effective solution for residential purpose however; few of the challenging problems have been facing such as vehicle parking and other basic enmities space. Therefore, many structures provide a common either in single, multiple floors, or underground basements parking in this kind of structure often seen in the residential as well as a commercial complex. It is more important to remember that in different parts of the world there are difference in seismic forces due to different seismic zones. Engineers and architects are making various efforts in this direction. Twin towers play an important role in addressing such issues because they give the system more stability, particularly in seismically active areas. Bridge is provided at a suitable height to balance the movement and to link two buildings.

II. TWIN TOWER STRUCTURE

In architecture, the term "twin towers" refers to two tall buildings that are virtually identical in appearance and height, and are commonly built close together as part of a single complex. Recent days, Twin towers are vastly in demand due to its architectural and structural design, individual plan along with more space with same foundation support. Conventional practices across the world to combat the seismic forces and wind effects as it is more important phenomenon now a days because of increasing construction of skyscraper are obsolete and need new practices and arrangements because the architectural and structural demand is poles apart from earlier construction. To full the increasing demand of living space along with commercial space various efforts are made to fulfill the need of hour. Twin tower is the best example to rectify such kind of problem which not only comply the demand but also a mark of social and economic prosperity.

III. PODIUM STRUCTURE

Podium or podia, in architecture, any of various elements that form the “foot,” or base, of a structure, such as a raised pedestal or base, a low wall supporting columns, or the structurally or decoratively emphasized lowest portion of a wall. Load bearing elements such as walls and columns of superstructure above the podium slab may not align with substructure load bearing elements below. Podium slabs are special type of floor system that transfers loads from a steel or wood frame structure above the slab to walls and columns below. Typically, the superstructure built from wood, metal studs or structural steel. Generally, this type of slab constructed and placed at ground level parking with 3-4 levels of conventional residential construction above. The name is derived from the “podium” that separates the two occupancies.

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IV. SEISMIC ANALYSIS

Earthquake is a natural procedure of shaking ground due to movement of tectonic plate. The force of earthquake is random so the design engineer need to care full predict of these force and analyze the structure under these random force. Earthquake loads are to be carefully modeled so as to assess the real behavior of structure with a clear understanding that damage is expected but it should be regulated. Earthquake plays an influential role in analysis and design of structures. Seismic analysis is a branch of structural analysis that involves calculation of a building's (or non building's) earthquake response. Analysis is the process to determine the behavior of structure under specified load combinations.

A. Equivalent Static Lateral Force Method –

This is a very simple method of analysis. The main assumptions in these method are that the lateral force is equivalent to actual loading. In these method, the Base Shear which is total horizontal force on the structure is calculated on the basis of the structure mass and its fundamental time period of vibration. The total design lateral force or design seismic base shear (V_B) along any principal direction shall be determined with the help of following expression:

$$V_B = A_h W$$

Where,

A_h = Design horizontal acceleration spectrum using fundamental natural period T_a,W = seismic weight of all the Building

The Design horizontal Seismic Coefficient A_h for a Structure will be evaluated by expression:

$$A_h = \frac{Z\ I\ Sa}{2\ R\ g}$$

Z = Zone Factor,

I = Importance Factor

Sa/g = Average response Spectrum Coefficient using soil type and fundamental time periodR = Response reduction factor

Above the Value of W, Z, I, Sa/g, and R are dependent on the IS 1893 (Part 1): 2016

B. Response Spectrum Method

Tuned Mass Damper (TMD) is a devises which combination of a mass, a sprig and a damper that attached to structure for reducing the dynamic response of structure. They work on the principal that the frequency of damper is tuned to particular structure frequency. energy is dissipated the damper inertia force acting on the structure. The properties of dampers are calculating by the following formula.

V. MODELING

In present study, four models of three dimensional R. C. Frame Twin Tower Structures are modeled for G+4 Podium+25 Floor building with symmetrical plan area of 3250 m2. The R.C. frame structures are designed and analyzed according to IS 456:2000 and IS 1893:2016 by using ETABS software. Non linear Dynamic Analysis performed on four symmetrical R.C. Frame Structures: Twin Tower connected by Podium, Separate Twin Tower without Podium, Separate Twin Tower with Podium, Single Tower with full Podium. The Behavior of Twin Structures have been studied in terms of Displacement, Base Shear and Drift Ratio.

A. Structural Modeling

Table 1: Structural properties of model

Geometric Details		
Structure	Twin Tower Structure	
Types of Buildings	RC Frame Structure	
Plan Area	3250 M^2	
No. of Story	G+29	
Area of Podium	50mx65m	
Area of Tower A	15mx40m	
Area of Tower B	15mx40m	
Gap between Tower A and Tower B	25m	
Typical Story Height	Story 1 to 5	4m
	Story 6 to30	3.5m
Bottom Story Height	2m	

Lift Wall	2mx2m	
Elevation	105.5m	
Material Properties (Concrete)		
Grade of concrete	M-40	
Weight per unit Volume(KN/M^2)	25 KN/m^3	
Modulus of Elasticity, E (MPa)	31622.78	
Poisson,s Ratio U	0.2	
Coefficient of Thermal Expansion,α (1/°C)	5.5x10^{-06}	
Shear Modulus, G (MPa)	13176.16	
Material Properties (Steel Rebar)		
Grade of Steel	Fe-550	
Weight per unit Volume(KN/M^2)	76.97 KN/m^3	
Modulus of Elasticity, E (MPa)	2x10^5	
Coefficient of Thermal Expansion	0.0000117	
Member Properties		
Slab Thickness (mm)	Story 1 to 5	200mm
	Storey 6 to30	180mm
Size of Beams	Story 1 to 5	400mmx600mm
	Storey 6 to 30	300mmx500mm
Size of Column	Story 1 to 5	1200mm diameter
	Storey 6 to 16	1000mmx1000mm
	Story 17 to 30	700mmx700mm
Lift Wall Thickness	250mm	
Primary Load		
Floor Finishing Load (Dead Load)	1.5 KN/m^2	
Staircase Load	2 KN/m^2	
Live Load	3 KN/m^2	
Wall Load (on Each Beam)	Story 1 to 4	18KN/m
	Story 5 to 29	14.8KN/m
Seismic Properties		
Seismic Zone	IV	
Zone Factor (Z)	0.24	
Response Reduction Factor (R)	5	
Importance Factor (I)	1.5	
Soil Type	II	
Damping Ratio	0.05	
Analysis Software : ETABS 2019		

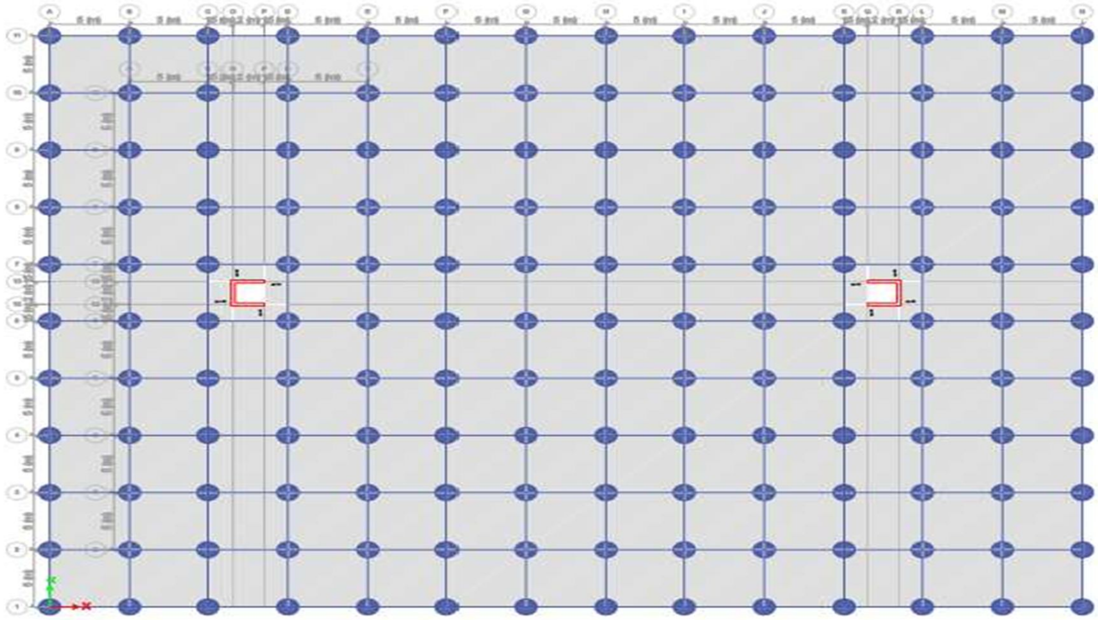

Figure 1 – Plan View of Podium

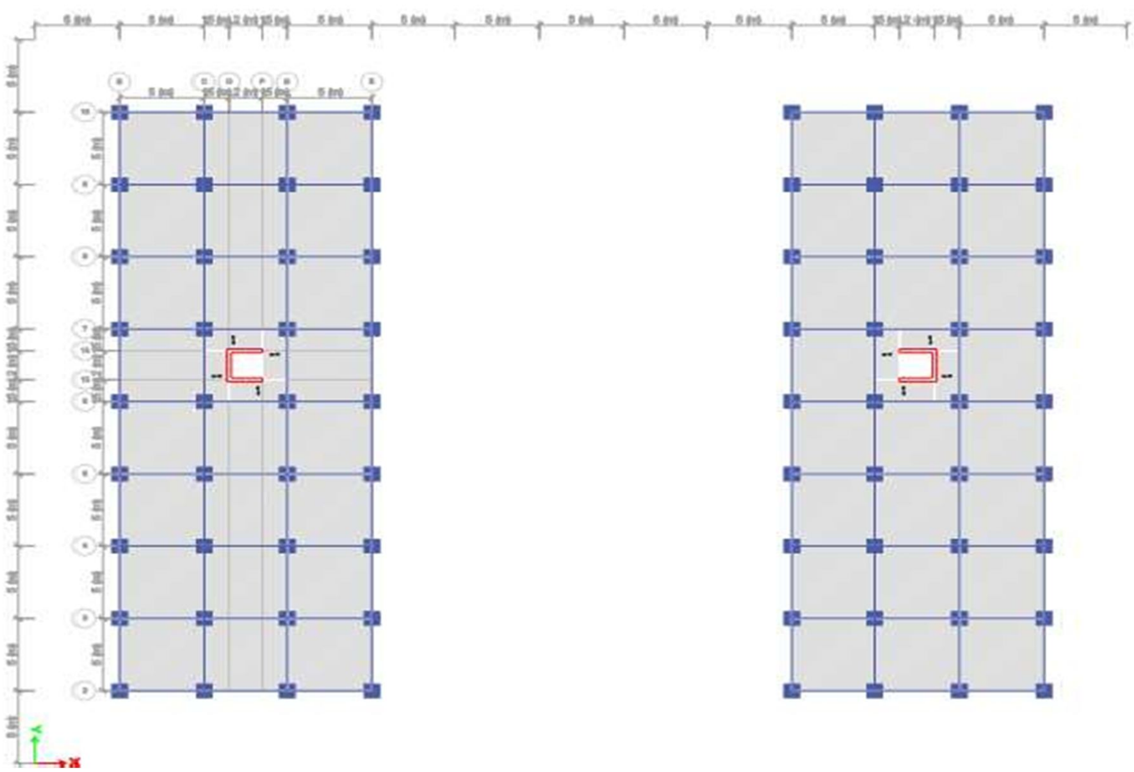

Figure 2 – Plan View of Tower A and Tower

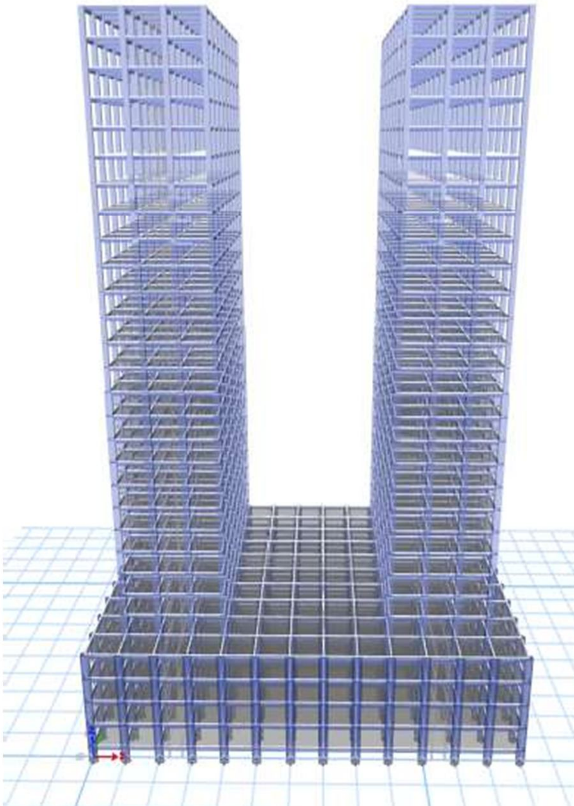

Figure 3 – 3D View of Model 1

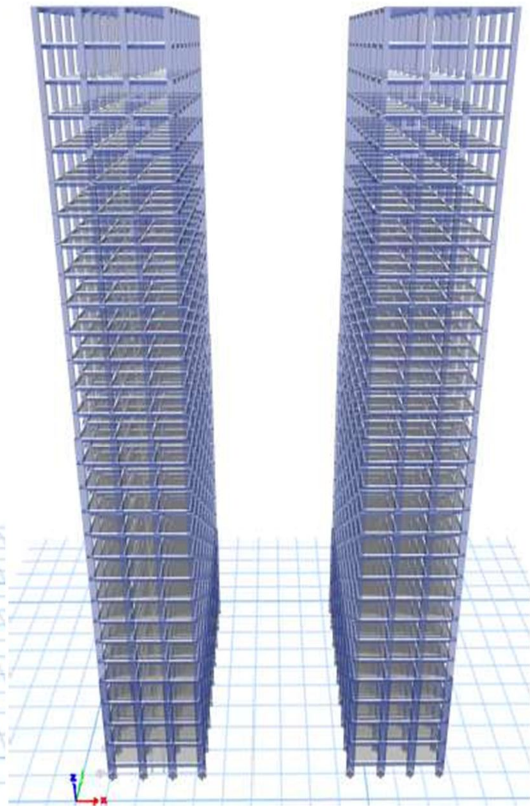

Figure 4 – 3D View of Model 2

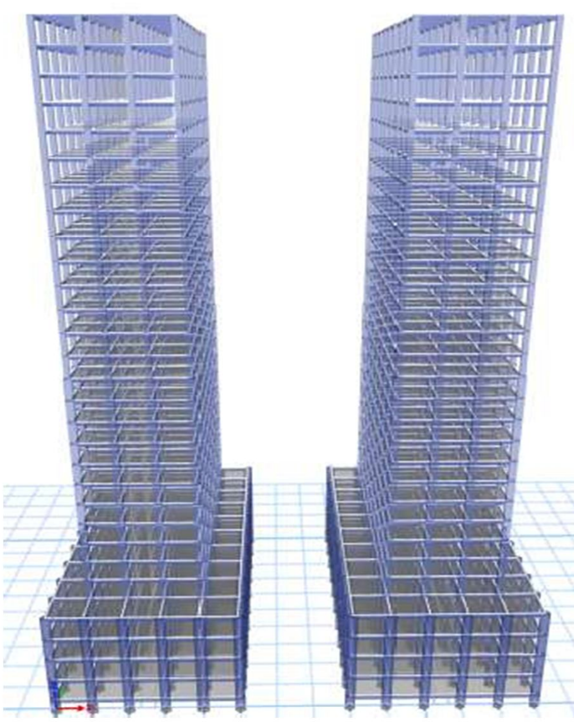

Figure 5 – 3D View of Model 3

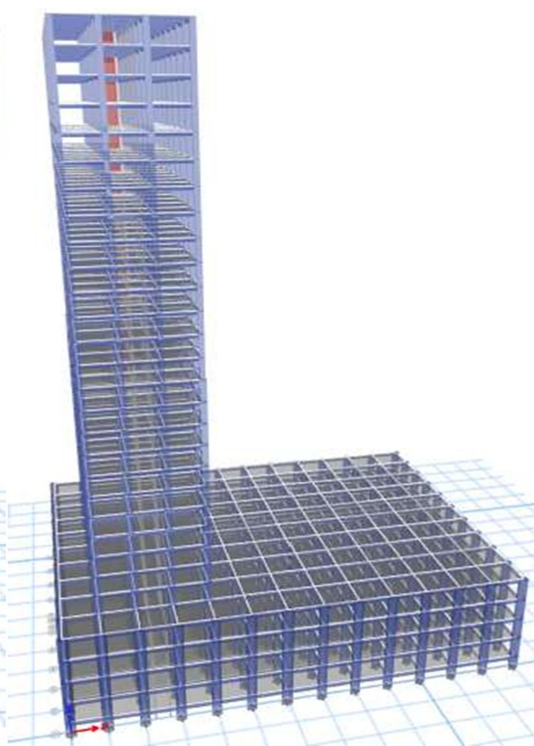

Figure 6 – 3D View of Model 4

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B. Design Properties

Table 2: Properties of Design Parameters

Parameter	Value
Mass Multiplier for Load Patterns	
Load Pattern	Multiplier
Dead	1
Live	0.5
Modal Load Case Data	
Load Case Subtype	Eigen
Maximum Number of Modes	12
Minimum Number of Modes	1
Stiffness Type	P-Delta

VI. RESULT AND DISCUSSION

The dynamic analysis of seismic loads are being carried out in accordance with the Indian Codes. The result in terms of displacement, base shear and drift ratio are compared for all four model in both X-direction and Y-direction by Equivalent Static Lateral Force Method and Response spectrum method of analysis.

A. Equivalent Static Lateral Force Method:

The displacement, and drift ratio due to earthquake forces in X and Y direction for all four model are shown in graphical representation below figure 7, 8, 9 and 10 respectively.

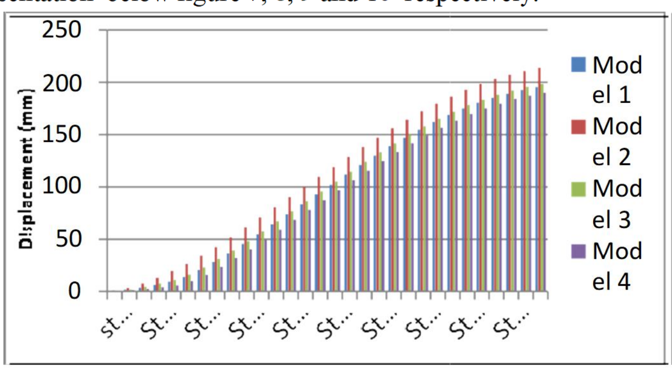

Figure 7 – Displacement due to Equivalent Method in X direction for all Models.

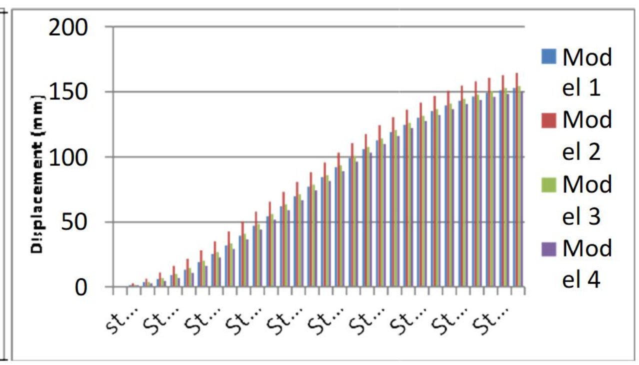

Figure 8 – Displacement due to Equivalent Force Force Method in Y direction for all Models.

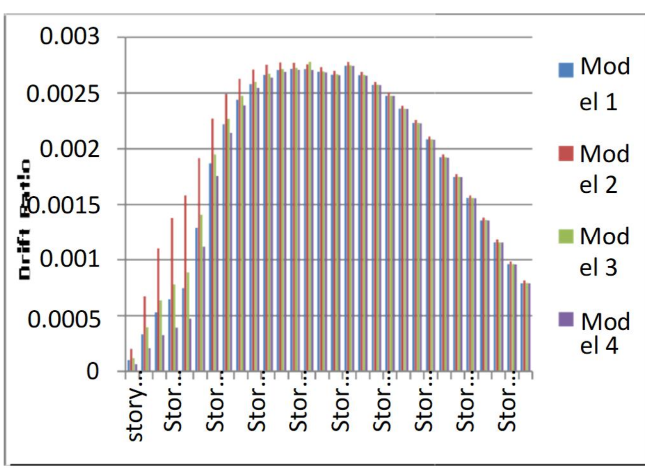

Figure 9 –Drift Ratio due to Equivalent Method in X direction for all Models.

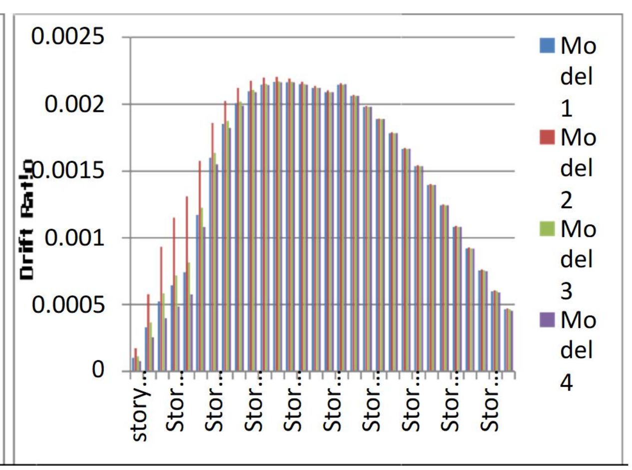

Figure 10 – Drift Ratio due to Equivalent Force Force Method in Y direction for all Models.

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B. Response Spectrum Method

The displacement, drift ratio and base shear due to response spectrum analysis in X and Y direction for all four model are shown in graphical representation below figure 11, 12, 13, 14 and 15 respectively.

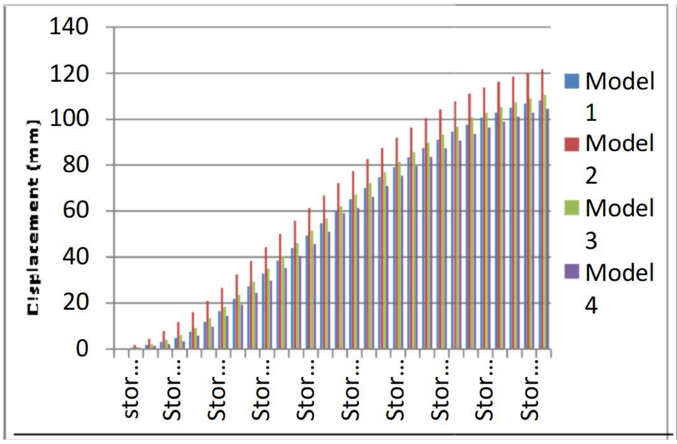

Figure 11 – Displacement due to Response Spectrum Method in X direction for all Models.

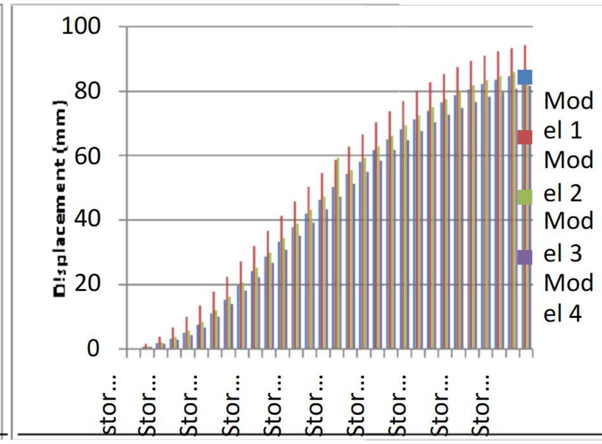

Figure 12 – Displacement due to Response Spectrum Method in Y direction for all Models.

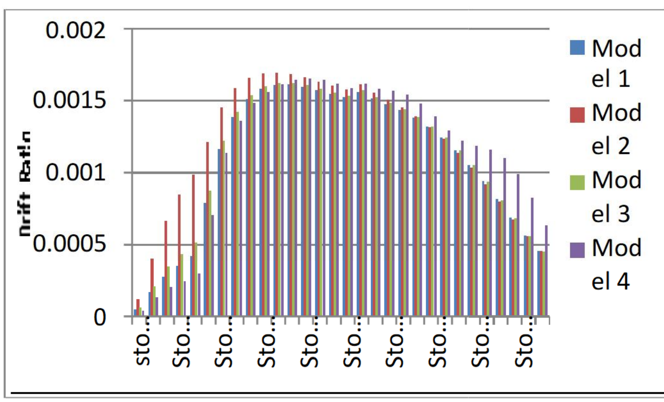

Figure 13 – Drift Ratio due to Response Spectrum in X direction for all Models.

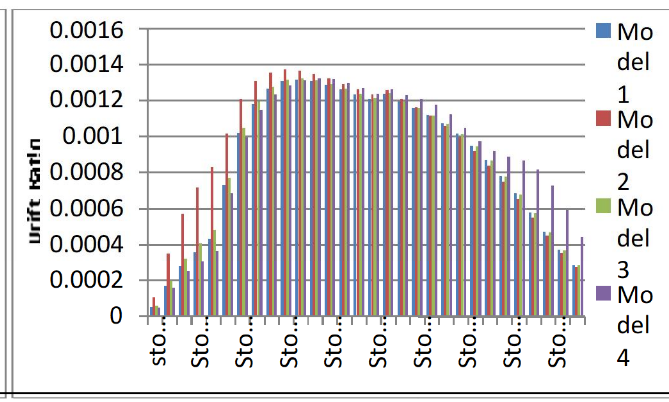

Figure 14 – Drift Ratio due to Response SpectrumMethod Method in Y direction for all Models.

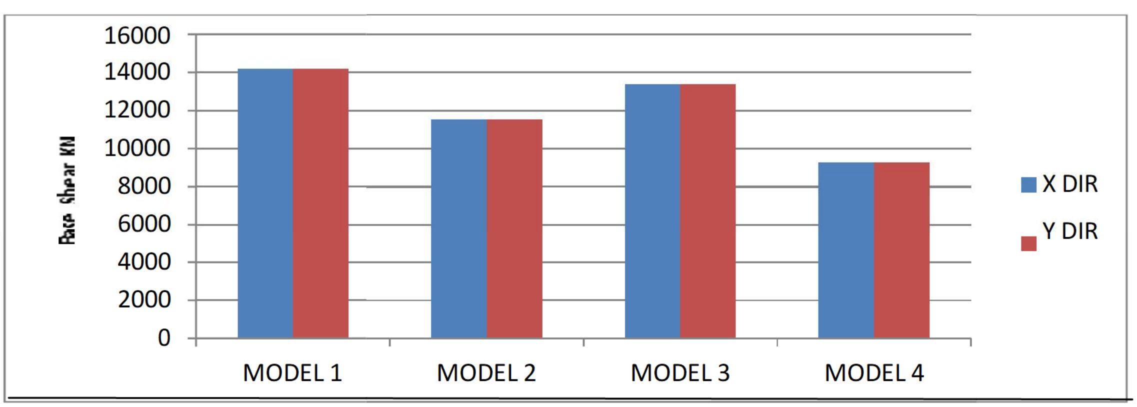

Figure 15 – Base Shear in both X and Y direction for all model.

VII. CONCLUSION

This study explains the behavior of all four modeled structures such as Twin Tower connected by Podium, Separate Twin Tower without Podium, Separate Twin Tower with Podium, Single Tower with full Podium under the performance of dynamic loads from which the following conclusion can be drawn, based on the result:

A. The analysis shows that the displacement and drift ratio of structure have greater value in the case of tower without podiumand same have lesser value is less of tower with podium.
B. The value of displacement due to equivalent static lateral force method in X direction increased by 9.26%, 1.57% and decreased by 2.88% for model 2, model 3 and model 4 respectively with respect to model 1.
C. The value of displacement due to equivalent static lateral force method in Y direction increased by 7.63%, 1.32% anddecreased by 2.33% for model 2, model 3 and model 4 respectively with respect to model 1.
D. The value of displacement due response spectrum method in X direction increased by 12.45%, 2.13% and decreased by 3.54% for model 2, model 3 and model 4 respectively with respect to model 1.
E. The value of displacement due response spectrum method in Y direction increased by 10.21%, 1.34% and decreased by 4.56% for model 2, model 3 and model 4 respectively with respect to model 1.
F. The value of base shear in X and Y direction decreased by 18.82%, 5.76% and decreased by 34.64% for model 2, model 3 and model 4 respectively with respect to model 1.
G. The value of drift ratio due to equivalent static lateral force method in X direction increased by 1.12%, 0.07% and decreased by 0.14% for model 2, model 3 and model 4 respectively with respect to model 1.
H. The value of drift ratio due to equivalent static lateral force method in Y direction increased by 1.70%, 0.18% and decreased by 0.13% for model 2, model 3 and model 4 respectively with respect to model 1.
I. The value of drift ratio due to response spectrum method in X direction increased by 4.47%, 0.68% and decreased by 2.11% for model 2, model 3 and model 4 respectively with respect to model 1.
J. The value of drift ratio due to response spectrum method in Y direction increased by 3.86%, 0.45% and decreased by 0.38% for model 2, model 3 and model 4 respectively with respect to model 1.

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