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ANALYSIS AND DESIGN OF SKYSCRAPER BUILDING OF G+60 STOREYS IN ALL SEISMIC ZONES BY USING ETABS SOFTWARE

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ABSTRACT:

The term "skyscraper" was first applied to buildings of steel framed construction of at least 10 storeys in the late 19th century, a result of public amazement at the tall buildings being built in major cities like Chicago, New York City, Tokyo, Beijing, etc. The structural definition of the word skyscraper was refined later by architectural historians, based on engineering developments of the 1880s that had enabled construction of tall multi-Storey buildings. This definition was based on the steel skeleton as opposed to constructions of load-bearing masonry, which passed their practical limit in 1891 with Chicago's Monad Nock Building. The design and construction of skyscrapers involves creating safe, habitable spaces in very tall buildings. The buildings must support their weight, resist wind and earthquakes, and protect occupants from fire. Yet they must also be conveniently accessible, even on the upper floors, and provide utilities and a comfortable climate for the occupants. The problems posed in skyscraper design are considered among the most complex encountered given the balances required between economics, engineering, and construction management. The objectives of the present work is to study the behavior of a Skyscraper Building subjected to earth quake load by adopting Response spectrum analysis. The present study is limited to Reinforced concrete (RC) multi-storied Skyscraper building with four different zones II, III, IV & V .The analysis is carried out with the help of FEM software's ETABS V 9.7.4. The building model in the study has G+60 (61) storeys with constant storey height of 3m. Four models are used to analyze with different bay lengths and the number of Bays and the bay-width along two horizontal directions are kept constant in each model for convenience.

Keywords: Skyscraper Building, Response spectrum analysis, Storey Drifts, ETABS V 9.7.4

1. INTRODUCTION

1.1 GENERAL

A skyscraper is a continuously habitable high-rise building that has over 40 or 50 floors and is taller than approximately 100 m (328 ft). Generally, the term first referred to buildings with 10 to 20 floors in 1880s. The definition shifted with advancing construction technology during the 20th Century.[1] Skyscrapers may contain offices, commercial and residential uses. For buildings above a height of 300 m (984 ft), the term "supertall" can be used, while skyscrapers reaching beyond 600 m (1,969 ft) are classified as "megatall".

One common feature of skyscrapers is having a steel framework that supports curtain walls. These curtain walls either bear on the framework below or are suspended from the framework above, rather than resting on load-bearing walls of conventional construction. Some early skyscrapers have a steel frame that enables the construction of load-bearing walls taller than of those made of reinforced concrete.

Modern skyscrapers' walls are not load-bearing, and most skyscrapers are characterized by large surface areas of windows made possible by steel frames and curtain walls. However, skyscrapers can have curtain walls that mimic conventional walls with a small surface area of windows. Modern skyscrapers often have a tubular structure, and are designed to act like a hollow cylinder to resist wind, seismic, and other lateral loads. To appear more slender, allow less wind exposure, and transmit more daylight to the ground, many skyscrapers have a design with setbacks, which are sometimes also structurally required.

Fig 1: Oriel Chambers, Liverpool. The world's first glass curtain walled building.

Fig 2: The Wainwright Building, a 10-story red brick office building

1.2 TUBE STRUCTURAL SYSTEMS

The tubular systems are fundamental to tall building design. Most buildings over 40-storeys constructed since the 1960s now use a tube design derived from Khan's structural engineering principles, examples including the construction of the World Trade Center, Aon Center, Petronas Towers, Jin Mao Building, and most other super tall skyscrapers since the 1960s. The strong influence of tube structure design is also evident in the construction of the current tallest skyscraper, the BurjKhalifa.

1.3 OBJECTIVE OF THE STUDY

Following are the main objectives of the work:

1. The main objective of the present work is to study the effect of Earthquake load for four Zones in India of Skyscraper buildings for Medium soil condition.
2. In the present study, the effect of Earthquake load for Skyscraper buildings will be evaluated by Response spectrum method of analysis.
3. In the present work, the Skyscraper building of G+60 storeys will be modeled for different Zones by considering IS: 1893:2002 Code.
4. The analysis of the building will be carried out by using ETABS V9.7.4.
5. The results from the models (storey drift, storey shear) will be compared for different Zones of Earthquake.

1.4 FUTURE SCOPE OF THE PAPER

In the present paper a typical skyscraper of G+60 storeys is analyzed using commercial software ETABS V9.7.4 by response spectrum analysis. Storey drift, Shear force, Bending moments in both X and Y directions are analyzed for different zones of earthquake in India. The analysis is made based on damping ration followed in the code IS 1893:2002.

As of now, the latest version of ETABS Software is updated with the IS 1893:2002 code only. When the software updates with the latest code i.e., IS 1893:2016 the same project can be analyzed by the new code and a comparative study can be made. The seismic design mainly depends upon the Damping ratio, Topography and Soil conditions.

2. LITERATURE REVIEW

Douglas.,et al (1996) studied With the advent of steel shapes and forms, the dungeons of masonry structures of old were no longer necessary. The skyscraper in comparison was actually well lit and airy. The place was Chicago, the year was 1883, the man was the architect and engineer William LeBaron 29 and wonderment, which has only pervaded to this day creating a public advertisement that, had no equal.

Nash., et al (2005) studied with Once the New York area got a hold of the skyscraper there was no stopping the massive amount of tall building construction taking place in Manhattan. In 1890 there were 6 buildings over 10 storied in

New York, by 1908 there were 538 (Nash, 2005). In those 18 years tall buildings in the city grew by nearly 900%! This count was taken at 10 storeys but the number is still staggering to acknowledge.

Zukowsky and Thorne., et al (2000) studied with Further demonstrating that the construction of tall buildings requires an enormous amount of financial backing and clout, the skyscraper surge in Asia took a tremendous dip in the same year that the Petronas Towers were completed. 1998 saw numerous volatile highs and lows in stock markets around the world (Zukowsky and Thorne, 2000). In addition, there were drastic downturns in Asian economies which led to the direct cancellation and the postponing of several tall buildings (Zukowsky and Thorne, 2000).

3. METHODOLOGY

3.1 METHOD FOR ANALYSIS OF THE STRUCTURE

The seismic analysis should be carried out for the buildings that have lack of resistance to earthquake forces. Seismic analysis will consider dynamic effects hence the exact analysis sometimes become complex. However for simple regular structures equivalent linear static analysis is sufficient one. This type of analysis will be carried out for regular and low rise buildings and this method will give good results for this type of buildings. Dynamic analysis will be carried out for the building as specified by code IS 1893-2002 (part1). Dynamic analysis will be carried out either by Response spectrum method or site specific Time history method. Following methods are adopted to carry out the analysis procedure.

3.2 RESPONSE SPECTRUM ANANLYSIS

The representation of maximum response of idealized single degree freedom system having certain period and damping, during earthquake ground motions. This analysis is carried out according to the code IS 1893-2002 (part1). Here type of soil, seismic zone factor should be entered from IS 1893-2002 (part1). The standard response spectra for type of soil considered is applied to building for the analysis in ETABS 2013 software. Following diagram shows the standard response spectrum for medium soil type and that can be given in the form of time period versus spectral acceleration coefficient (Sa/g).

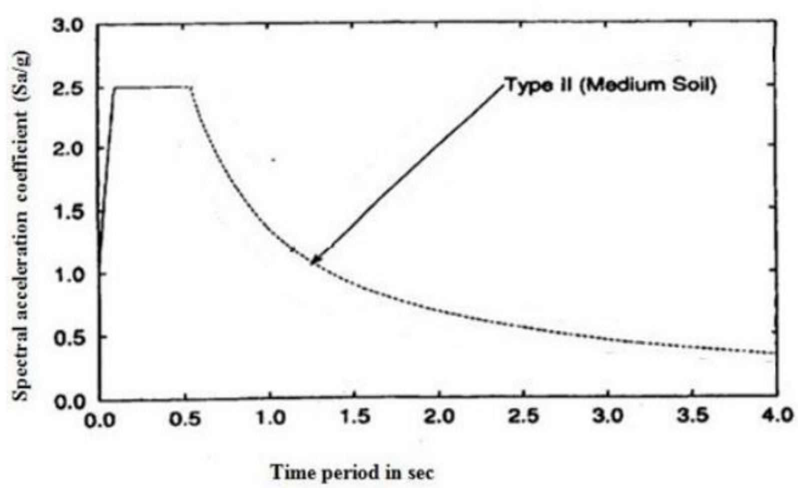

Fig 3: Response spectrum for medium soil type for 5% damping

This approach permits the multiple modes of response of a building to be taken in to account (in the frequency domain). This is required in many building codes for all except very simple or very complex structures. The response of a structure can be defined as a combination of many special shapes (modes) that in a vibrating string correspond to the "harmonic" computer analysis can be used to determine these modes for a structure. For each mode, a response is read from the design spectrum, based on the modal frequency and the modal mass, and they are then combined to provide an estimate of the total response of the structure. In this we have to calculate the magnitude of forces in all directions i.e. X, Y & Z and then see the effects on the building. Combination methods include the following:

- absolute - peak values are added together
- square root of the sum of the squares (SRSS)
- complete quadratic combination (CQC)

3.3 BUILDING DESIGN CONSIDERATIONS

Type of structure	RCC frame structure
Number of storeys(G+60)	61 storeys
Number of lines in X-direction	12
Number of lines in Y-direction	12
Storey to storey height	3m
Ground storey height	3.5 m
Grade of concrete	M40 for columns, slab and beams
Thickness of slab	0.15 m
Beam size	0.8m×0.8m
Column size	1m×1m
Density	For concrete 25kN/m^3 For brick wall 19kN/m^3
Soil type	Medium

3.4 MODEL IN ETABS V9.7.4

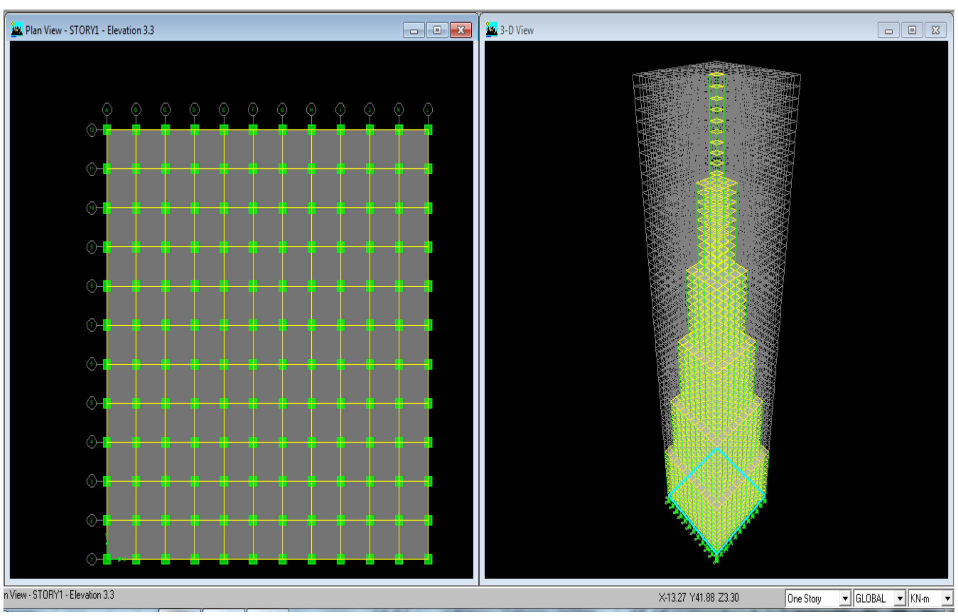

Fig 4: Model in ETABS

4. RESULTS AND ANALYSIS

4.1 STOREY DRIFT

Drift is defined as the lateral displacement. Story drift is the drift of a multistory building relative to the level below. Inter story drift is the difference between the roof and floor displacements of any given story as the buildings ways during the earthquake, normalized by the story height. For example, for a 10 foot high story, an inter story drift of 0.10 indicates that the roof is displaced one foot in relation to the floor below.

4.1.1 Comparison of Drift X For Different Zones

Table 1. Drift values (meters) in X direction

Story	DriftX in Zone2	Drift X Zone3	DriftX in Zone4	DriftX in Zone5
STORY61	0.00042	0.000672	0.001009	0.001513
STORY60	0.00046	0.000736	0.001105	0.001657
STORY59	0.000502	0.000803	0.001205	0.001807
STORY51	0.000238	0.000381	0.000571	0.000856
STORY50	0.000256	0.000409	0.000614	0.00092
STORY49	0.000277	0.000443	0.000665	0.000997
STORY41	0.000197	0.000315	0.000472	0.000708
STORY40	0.000208	0.000333	0.000499	0.000749
STORY39	0.000222	0.000356	0.000533	0.0008
STORY31	0.000172	0.000275	0.000413	0.000619
STORY30	0.000178	0.000286	0.000428	0.000642
STORY29	0.000188	0.0003	0.00045	0.000676
STORY21	0.000163	0.000261	0.000392	0.000588
STORY20	0.000171	0.000273	0.00041	0.000615
STORY19	0.000181	0.000289	0.000434	0.000651
STORY11	0.000162	0.000259	0.000388	0.000582
STORY10	0.000166	0.000265	0.000398	0.000597
STORY9	0.000171	0.000274	0.000411	0.000617

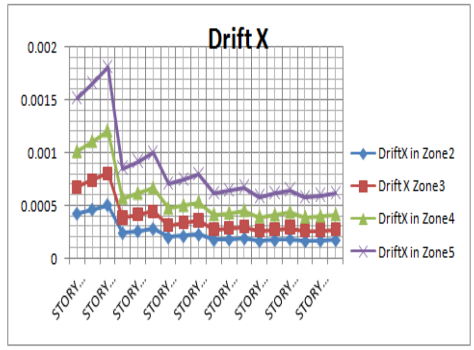

Fig 5: Graph for Storey drift in X direction

From **Fig 5** it can be observed that, the drift value decreases from the top storey to the bottom storey and the maximum value of drift is found in Seismic zone 5 than other seismic zones.

4.1.2 Comparison of Drift Y for Different Zones

Table 2. Drift values (meters) in Y direction

Story	DriftY in Zone2	Drift Y in Zone3	DriftY in Zone4	DriftY in Zone5
STORY61	0.000505	0.000808	0.001211	0.001817
STORY60	0.000553	0.000885	0.001327	0.001991
STORY59	0.000603	0.000965	0.001447	0.00217
STORY51	0.000244	0.00039	0.000585	0.000878
STORY50	0.00026	0.000416	0.000624	0.000937
STORY49	0.00028	0.000448	0.000673	0.001009
STORY41	0.000199	0.000318	0.000477	0.000715
STORY40	0.000211	0.000337	0.000506	0.000759
STORY39	0.000226	0.000362	0.000543	0.000814
STORY31	0.000178	0.000285	0.000427	0.000641
STORY30	0.000184	0.000295	0.000443	0.000664
STORY29	0.000194	0.00031	0.000465	0.000697
STORY21	0.000164	0.000263	0.000394	0.000591
STORY20	0.000171	0.000274	0.000411	0.000616
STORY19	0.000181	0.000289	0.000434	0.000651
STORY11	0.000163	0.000261	0.000392	0.000588
STORY10	0.000168	0.000269	0.000403	0.000604
STORY9	0.000174	0.000278	0.000418	0.000627

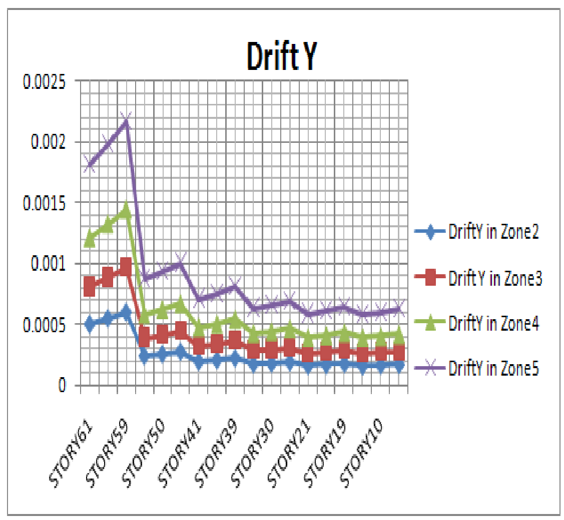

Fig 6: Graph for Storey drift in Y direction

From **Fig 6** it can be observed that, the storey drift (lateral displacement) has less values in Zone 2 and has higher values in Zone 5.The greater the drift, the greater the likelihood of damage. Peak inter storey drift values larger than 0.06 indicate sever damage, while values larger than 0.025 indicate that the damage could be serious enough to pose a serious threat to human safety. Values in excess of 0.10 indicates probable building collapse.

4.2 BUILDIND TORQUE (T):

Torque is a twisting or turning force that tends to cause rotation around an axis, which might be a center of mass or a fixed point. Torque can also be thought of as the ability of something that is rotating, such as a gear or a shaft, to overcome turning resistance.

Table 3. Building Torque(T) values

Story	Building Torque (T) in Zone2	Building Torque (T) in Zone3	Building Torque (T) in Zone4	Building Torque (T) in Zone5
STORY61	1182.87	1892.593	2838.889	4258.333
STORY60	2692.123	4307.397	6461.095	9691.642
STORY59	4079.694	6527.511	9791.267	14686.9
STORY51	12588.47	20141.56	30212.34	45318.51
STORY50	15374.13	24598.6	36897.9	55346.85
STORY49	18023.78	28838.05	43257.08	64885.62
STORY41	36041.36	57666.18	86499.26	129748.9
STORY40	40333.21	64533.14	96799.71	145199.6
STORY39	44445.67	71113.06	106669.6	160004.4
STORY31	72405.16	115848.3	173772.4	260658.6
STORY30	78024.96	124839.9	187259.9	280889.9
STORY29	83595.92	133753.5	200630.2	300945.3
STORY21	131854.1	210966.6	316449.8	474674.8
STORY20	142306.3	227690.1	341535.2	512302.8
STORY19	152723.3	244357.4	366536	549804.1
STORY11	229938.4	367901.4	551852.2	827778.2
STORY10	241599.1	386558.5	579837.8	869756.7
STORY9	252306.1	403689.8	605534.6	908302

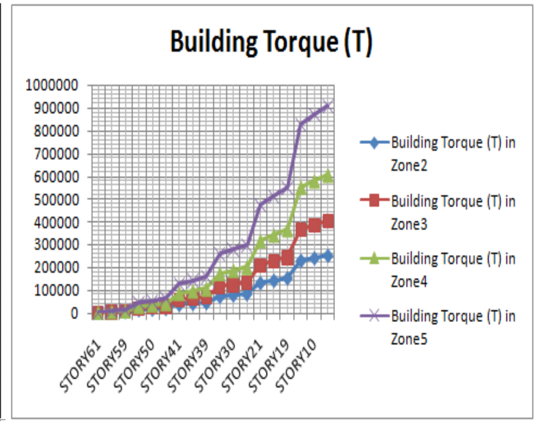

Fig 7: Graph for Building Torque

From **Fig 7** it can be observed that, the value of building torque (T) also has less value for the Zone2 than other Zones (i.e, Zone3, Zone4, and Zone5) in all the cases. The value of Building Torque (T) Increases from the 61st storey to Bottom storey and it found to be maximum value for the Zone5 soil.

4.3 SHEAR FORCE

4.3.1 SHEAR IN X- DIRECTION(VX)

Table 4. Shear values(kN) in X direction

Story	Shear force (VX) in Zone2	Shear Force (VX) in Zone3	Shear force (VX) in Zone4	Shear force (VX) in Zone5
STORY61	28.75	46	69.01	103.51
STORY60	65.81	105.29	157.94	236.91
STORY59	100.31	160.5	240.75	361.13
STORY51	323.03	516.85	775.27	1162.91
STORY50	389.31	622.9	934.34	1401.52
STORY49	451.29	722.06	1083.09	1624.64
STORY41	809.44	1295.1	1942.65	2913.98
STORY40	870.22	1392.35	2088.53	3132.8
STORY39	927.93	1484.68	2227.03	3340.54
STORY31	1308.62	2093.8	3140.7	4711.05
STORY30	1379.07	2206.52	3309.78	4964.67
STORY29	1451.57	2322.52	3483.78	5225.66
STORY21	2077.12	3323.39	4985.08	7477.62
STORY20	2191.63	3506.61	5259.91	7889.87
STORY19	2305.3	3688.48	5532.72	8299.07
STORY11	3088.74	4941.99	7412.98	11119.47
STORY10	3187.68	5100.29	7650.43	11475.64
STORY9	3278.07	5244.91	7867.37	11801.05

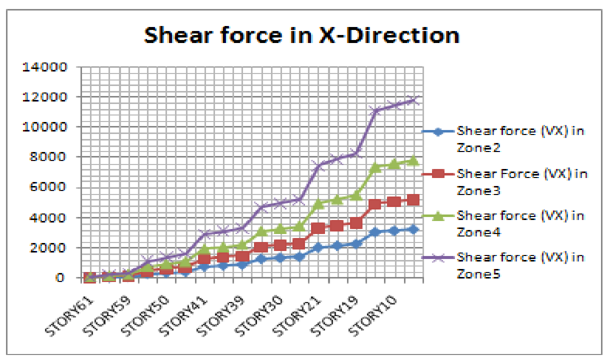

Fig 8: Graph for Shear in X direction

From **Fig 8** it can be observed that, the maximum value of shear force in X-Direction was obtained for Seismic zone 5 and minimum value is obtained for Seismic zone 2. The Shear force value increases from 61th storey to bottom storey.

4.3.2 SHEAR IN Y- DIRECTION(VY)

Table 5. Shear values (kN) in Y direction

Story	Shear force (VY) in Zone2	Shear Force (VY) in Zone3	Shear force (VY) in Zone4	Shear force (VY) in Zone5
STORY61	41.96	67.14	100.71	151.07
STORY60	94.97	151.95	227.92	341.88
STORY59	143.06	228.89	343.33	515
STORY51	372.82	596.52	894.77	1342.16
STORY50	423.29	677.27	1015.91	1523.86
STORY49	473.27	757.24	1135.85	1703.78
STORY41	823.93	1318.29	1977.44	2966.16
STORY40	901.53	1442.46	2163.68	3245.53
STORY39	978.99	1566.39	2349.58	3524.37
STORY31	1475.54	2360.87	3541.3	5311.95
STORY30	1547.2	2475.53	3713.29	5569.93
STORY29	1615.92	2585.47	3878.2	5817.31
STORY21	2109.7	3375.51	5063.27	7594.9
STORY20	2205.97	3529.55	5294.33	7941.49
STORY19	2308.54	3693.66	5540.49	8310.73
STORY11	3202.63	5124.21	7686.31	11529.47
STORY10	3338.52	5341.63	8012.44	12018.66
STORY9	3466.27	5546.04	8319.06	12478.59

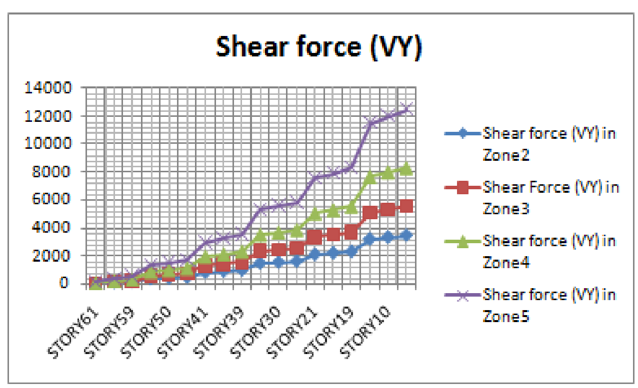

Fig 9: Graph for Shear in Y direction

From **Fig 9** it can be observed that, the maximum value of shear force in Y-Direction was obtained for Seismic zone 5 and minimum value is obtained for Seismic zone 2. The Shear force value increases from 61thstorey to 1ststorey.

4.4 BENDING MOMENT

4.4.1 Bending moment in X direction(MX)

Table 6. Bending moment values in X direction

Story	Bending moment (MX) in Zone2	Bending Moment (MX) in Zone3	Bending moment (MX) in Zone4	Bending moment (MX) in Zone
STORY61	125.892	201.428	302.141	453.212
STORY60	410.788	657.261	985.891	1478.837
STORY59	839.925	1343.879	2015.819	3023.728
STORY51	7622.292	12195.67	18293.5	27440.25
STORY50	8837.614	14140.18	21210.27	31815.41
STORY49	10171.07	16273.72	24410.58	36615.87
STORY41	24664.61	39463.38	59195.07	88792.6
STORY40	26977.08	43163.33	64745	97117.49
STORY39	29453.07	47124.92	70687.37	106031.1
STORY31	55472.66	88756.25	133134.4	199701.6
STORY30	59454.46	95127.14	142690.7	214036.1
STORY29	63598.71	101757.9	152636.9	228955.3
STORY21	101839.8	162943.7	244415.6	366623.4
STORY20	107195.1	171512.2	257268.3	385902.5
STORY19	112707.4	180331.8	270497.8	405746.7
STORY11	164815.2	263704.3	395556.4	593334.6
STORY10	172595.3	276152.5	414228.7	621343
STORY9	180716.3	289146.1	433719.2	650578.7

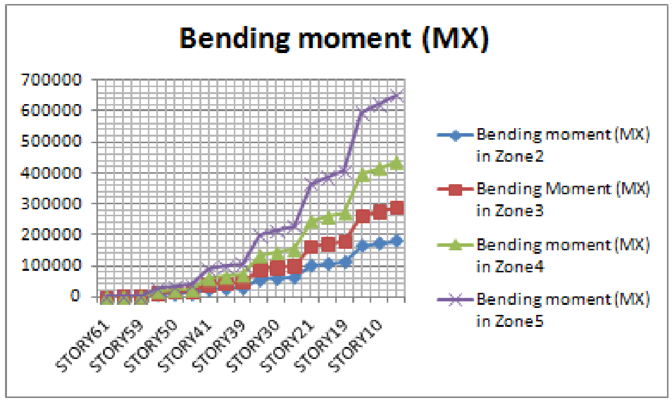

Fig 10: Graph for bending moment in X direction

From **Fig 10** it can be observed that the maximum value of bending moment in X-Direction was obtained in Zone5 and minimum value of bending moment was obtained for Seismic zone2. The value of bending moment is increases from 61ststorey to Bottom storey.

4.4.2 Bending moment in Y direction(MY)

Table 7. Bending moment values in Y direction

Story	Bending moment (MY) in Zone2	Bending Moment (MY) in Zone3	Bending moment (MY) in Zone4	Bending moment (MY) in Zone5
STORY61	86.257	138.011	207.016	310.525
STORY60	283.683	453.892	680.839	1021.258
STORY59	584.611	935.378	1403.067	2104.601
STORY51	5849.605	9359.369	14039.05	21058.58
STORY50	7006.798	11210.88	16816.32	25224.47
STORY49	8344.978	13351.96	20027.95	30041.92
STORY41	23991	38385.6	57578.4	86367.6
STORY40	26512.78	42420.45	63630.68	95446.02
STORY39	29181.11	46689.78	70034.66	105052
STORY31	54730.17	87568.27	131352.4	197028.6
STORY30	58394.63	93431.41	140147.1	210220.7
STORY29	62186.97	99499.16	149248.7	223873.1
STORY21	98070.48	156912.8	235369.2	353053.7
STORY20	103411.7	165458.7	248188.1	372282.2
STORY19	109006.3	174410.1	261615.1	392422.7
STORY11	163759.5	262015.3	393022.9	589534.3
STORY10	171891.4	275026.2	412539.3	618809
STORY9	180312.8	288500.4	432750.6	649126

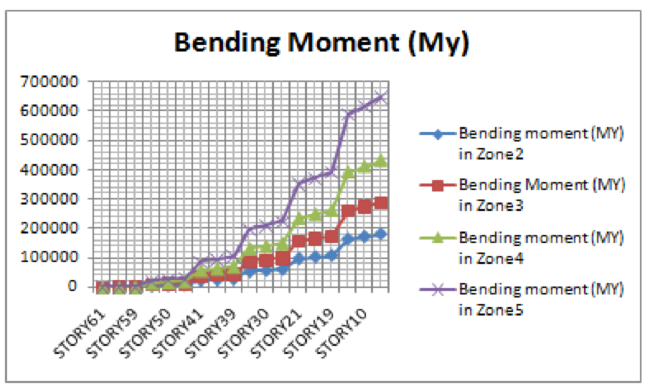

Fig 11: Graph for bending moment in Y direction

From **Fig 11** it can be observed that the maximum value of bending moment in Y-Direction was obtained in Zone5 and minimum value of bending moment was obtained for Seismic zone2. The value of bending moment is increases from 61ststorey to Bottom storey.

5. CONCUSIONS

From the above study the following conclusions are made

1. The values of storey drifts decrease from top storey to bottom storey and the maximum value is obtained for Zone 5 and minimum value is obtained for Zone 2 in both X-Direction and Y-Direction.
2. The maximum values of building torque (T) were obtained in Seismic Zone5 than remaining Zones (Zone2, Zone3, Zone4). The value of building twist decreases from 61thstorey to 1ststorey.
3. The maximum values of Shear forces and Bending moments are obtained for Zone5 than remaining Zones (Zone2, Zone3, Zone4). The forces and moments decrease from top storey to bottom storey (61th to 1ststorey).
4. Skyscraper Building subjected to earth quake load has been analyzed by adopting Response spectrum analysis by using ETABS V 9.7.4
5. In an overall it is concluded that Zone 5 is more suitable for skyscraper building than remaining Zones(Zone2,Zone3,Zone4).
6. Top storeys are more susceptible to the drifts, building torque, forces and moments and these values decrease as we move on to the bottom storeys.
7. As the height of the building increases, lateral forces plays a dominant role. Therefore, certain provisions shall be made in order to resist these lateral forces so that building performance under the effect of lateral loads can be improved.

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