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Study on dominance of wind and earthquake loads on height of RC buildings.

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ABSTRACT
The aim of this paper has been to study the behaviour of multi-storeyed buildings under naturally occurring wind and earthquake loads. Using the software ETABS, we have simulated a multi-storeyed building which is experiencing a basic wind speed of 55 m/s and is located in an Earthquake Zone V. Multi-storeyed buildings today are designed to withstand earthquake forces using the recommendations suggested by the IS 1893:2016 code or to withstand the wind forces by using IS 875:2016 code forwind loads, in order to ensure that it remains an economical endeavor. The data from the simulation has helped us identify the approximate height of a building at which wind loads trump the effects of earthquake load as well as determining which design parameters are best suited for low-rise and high-risebuildings.

I. INTRODUCTION

An approximate 2.4% of earth's land is occupied by India while contributing 17.5% to the world's population making it one of the most densely populated large countries in the world. As of 2018, World Bank census data suggests that 454.93 people reside per square kilometer. The ever-increasing population has led to an acute shortage of land prompting the advent of high rise residential and commercial towers. Moreover, India has a very diverse landscape which is subject to various different weather and natural phenomena such as Hurricanes, storms, monsoons, earthquakes etc. These require mitigation planning in order to keep man-made structures standing on their foundation.

Apart from the dead load and force of gravity acting on a multistoried building, the increase in height of the structure invites other varying forces such as Wind Load and Earthquake load to act on it. The height of the structure varies directly with the possibility of lateral forces and movement which may lead to catastrophic failures in case a natural disaster strikes, creating a need to design structures with required considerations.

A horizontally acting load on a multistoried building creates a moment which could overturn the building as well as giving rise to lateral deflections inducing a large amount of stress into the structure or possibly causing the structure to sway or vibrate. Earthquakes, cyclones and strong winds are random acts of God that cannot be predicted in advance and hence require mitigations in design. What we can predict is how prone the area in question is to these disastersbased on various factors such as distance from the coast, the seismic structure of the land etc. A few prominent cities that are prone to Seismic and Wind activity are Guwahati (Zone V), Srinagar (Zone V), Delhi (Zone IV), Mumbai (Zone III and Wind Speed 44 m/s), Kolkata (Wind Speed 50 m/s) and Chennai (Zone 3). Multi-storied buildings are designed by factoring in the effects of either Wind Load or Seismic Load; this is because it is highly improbable that both types of loads occur at the same instant. For a building that is subject to both these loads, by taking considerations for the dominant load we are able to counter the effects of both. The main objective is to determine the primary deflection causing load on the structure. Moreover, designing a building by taking in considerations for Wind load and Earthquake load is not economically feasible.

The dominancy of wind load and earthquake is determined in different cases by measuring the lateral deflections in each case. Structures are subjected to 3 different deformation parameters when a lateral load is applied; Storey Drift, Storey Displacement and Storey Shear.

<u>Storey Displacement</u>: The total displacement of a particular storey relative to the ground. The IS Code prescribes maximum permissible limits which require strict adherence.

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Storey Drift: This deformation helps us determine the relative lateral movement of a level to the level directly above or below it. It is measured as the ratio of displacement of two consecutive floors to the height of a floor. The IS Code dictates that the maximum permissible value of storey drift should under no circumstances, exceed 0.004 times the storey height.

Storey Shear: The sum of all design lateral forces at each level above the level in consideration.

A comparative analysis of these lateral deformations allows us to determine the dominant load acting on the structure, as we increase its height.

1.1 Effect of Earthquake on Multi-Storied Buildings-

- Earthquake tremors and jolts effectuate inertial forces which dissipate into the ground after passing down from the top levels through slab and beams, into columns and walls, transferring the force to the foundation.
- Earthquake tremors originate sub-terrain, and hence apply force on the foundation of a building. This causes the foundation to come into motion while the higher levels of the building remain at rest.
- Therefore earthquake load causes shearing of the structure at joints and other points of the structure which are susceptible to failure.

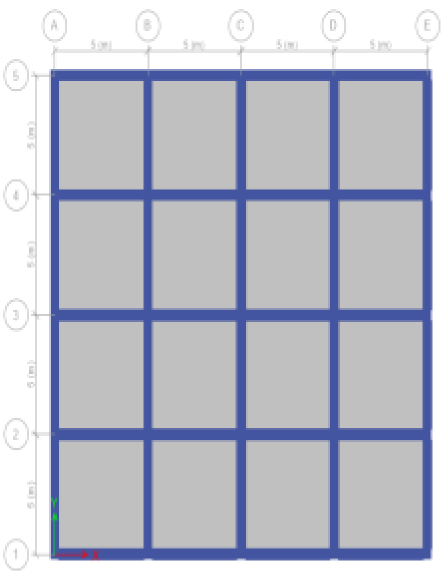
1.2Effect of Wind on Multi-Storied Buildings-

- The effect of wind load varies directly with the height of a multi-storey building,
- It also depends on the velocity of the wind, as well as the total surface area of the building which is attacked by the wind.
- The effects of wind on a multistoried building can be broadly categorized into 3 types- static, dynamic and aerodynamic.
- Factors such as structural stiffness, mass damping, architectural shape and form, govern the response of a multi-storey building to lateral loads, especially wind load.

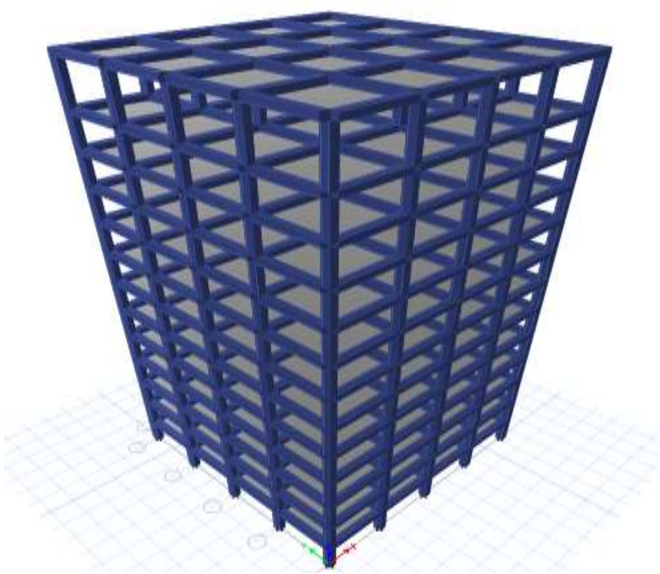
II. METHODOLOGY

In order to simulate the required conditions on a 3-D model of a multistoried building, we have used the E-TABS software, which has helped us analyze the lateral loads. The references used are all based on the IS Code and the building is designed for construction in Agartala (Wind speed = 55 m/s, Zone V). Our simulation has a 20 x 20 m^2 square configuration, as buildings with this type of configuration perform best seismically.

The base runs 20 m in both directions, X – axis and Y – axis and the area is divided into 16 congruent bays. The depth of slab is 125 mm throughout. The size of columns is 400 mm x 400 mm, size of beam is 230 x 450 mm and the height of a floor is 3 meter. The grade of concrete used is M25, the grade of rebar is Fe415, the concrete density is 25 Kn/m^3 and the brick density is 19 Kn/m^3.



Plan View



3-D View

S.N	Seismic Data	As per IS 1893 (Part-1):2016
1	Zone	V
2	Zone factor	0.36
3	Importance Factor (I)	1.2
4	Soil type	Type II (Medium stiff)
5	Response Reduction Factor ®	5 (SMRF)
6	Damping Ratio	5%
7	Earthquake Load	As per IS 1893 (part-1):2016

S.N	Wind Data	AS Per IS 875 : 2016
1	Wind Speed	55 m/s
2	Terrain Category	2
3	Structure Class	B
4	Risk Coefficient (k1)	1
5	Terrain, height, and structure size (k2)	1.18
6	Topography Factor (k3)	1.40
7	Wind Load	As per IS 875: Part 3

After selecting the optimal model configuration, we assigned the material and structural properties of its components. Keeping the base configuration and material properties constant, the height of the building was varied to determine the inflection point in the height.

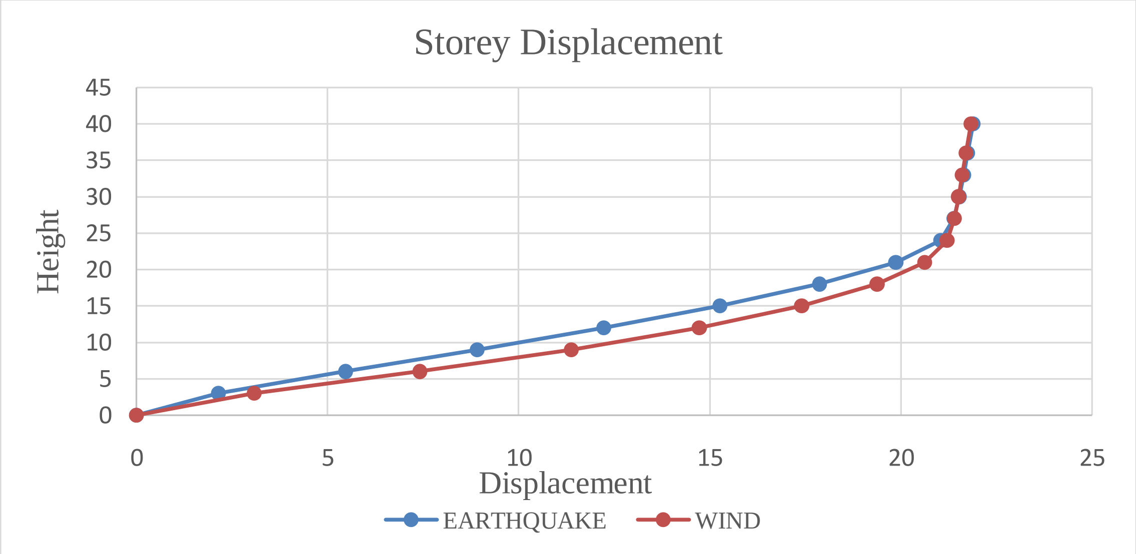
Initially, a G+5 model was simulated separately under the application of both types of lateral loads (Wind Load and Earthquake Load). It was observed that the displacement caused, was greater in the case of Earthquake load. This result implied and affirmed that Earthquake Load has a greater impact on short multistoried buildings. The same procedure was repeated on the model of a G+15 building and it was observed that in this case, Wind Load had a greater impact on the building.

The results from these simulations implied that the inflection point lies in between the height of the G+8 and G+15 models. Repeated iterations were carried out on these two reference models by varying their heights till we obtained simulations wherein the above mentioned trend was reversed.

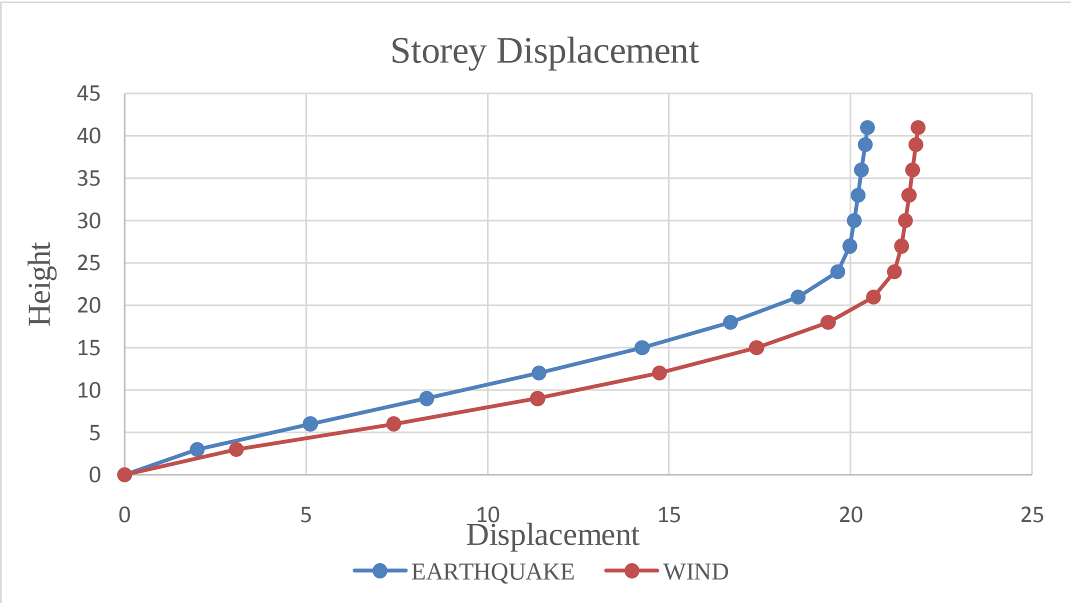
III. RESULTS

Successive iterations helped us in narrowing down the optimal range in which the inflection point lies. For the given base configuration, it was determined to be in between 40m and 41m.

Storey Displacement for 40m & 41m –



Story	Elevation	Earthquake	Wind
	m	mm	mm
Story13	40	21.887	21.835
Story12	36	21.745	21.706
Story11	33	21.639	21.611
Story10	30	21.529	21.514
Story9	27	21.389	21.405
Story8	24	21.041	21.209
Story7	21	19.865	20.629
Story6	18	17.875	19.38
Story5	15	15.265	17.407
Story4	12	12.223	14.726
Story3	9	8.91	11.375
Story2	6	5.474	7.413
Story1	3	2.146	3.08
Base	0	0	0

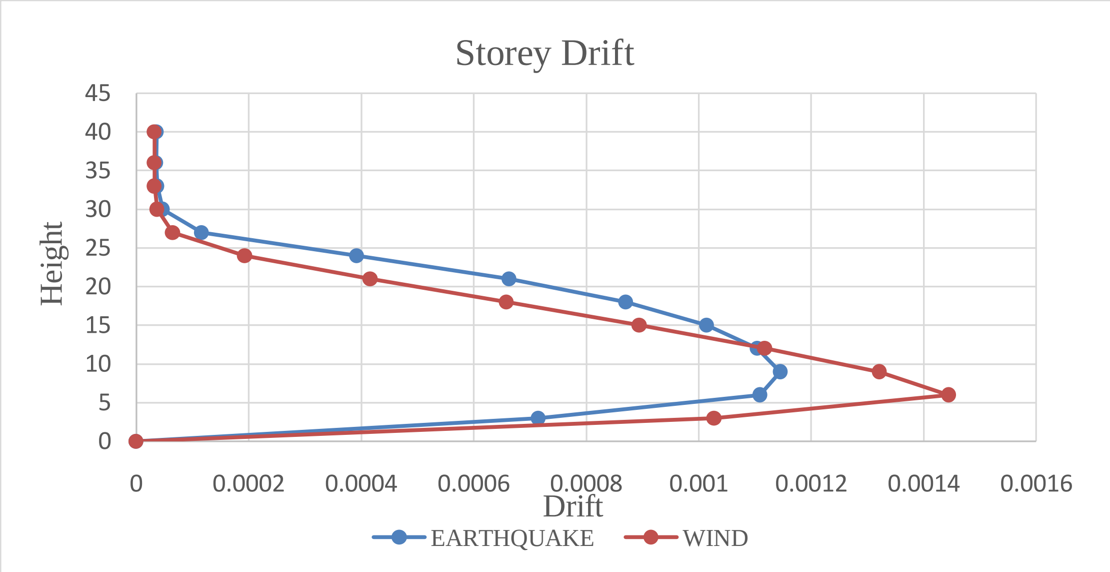


Story	Elevation	Earthquake	Wind
Story14	41	20.455	21.854
Story13	39	20.391	21.792
Story12	36	20.295	21.699
Story11	33	20.198	21.605
Story10	30	20.097	21.51
Story9	27	19.967	21.401
Story8	24	19.643	21.206
Story7	21	18.545	20.627
Story6	18	16.688	19.379

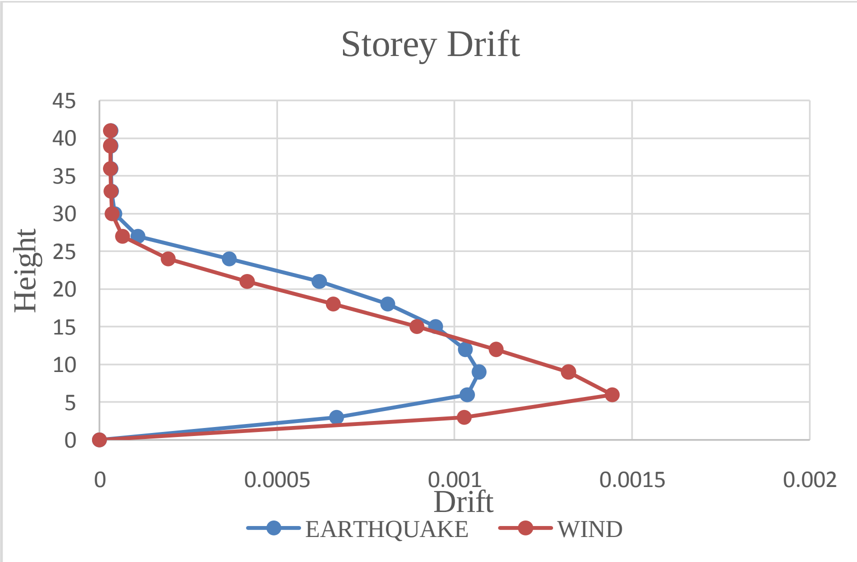
Story5	15	14.252	17.406
Story4	12	11.412	14.726
Story3	9	8.319	11.374
Story2	6	5.111	7.413
Story1	3	2.004	3.08
Base	0	0	0

The maximum displacement in case of the 40m model is greater under the application of earthquake load, whereas in the case of the 41m model, the maximum displacement is attributed to the application of wind load.

Storey Drift for 40m and 41m–



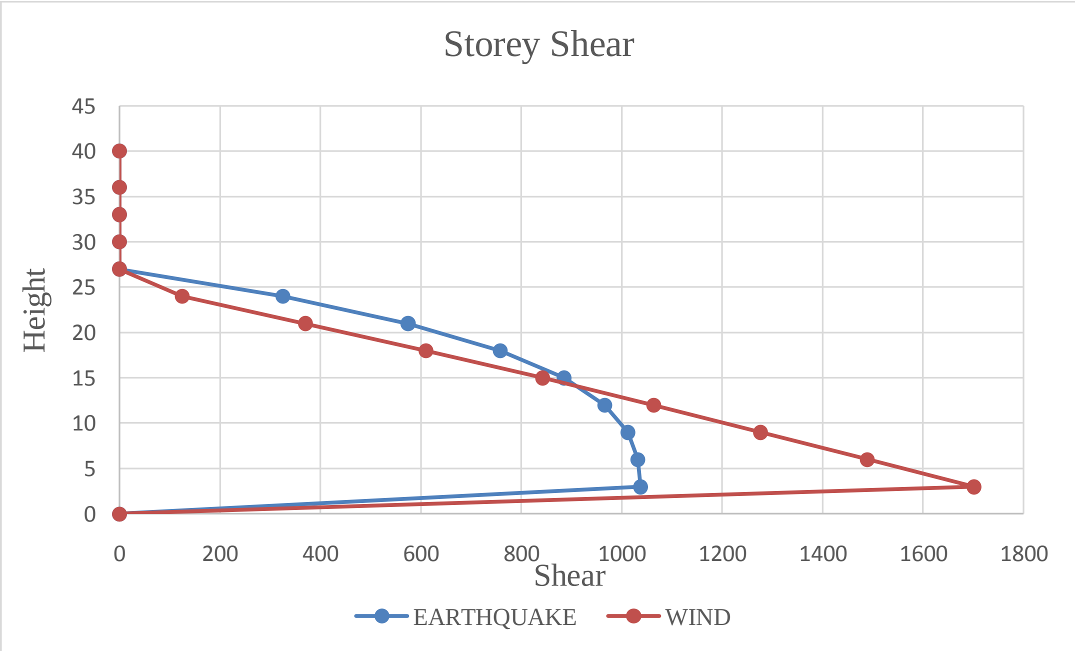
Story	Elevation	Earthquake	WIND
Story13	40	0.000036	0.000032
Story12	36	0.000035	0.000032
Story11	33	0.000037	0.000032
Story10	30	0.000047	0.000037
Story9	27	0.000116	0.000065
Story8	24	0.000392	0.000193
Story7	21	0.000663	0.000416
Story6	18	0.00087	0.000658
Story5	15	0.001014	0.000894
Story4	12	0.001104	0.001117
Story3	9	0.001145	0.001321
Story2	6	0.001109	0.001444
Story1	3	0.000715	0.001027
Base	0	0	0



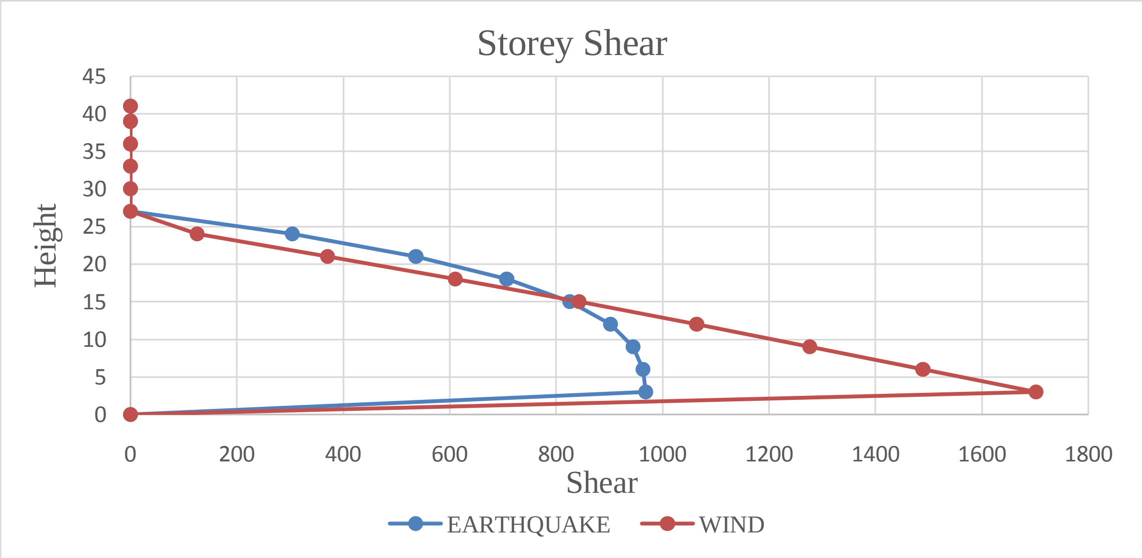
Story	Elevation	Earthquake	WIND
Story14	41	0.000032	0.000031
Story13	39	0.000032	0.000031
Story12	36	0.000032	0.000031
Story11	33	0.000034	0.000032
Story10	30	0.000043	0.000036
Story9	27	0.000108	0.000065
Story8	24	0.000366	0.000193
Story7	21	0.000619	0.000416
Story6	18	0.000812	0.000658
Story5	15	0.000947	0.000894
Story4	12	0.001031	0.001117
Story3	9	0.001069	0.001321
Story2	6	0.001036	0.001444
Story1	3	0.000668	0.001027
Base	0	0	0

The maximum storey drift remains constant under the application of wind load and is greater than the maximum storey drift caused by earthquake load for both the models.

Storey Shear for 40m and 41m-



Story	Elevation	Earthquake	WIND
Story13	40	0	0
Story12	36	0	0
Story11	33	0	0
Story10	30	0	0
Story9	27	0	0
Story8	24	325.4913	124.9947
Story7	21	574.6956	370.4725
Story6	18	757.7845	609.9894
Story5	15	884.9296	842.7898
Story4	12	966.3024	1063.835
Story3	9	1012.0746	1276.823
Story2	6	1032.4178	1489.178
Story1	3	1037.5036	1701.533
Base	0	0	0



Story	Elevation	Earthquake	WIND
Story14	41	0	0
Story13	39	0	0
Story12	36	0	0
Story11	33	0	0
Story10	30	0	0
Story9	27	0	0
Story8	24	303.9146	124.9947
Story7	21	536.5993	370.4725
Story6	18	707.5512	609.9894
Story5	15	826.2679	842.7898
Story4	12	902.2465	1063.835
Story3	9	944.9845	1276.823
Story2	6	963.9792	1489.178
Story1	3	968.7279	1701.533
Base	0	0	0

The maximum storey shear remains constant under the application of wind load and is greater than the maximum storey shear caused by earthquake load for both the models as well.

IV. CONCLUSION & DISCUSSIONS -

- For a given base configuration, the above results have determined that the point in the total height at which the governing design mitigation load switches from Earthquake load to Wind load, lies between 40m and 41m. This range has been determined by simple iteration and is supported by the graphical data achieved after running the simulations successfully.
- While analyzing storey displacement it is observed that for a 40m building, the maximum displacement is greater under the application of Earthquake Load where as in the 41m model, it is observed that the maximum displacement is under the application of Wind Load. Therefore, storey displacement which is the governing deformation parameter shows a clear reversal in trends at the end point of the 40m-41m range.
- The analysis of storey drift and storey shear shares a similar trend in which the values of both parameters remains at a constant under the application of wind load, whereas under the

application of Earthquake load there is a decrease when moving from 40m to 41m.

- All 3 deformation parameters seem to be at a constant in both models under the application of wind load. On the other hand, there is a clear decrease in all 3 parameters of both models when earthquake load is applied.
- The decrease in deformation parameters under the application of earthquake load, when moving from 40m to 41m, shows a uniform 6.6% drop.

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