Study of Effect of Soft Storey on High Rise (G+29) Cylindrical Shaped Structure under Earthquake & Wind Effect

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Abstract-- **In countries like India now a day construction industry growing rapidly. The growth is due to developing phase of the country. So the high rise buildings are constructed and used for different purposes. In such condition soft storey becomes an unavoidable feature of multi-storied buildings in India. Soft stories are widely used for Parking, Offices etc. In previous earthquake studies, potential hazards associated with soft storey have been observed. Soft storey means the open storey and these are composed of columns only so it becomes soft i.e. week in stiffness relative to the other stories. Structurally such unbalances are not safe & unhealthy and the soft stories in buildings are well known for being susceptible to collapse through past big earthquakes.**

Generally high rise buildings are affected more by wind than the earthquakes. As wind is a randomly varying dynamic phenomenon, and it has significant dynamic effects on buildings and structures especially on high rise flexible structures. For primary design of structure including the proportioning of the structure, varying site parameters, varying wind force on the structure and structural parameters should be known. So soft stories in high rise buildings becomes more critical and more susceptible to collapse due to high wind.so in this paper a study is done on the multiple soft stories in high rise building under the effect of earthquake and wind.

Keywords-- **ETABS 2016, Infill, Seismic analysis, Soft storey, Wind analysis.**

1. INTRODUCTION

Codes and standards are the mainstream of information to the designers of civil engineering structure. Earthquakes and winds are natural hazards under which disasters are mainly caused by damage or collapse of buildings. Objective of seismic as well as wind analysis are stated as the structure should be able to endure minor shaking intensity without sustaining any damage, thus leaving the structure serviceable after the event. The structure should withstand moderate level of earthquake ground motion and the variation of wind force on a structure with variation of site parameters and structural parameters without structural damage, but possibly with some non-structural damage. The structure should sustain sever earthquake ground motion and high wind loads without collapse of structural framework, but possibly with some structural as well as non-structural damage.

1.1 Soft Storey

Now a day construction of multi-storeyed high rise Reinforced Concrete (RC) frame buildings is becoming common in country like India. The most common type of vertical irregularity occurs in buildings that have an open ground story. Many buildings constructed in recent times have a special feature that some stories within the building are left open for the purpose of parking, reception, offices, service purpose etc. Such buildings are often called open storey or soft storey buildings or buildings on stilts. Such stories become soft and weak relative to the other stories, due absence of masonry walls in the storey. Structurally those unbalances are not safe and unhealthy and soft storey buildings are well known for being susceptible to collapse through past earthquakes.

1.2 Behaviour of Soft Storey

In buildings with soft stories the inter-storey drift in the soft storey is large. The strength demand on the column in such storey for these building is also large, however in the other stories the forces in the columns are effectively reduced due to presence of brick infill walls which share the forces. If the open floor is significantly less strong or more flexible, a large portion of the total building deflections tends to concentrate in that floor. The presence of walls in other stories makes them much stiffer than the open storey. Thus the other stories move almost together as a single block and most of the horizontal displacement of the building occurs in the soft storey. Thus, such building behaves like multiple units and shows irregular direction of motion. If only one open storey at ground level is present in the building, then such building behaves like an inverted pendulum with the open story columns acting as the pendulum rod and the rest of the building acting as a rigid pendulum mass during earthquake. As a consequence, large movement occurs in the ground story alone and the columns in the open ground storey are severely stressed. If the columns are weak (do not have the required strength to resist these high stresses), they may be severely damaged which may even lead to collapse of the building.

Soft storey RC frame buildings are commonly analysed and designed as bare frames. However actual behaviour of bare frames is entirely different from that of the bare frames. In soft storey buildings, ground storey is bare and open stories are infilled with

masonry. Therefore, it is of interest to analyse and compare displacement, stiffness etc. of the same frame, modelling it as bare frame and as soft storey frame. Such comparison will be useful to understand how the performance of soft storey frame is different from that of the bare frame. In this paper seismic analysis and wind analysis have been studied to understand the behaviour of multi-storeyed RC frame building with four different models prepared according to IS 1893 (Part 1): 2002 using commercial software ETABS.

2. MODELLING
For the study two models are prepared on ETABS 2016. One model is of bare frame while the other is with the bracings around the soft stories and the different loads and load combinations are applied on each model.
2.1 Building details

2.1.1 Architectural details to study the behavior of RCC building under high Seismic forces as here taken

- Area covering   : 21.5 x 22.5 m. (As shown in fig 01)
- Total Height of the building   : 95 m
- Floor to Floor Height   : 3 m
- Floor to Floor Height AT service floor   : 3.4 m

2.1.2 Codes used for analysis of the structure

- R.C.C. design   : IS 456: 2000
- Earthquake design   : IS1893: 2016
- Code for Dead load   : IS875: Part 1
- Code for Live load   : IS875: Part 2
- Code for wind load   : IS875: Part 2

2.1.3 The basic parameters considered for the Analysis and design

- Slab depth: 125 mm thick   : Assumed
- Live load in floor area   : 2 kN/sq m   : As per IS 875 Part 2
- Live load in Balcony area:2 kN/sq m   : As per IS 875 Part 2
- Live load in passage area: 2 kN/sq m   : As per IS 875 Part 2
- Live load in urinals: 2 kN/sq m   : As per IS 875 Part 2
- Floor finish load: 1.5 kN/ sq m   : As per IS 875 Part 1
- Wall thickness: 230 mm thick wall   : Assumed
- Stair case loading: 3 kN/sq m   : As per IS 875 Part 2
- Lift shaft: 230 mm thick shear wall   : Assumed

2.1.4 Structural details

Table 2.1 Columns Details

	RCC Normal	RCC WITH Brace frame
Foundation to 10th	230X750 MM	230X750 MM
10th floor to 20th	230X700MM	230X700MM
20th to30th floor	230X650MM	230X650MM

Table 2.2 Beams Details

	RCC Normal	RCC WITH Brace frame
Foundation to 10th	230X600 MM	230X600 MM
10th floor to 20th	230X530MM	230X530MM
20th to30th floor	230X450MM	230X450MM

2.2 Modelling with ETABS

3-D model is being prepared for the frame static analysis and dynamic time history analysis Of the building in ETABS version 16.0.2
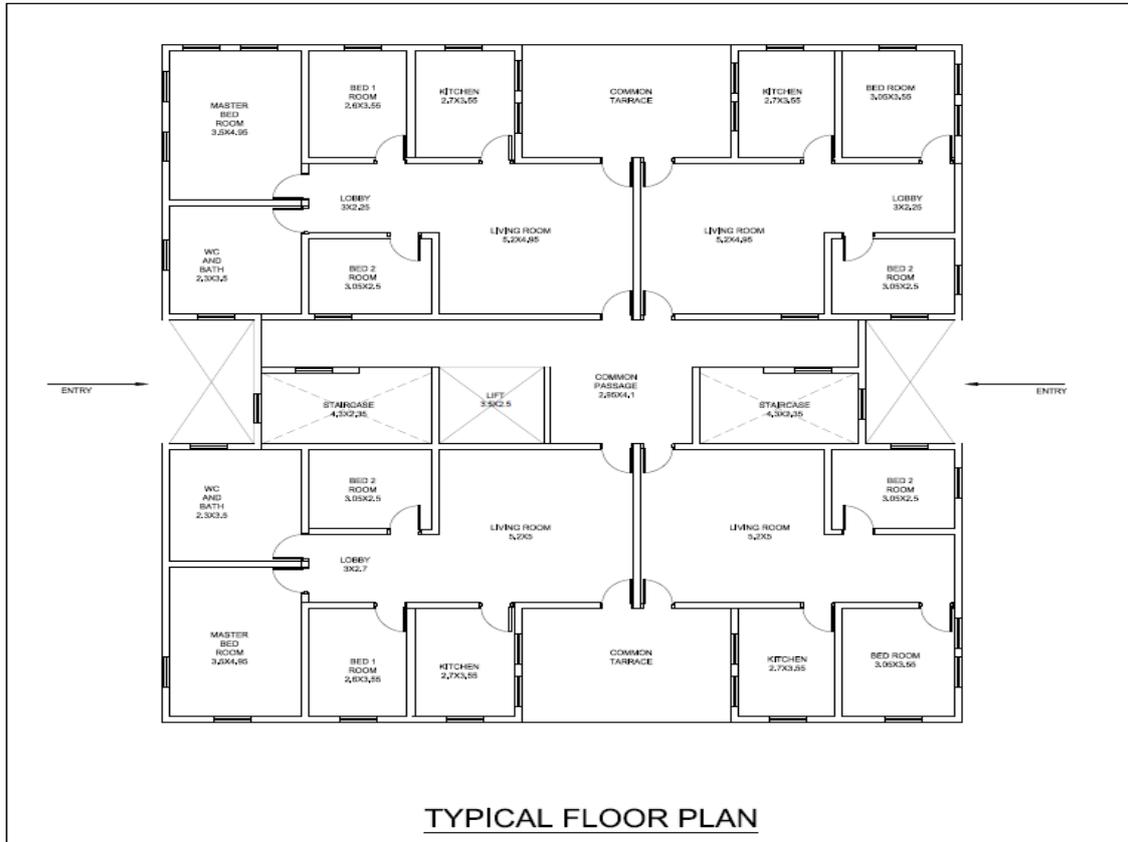

TYPICAL FLOOR PLAN

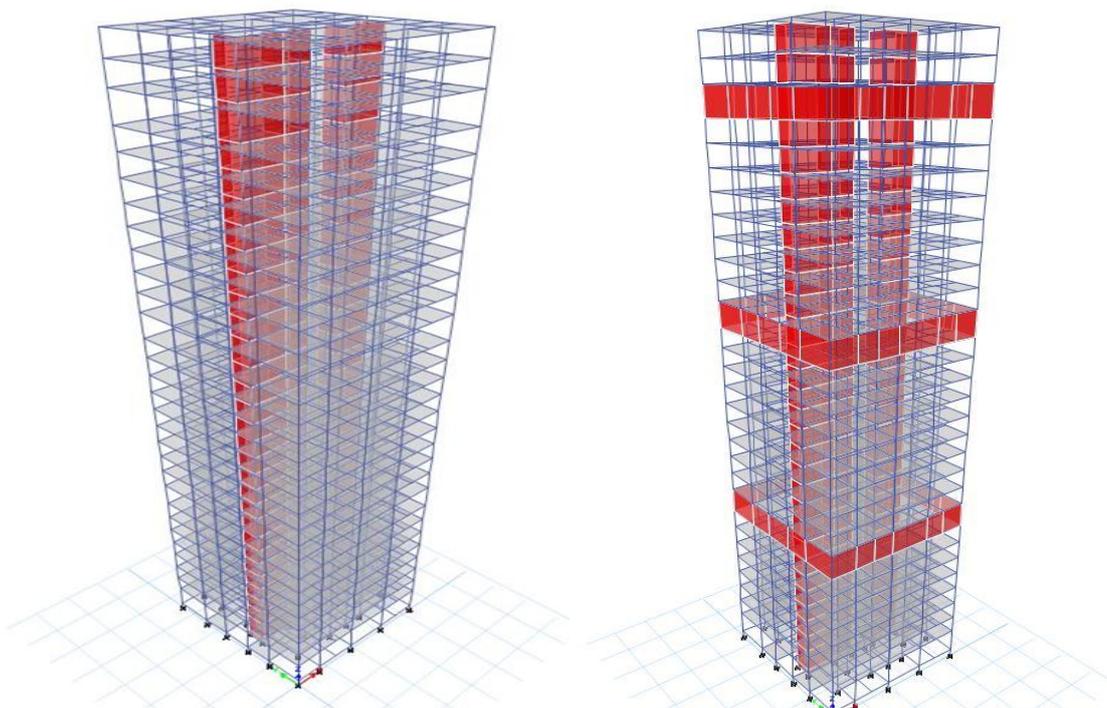FIG 01: SHOWS THE PLAN OF THE BUILDING

FIG 02: SHOWS THE SKELETON MODEL AND 3D VIEW OF THE STRUCTURE NORMAL AND BRACE FRAME

2.3 Designing with ETABS

Sr. no	Particular	Details	Remarks
1	Foundation depth	9 M below ground level	No basement provided
2	Foundation type	Raft Foundation	Column fixed at raft
3	No. of stories	G + 29	3 M hieght
4	Walls	9" thick	For external walls
5	Lift	Central shaft	Machin room at top
6	Water Tank	At terrace level	

2.4 Earthquake parameters considered

- Zone   : II (AURANGABAD)
- Soil type   : Hard soil
- Importance factor   : 1
- Time period   : Based on IS 1893

3. RESULTS
3.1. TIME PERIOD OF THE STRUCTURE UNDER STATIC AND DYNAMIC LOAD CONSIDERATION (FOR NORMAL FRAME)

3.1.1 Static Fundamental time period

Case	TIME PERIOD IN SEC
EX	1.76
EY	1.81

3.1.2 Modal time period

Case	Mode	Period
		sec
Modal	1	5.396
Modal	2	4.662
Modal	3	3.29

3.2 TIME PERIOD OF THE STRUCTURE UNDER STATIC AND DYNAMIC LOAD CONSIDERATION (FOR BRACED FRAME)
3.2.1 Static Fundamental time period

Case	TIME PERIOD IN SEC
EX	1.76
EY	1.81

3.2.2 Modal time period

Case	Mode	TIME Period
Modal	1	4.194
Modal	2	3.812
Modal	3	2.685

3.3 BASE SHEAR DETAILS

	RCC NORMAL FRAM	RCC BRACE FRAME
BASE SHEARFOR STATIC EX	3166.26 KN	3091.07 KN
BASE SHEAR FOR STATIC EY	3078.89KN	3005.75 KN
BASE SHEAR FOR DYNAMIC X	3166.26 KN	3091.07 KN
BASE SHEAR FOR DYNAMIC Y	3078.89 KN	3005.74 KN

3.4 DISPLACEMENT DETAILS

DIRECTIONS	RCC NORMAL FRAM	RCC BRACE FRAME
Max storey displacement for EX	0.194 M	0.114
Max storey displacement for Ey	0.185M	0.120
Max storey displacement for DYNAMIC X	0.136M	0.079
Max storey displacement for DYNAMIC Y	0.148M	0.092
Max storey displacement for WIND X	0.091M	0.057
Max storey displacement for WIND Y	0.08M	0.061

3.5 DRIFT DETAILS

DIRECTIONS	RCC NORMAL FRAM	RCC BRACE FRAME
Max storey Drift for EQX	0.0025	0.0017
Max storey Drift for EQy	0.0024	0.00175
Max storey Drift for DYNAMIC X	0.0018	0.0013
Max storey Drift for DYNAMIC Y	0.0019	0.0014
Max storey Drift for WIND X	0.0011	0.00085
Max storey Drift for WIND Y	0.0011	0.00085

3.6 TABLES

3.6.1 FOR RCC NORMAL FRAME TABLE FOR STOREY STIFFNESS IN EX DIRECTION

Story	Load Case	FOR NORMAL FRAME		FOR BRACED FRAME	
		Stiffness X	**Stiffness Y**	**Stiffness X**	**Stiffness Y**
		kN/m	**kN/m**	**kN/m**	**kN/m**
TARRACE	EX	72827.527	0	116012.8	0
29	EX	142509.865	0	232979.2	0
28	EX	154514.744	0	299025.4	0
27	EX	231500.797	0	378163.8	0
26	EX	278761.684	0	426278.8	0
25	EX	319883.735	0	473504.1	0
24	EX	355991.645	0	517729.3	0
23	EX	388127.277	0	562667.7	0
22	EX	417256.323	0	612213.7	0
21	EX	445599.66	0	670999.5	0
20	EX	472056.121	0	763452.2	0
19	EX	372861.925	0	823965.8	0
18	EX	510180.587	0	814429.1	0
17	EX	533959.688	0	780187.6	0
16	EX	556559.875	0	780025.5	0
15	EX	578964.398	0	790547.7	0
14	EX	601866.912	0	812999.5	0
13	EX	626153.672	0	848064.6	0
12	EX	652684.327	0	901182.2	0
11	EX	684581.468	0	981116.5	0
10	EX	719374.31	0	1136270	0
9	EX	571610.297	0	1426649	0
8	EX	817330.417	0	1294445	0
7	EX	880891.93	0	1240648	0
6	EX	958857.367	0	1270904	0
5	EX	1060905.371	0	1340290	0
4	EX	1203215.123	0	1465033	0
3	EX	1420238.254	0	1676318	0
2	EX	1797351.431	0	2062151	0
1ST	EX	2074783.444	0	2288550	0
PLINTH	EX	28058505.25	0	29585246	0

3.6.2 FOR NORMAL FRAME TABLE FOR STOREY STIFFNESS IN EY DIRECTION

Story	Load Case	FOR NORMAL FRAME		FOR BRACED FRAME	
		Stiffness X	Stiffness Y	Stiffness X	Stiffness Y
		kN/m	kN/m	kN/m	kN/m
TARRACE	EY	0	56811.57	0	85619.5
29	EY	0	110535	0	172224.1
28	EY	0	119146	0	209059.4
27	EY	0	176855.7	0	274394.9
26	EY	0	211541.8	0	305484.5
25	EY	0	241330.1	0	335834.5
24	EY	0	267204.5	0	366056.4
23	EY	0	290251.6	0	399075.4
22	EY	0	311367.4	0	438381.5
21	EY	0	332884.1	0	490269.9
20	EY	0	353439.3	0	570244.4
19	EY	0	279062.7	0	578604.6
18	EY	0	381542.3	0	607895.4
17	EY	0	398956	0	571037.5
16	EY	0	415538.2	0	561149.2
15	EY	0	431730.7	0	564219.7
14	EY	0	448248.8	0	579058
13	EY	0	465887.9	0	606804
12	EY	0	485402.9	0	652205.9
11	EY	0	510175.1	0	727886.2
10	EY	0	537298	0	869269.8
9	EY	0	425420.1	0	1009370
8	EY	0	606848.3	0	990522.2
7	EY	0	651057.8	0	922182.2
6	EY	0	705176.7	0	918357.1
5	EY	0	775529.8	0	951989.3
4	EY	0	874702.3	0	1029141
3	EY	0	1029288	0	1173346
2	EY	0	1311421	0	1458523

| 1ST | EY | 0 | 1665903 | 0 | 1809091 |
| PLINTH | EY | 0 | 18692831 | 0 | 19633479 |

3.6.3 FOR NORMAL FRAME TABLE FOR STOREY STIFFNESS IN DEX DIRECTION

Story	Load Case	FOR NORMAL FRAME		FOR BRACED FRAME	
		Stiffness X	**Stiffness Y**	**Stiffness X**	**Stiffness Y**
		kN/m	**kN/m**	**kN/m**	**kN/m**
TARRACE	DEX	153529.13	64390.36	233404.5	111165.4
29	DEX	279026.475	112526.2	445350.8	218174.4
28	DEX	277290.965	107436.4	564271.6	274517.6
27	DEX	389351.865	148697.4	635499.4	291703
26	DEX	415358.673	157465.9	649964.7	277025.5
25	DEX	426039.564	163761.8	651849.9	274999.7
24	DEX	429183.636	170771.2	643967.7	279440.8
23	DEX	430279.856	179840.9	649331.1	292776.7
22	DEX	433232.261	190696.4	673772.5	318715.1
21	DEX	442702.641	204201.7	728766.2	366459.7
20	DEX	454689.656	217032.2	852286.8	465082.5
19	DEX	347709.762	168335.6	958697.9	605405.7
18	DEX	472694.817	230616.1	853085.9	483815.9
17	DEX	484078.531	237809.4	742104.1	408342.2
16	DEX	494553.731	243723.7	702233.1	382312.5
15	DEX	505099.606	249090.4	688661.5	372745.1
14	DEX	517102.994	254648.3	697653.2	375943.5
13	DEX	532519.64	261069.5	729176.6	391632.6
12	DEX	553524.101	268918.6	791556.8	423958.5
11	DEX	586594.131	281294.8	907712.2	487253.2
10	DEX	628317.79	295071.2	1170408	639145.8
9	DEX	503893.784	228116.1	1824412	1114513
8	DEX	729845.636	325298.1	1345707	696429.6
7	DEX	809737.564	347792.2	1194014	578999.6
6	DEX	902769.874	373098	1186503	550652.8
5	DEX	1012370.154	403232.6	1228348	549683.7

4	DEX	1147581.079	442751.7	1317594	572142.2
3	DEX	1332281.698	501533.9	1469192	624789.6
2	DEX	1633068.886	606653	1745487	735079.6
1ST	DEX	1823757.363	693255.1	1884206	814169.8

3.6.4 FOR NORMAL FRAME TABLE FOR STOREY STIFFNESS IN DEY DIRECTION

Story	Load Case	FOR NORMAL FRAME		FOR BRACED FRAME	
		Stiffness X	Stiffness Y	Stiffness X	Stiffness Y
		kN/m	kN/m	kN/m	kN/m
PLINTH	DEX	26110783.14	7161250	26255481	8076314
TARRACE	DEY	87226.522	118597.2	147159.1	165756.4
29	DEY	153492.825	212266.4	289700.9	319967.8
28	DEY	147601.392	208581.4	377233.6	378276
27	DEY	205227.841	290925.7	388163.9	459537.9
26	DEY	218562.304	307737.6	365455.3	471129.6
25	DEY	228503.552	315439	366390.4	479834.2
24	DEY	239247.278	320931.5	373033.8	486631.8
23	DEY	252283.245	329203	389601.4	497576.3
22	DEY	266949.531	342114.9	420997.8	518589.9
21	DEY	284269.003	361015.5	478192.1	558983.4
20	DEY	300005.333	381469.9	612761.4	639759.1
19	DEY	231098.31	299510	843775.1	656652.1
18	DEY	315575.796	407593.9	626581.7	664954.1
17	DEY	324841.553	419503.3	517161	608539.9
16	DEY	333012.154	432265.8	483312.2	589763.7
15	DEY	341214.857	447375.4	471083.5	587925.2
14	DEY	350223.838	465470.6	476546.7	601239
13	DEY	360658.347	486136.3	499290.7	631175.9
12	DEY	372928.094	508445.9	545101.8	683734
11	DEY	390927.716	535246.9	632516.3	776021.2
10	DEY	410154.041	563000.6	835801.1	960979.1
9	DEY	318391.465	442662.8	1558792	1222675
8	DEY	453921.627	626930.8	917297.9	1100674
7	DEY	485934.465	675105.7	754659.2	1001415
6	DEY	521818.752	740497	716884.5	994592.2

5	DEY	564910.554	828167.1	716242.8	1033422
4	DEY	621455.369	947156	746062.2	1118159
3	DEY	704969.283	1119442	813383.4	1266971
2	DEY	853378.134	1412714	959552.3	1547388
1ST	DEY	943112.137	1725802	1022414	1842117
PLINTH	DEY	13920185.16	19511497	14596261	19961055

3.7 GRAPHS FOR RCC NORMAL FRAME
3.7.1 RCC NORMAL FRAME BASE SHEAR DETAILS
3.7.1.1 STATIC BASE SHEAR IN X DIRECTION
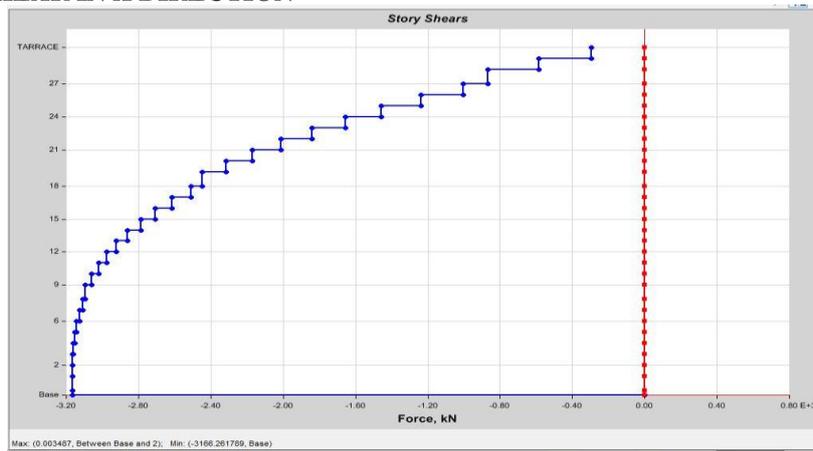
GRAPH: 01

3.7.1.2 STATIC BASE SHEAR IN Y DIRECTION
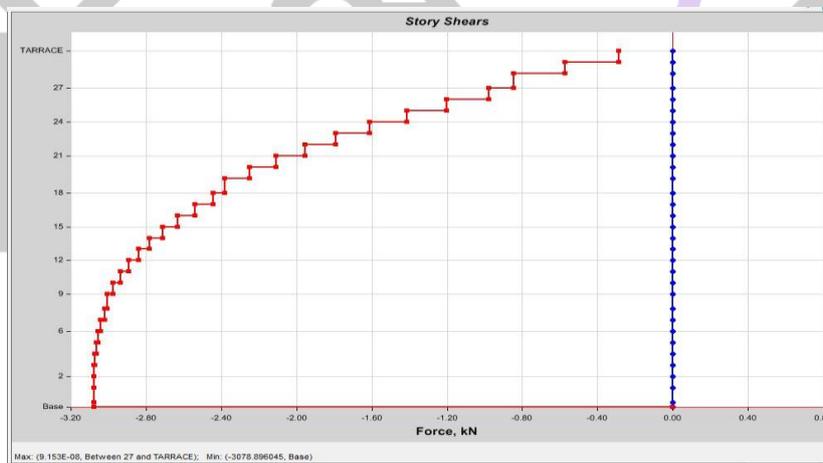
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3.7.1.3 DYNAMIC BASE SHEAR IN X DIRECTION
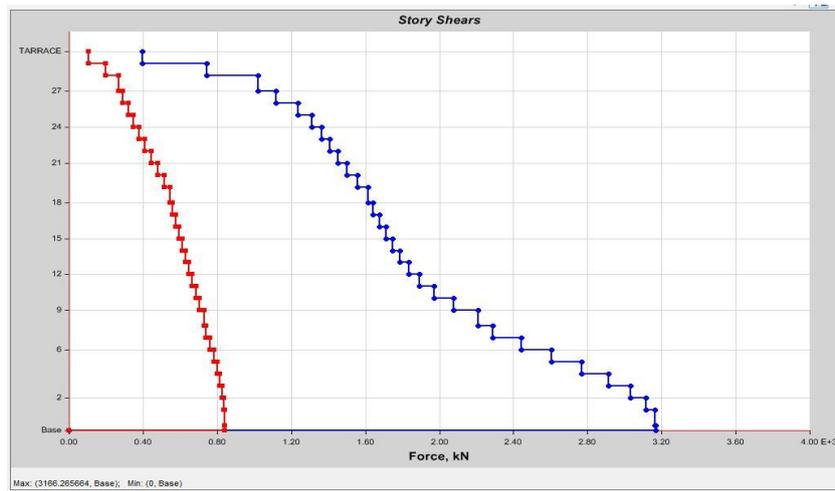
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3.7.1.4 DYNAMIC BASE SHEAR IN Y DIRECTION
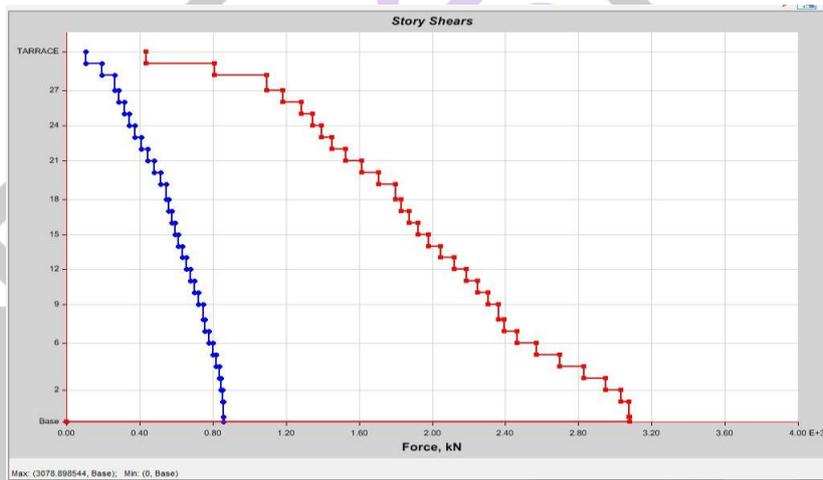
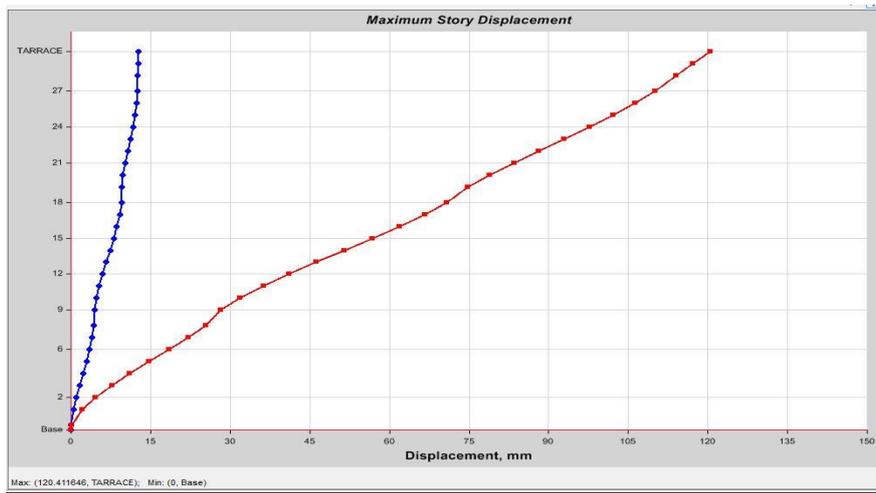GRAPH: 04

3.7.2 NORMAL RCC FRAME DISPLACEMENT DETAILS
3.7.2.1 DISPLACEMENT FOR STATIC EARTHQUAKE IN X DIRECTION
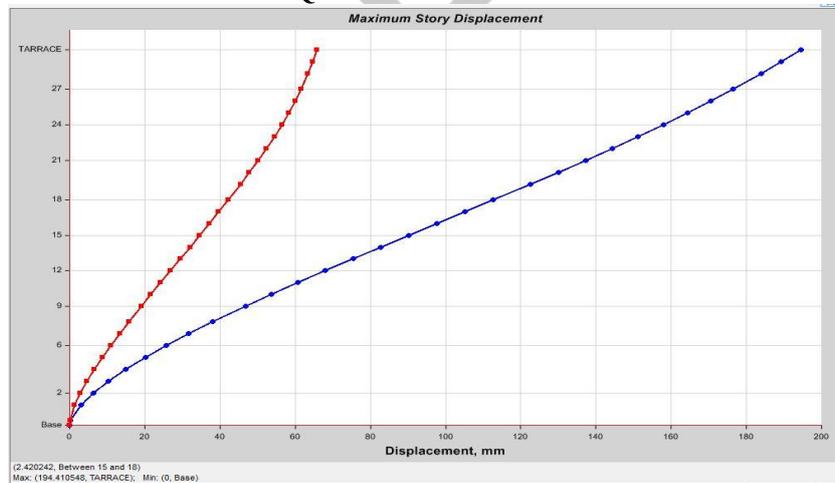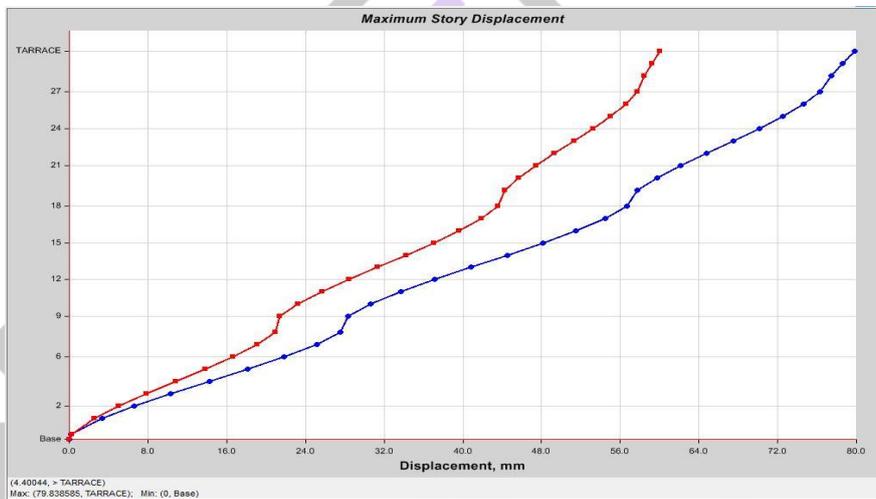

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3.7.2.2 DISPLACEMENT FOR STATIC EARTHQUAKE IN Y DIRECTION
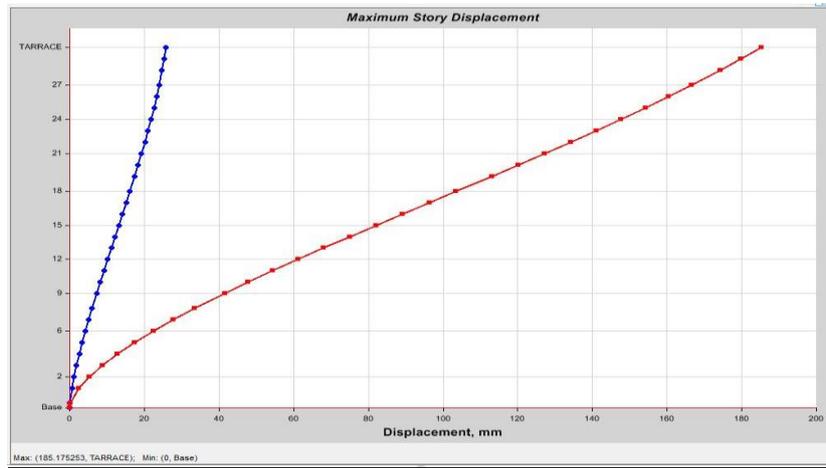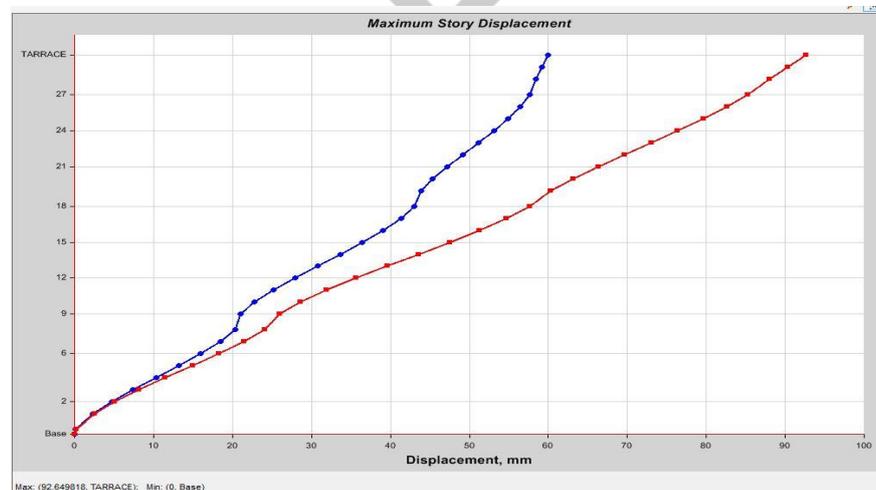

GRAPH: 06

3.7.2.3 DISPLACEMENT FOR DYNAMIC EARTHQUAKE IN X DIRECTION
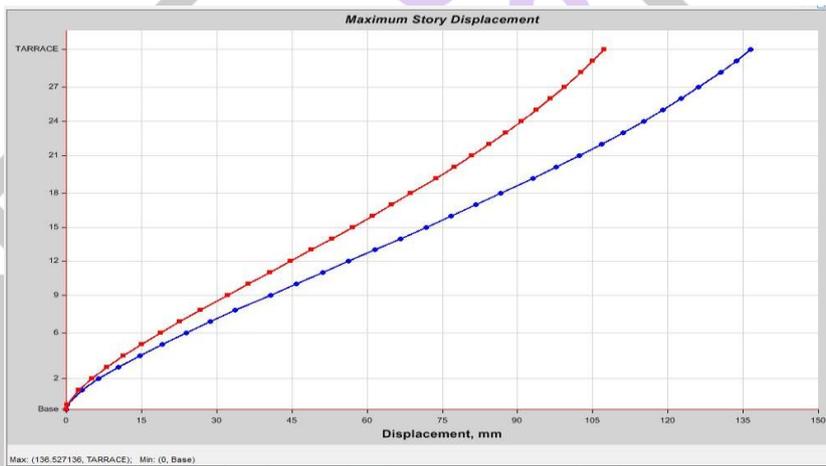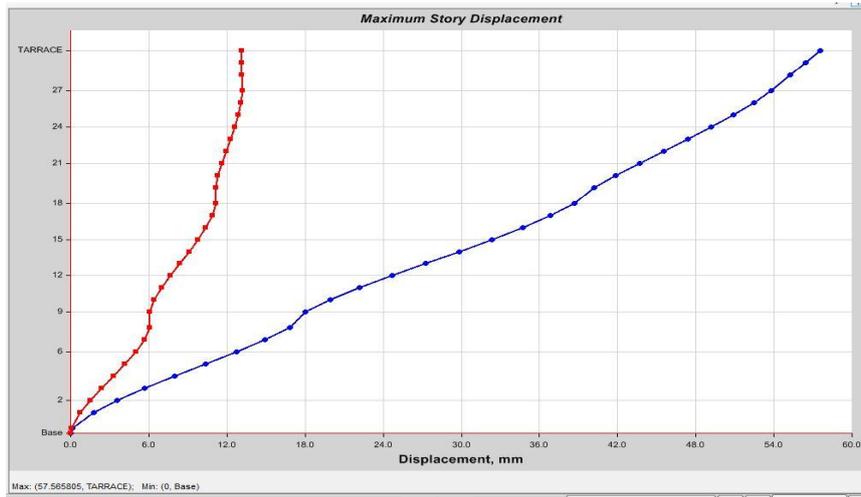

GRAPH: 07

3.7.2.4 DISPLACEMENT FOR DYNAMIC EARTHQUAKE IN Y DIRECTION
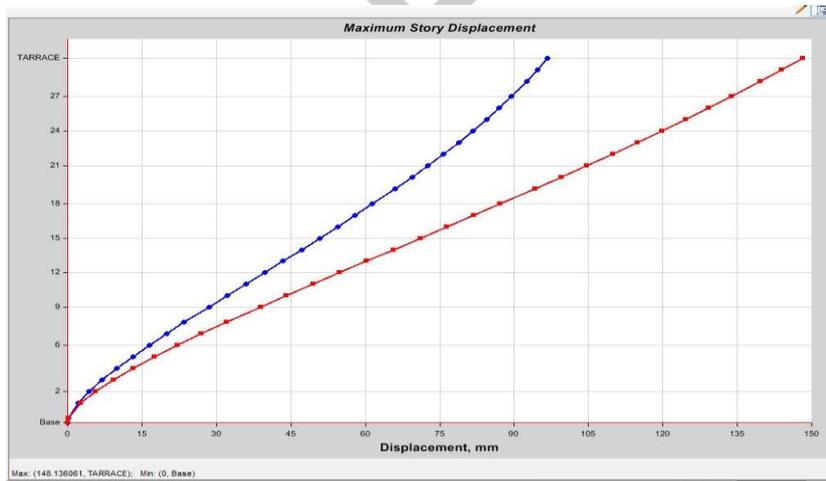


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3.7.2.5 DISPLACEMENT FOR WIND IN X DIRECTION
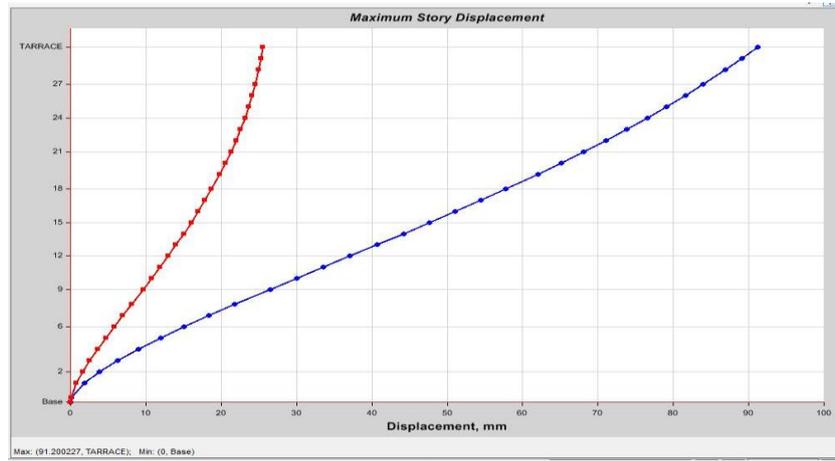
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3.7.2.6 DISPLACEMENT FOR WIND IN Y DIRECTION
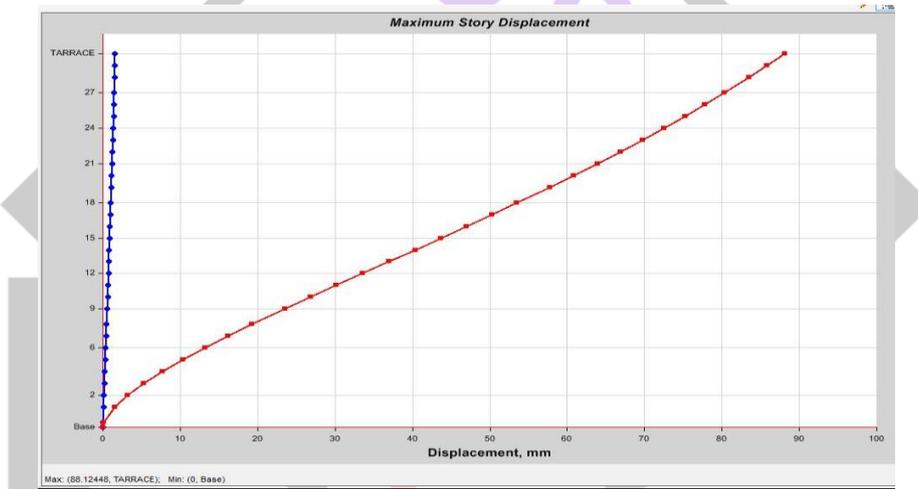
GRAPH: 10

3.7.3 NORMAL RCC FRAME.DRIFT DETAILS
3.7.3.1 DRIFT FOR STATIC EARTHQUAKE IN X DIRECTION
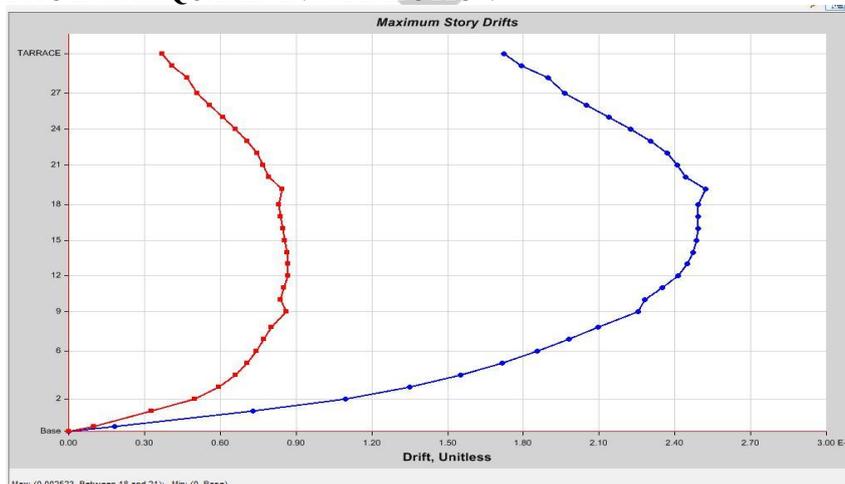
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3.7.3.2 DRIFT FOR STATIC EARTHQUAKE IN Y DIRECTION
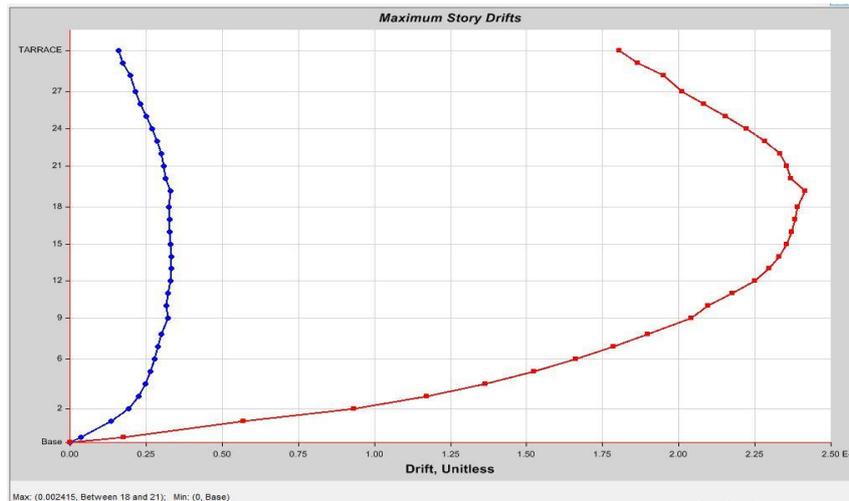
GRAPH: 12

3.7.3.3 DRIFT FOR DYNAMIC EARTHQUAKE IN X DIRECTION
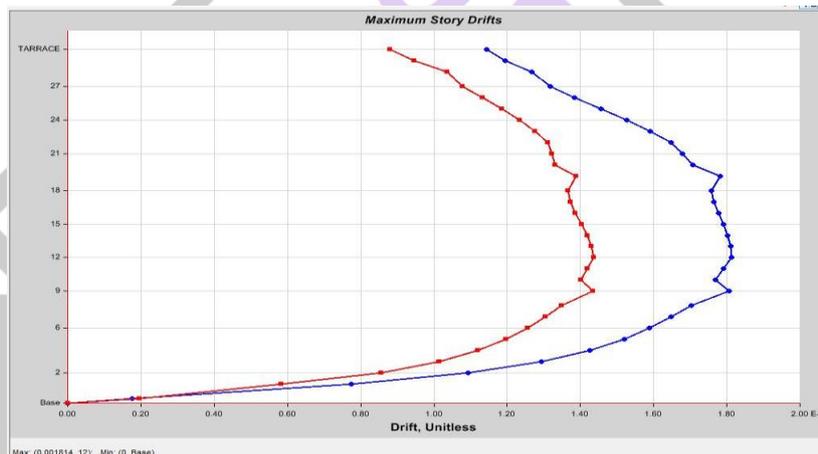
GRAPH: 13

3.7.3.4 DRIFT FOR DYNAMIC EARTHQUAKE IN Y DIRECTION
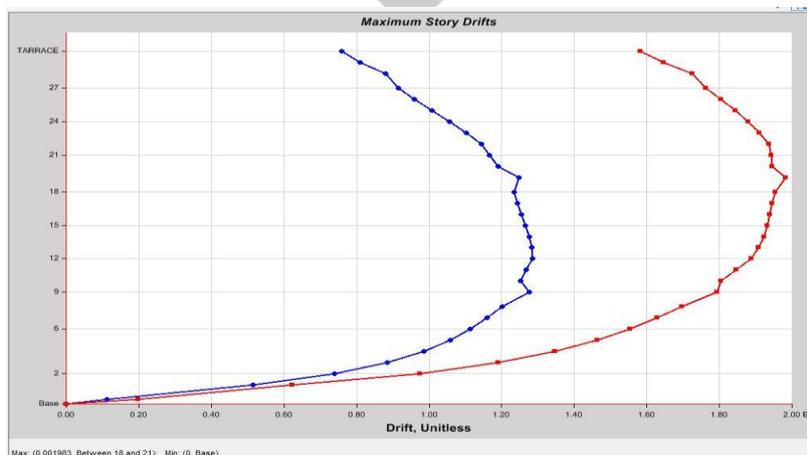
GRAPH: 14

3.8 GRAPHS FOR RCC BRACED FRAME
3.8.1 BASE SHEAR DETAILS
3.8.1.1 STATIC BASE SHEAR IN X DIRECTION
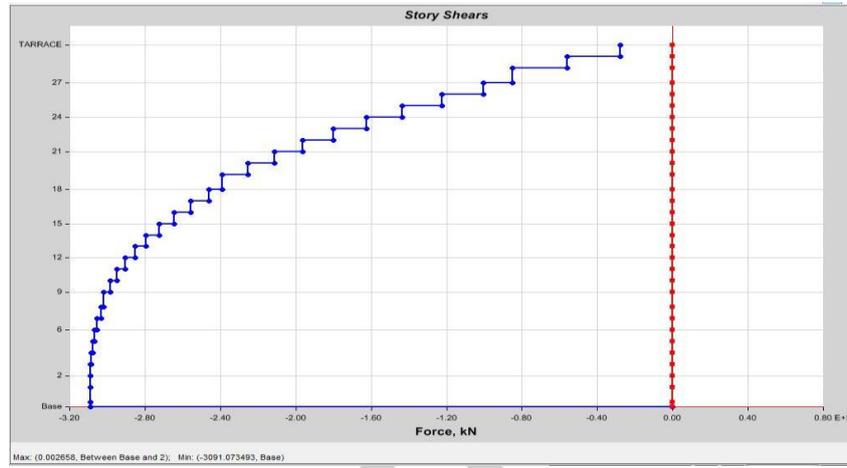
GRAPH: 01

3.8.1.2 STATIC BASE SHEAR IN Y DIRECTION
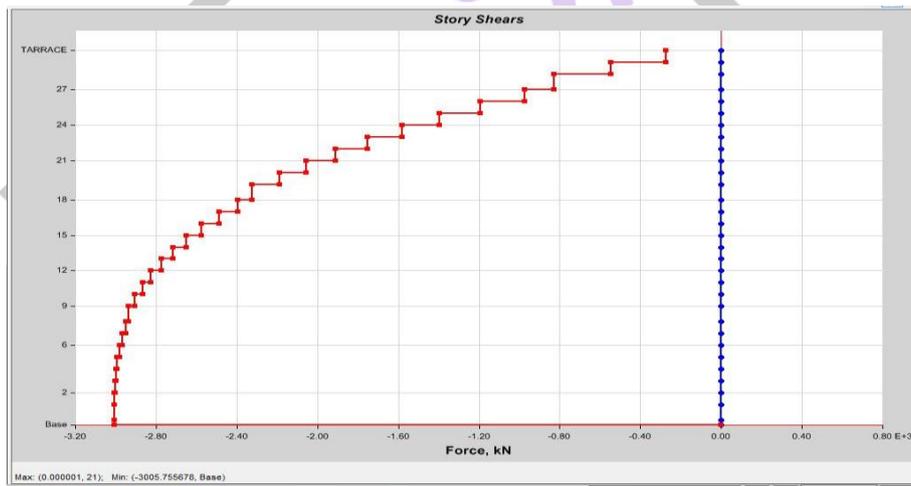
GRAPH: 02

3.8.1.3 DYNAMIC BASE SHEAR IN X DIRECTION
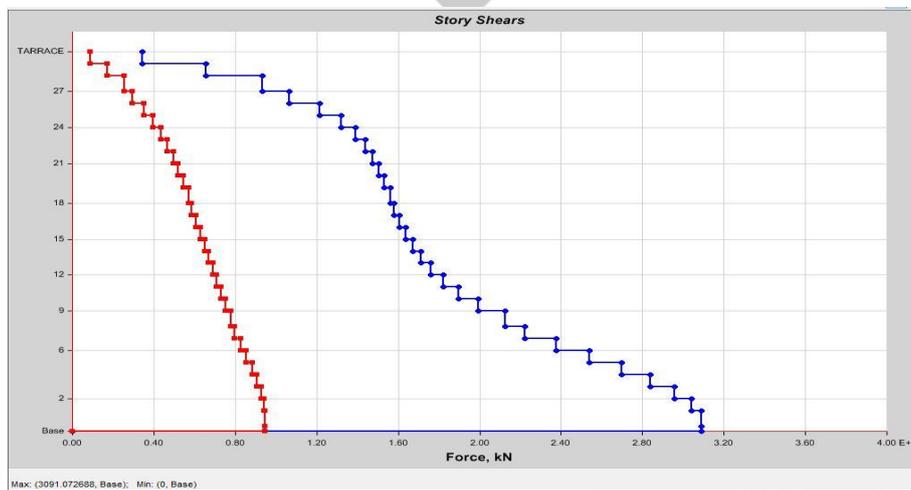
GRAPH: 03

3.8.1.4 DYNAMIC BASE SHEAR IN Y DIRECTION
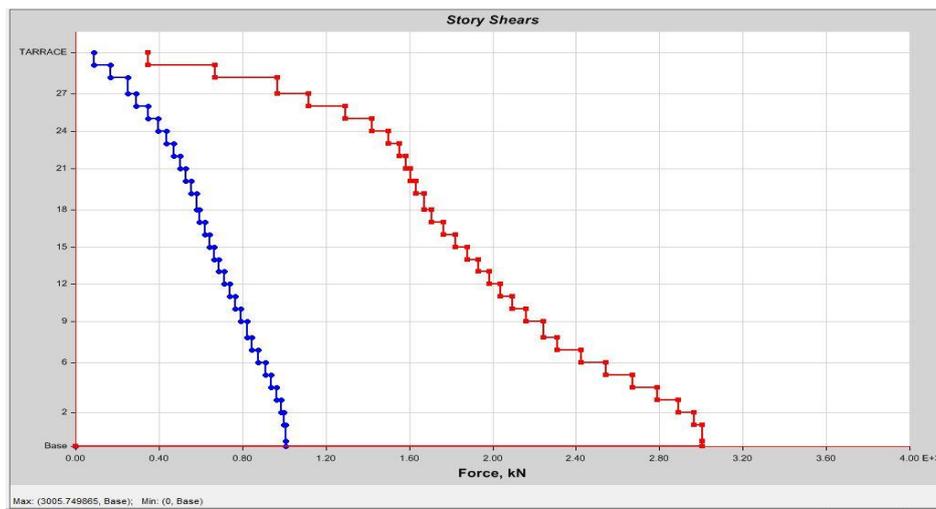
GRAPH: 04

3.8.2 DISPLACEMENT DETAILS
3.8.2.1 DISPLACEMENT FOR STATIC EARTHQUAKE IN X DIRECTION

GRAPH: 05

3.8.2.2 DISPLACEMENT FOR STATIC EARTHQUAKE IN Y DIRECTION

GRAPH: 06

3.8.2.3 DISPLACEMENT FOR DYNAMIC EARTHQUAKE IN X DIRECTION

GRAPH: 07

3.8.2.4 DISPLACEMENT FOR DYNAMIC EARTHQUAKE IN Y DIRECTION

GRAPH: 08

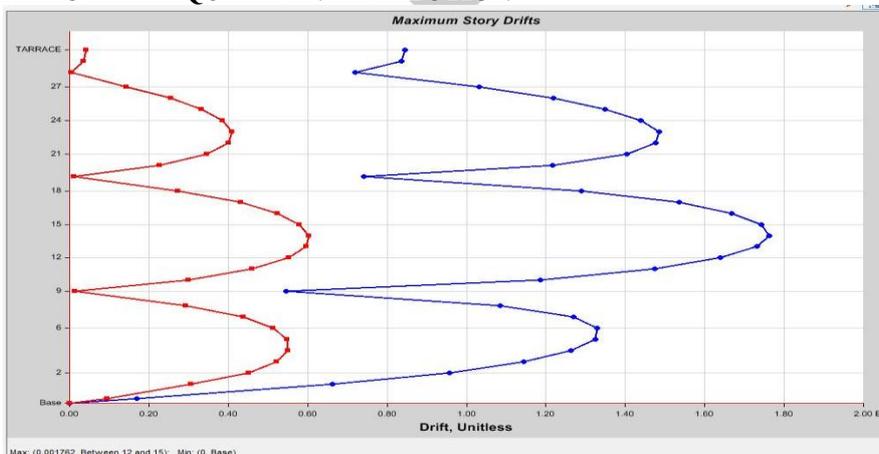### 3.8.2.5 DISPLACEMENT FOR WIND IN X DIRECTION

GRAPH: 09

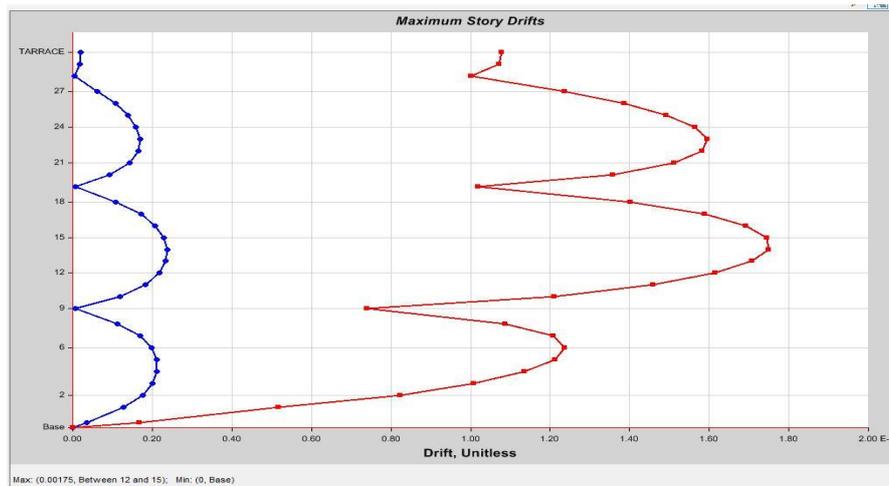### 3.8.2.6 DISPLACEMENT FOR WIND IN Y DIRECTION
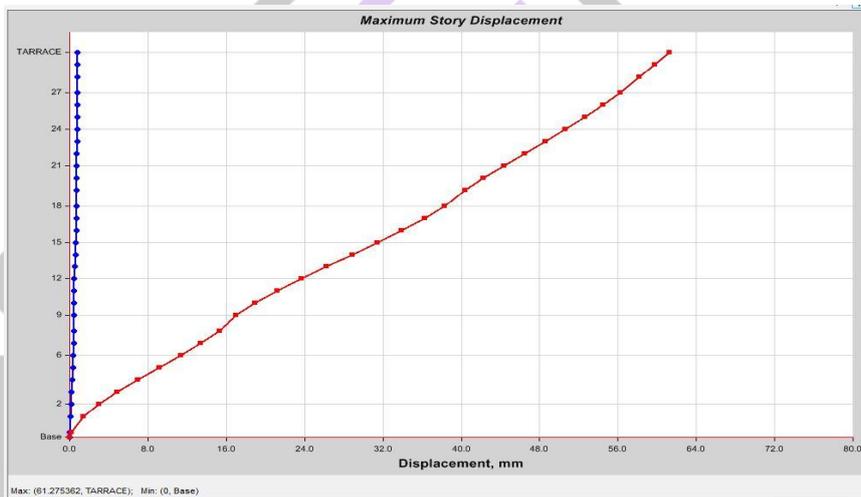
GRAPH: 10

3.8.3 DRIFT DETAILS
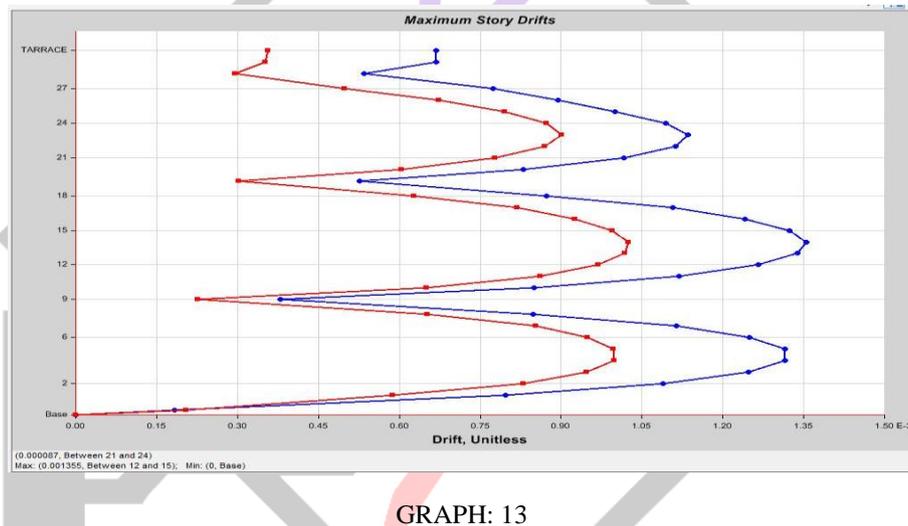### 3.8.3.1 DRIFT FOR STATIC EARTHQUAKE IN X DIRECTION

GRAPH: 11
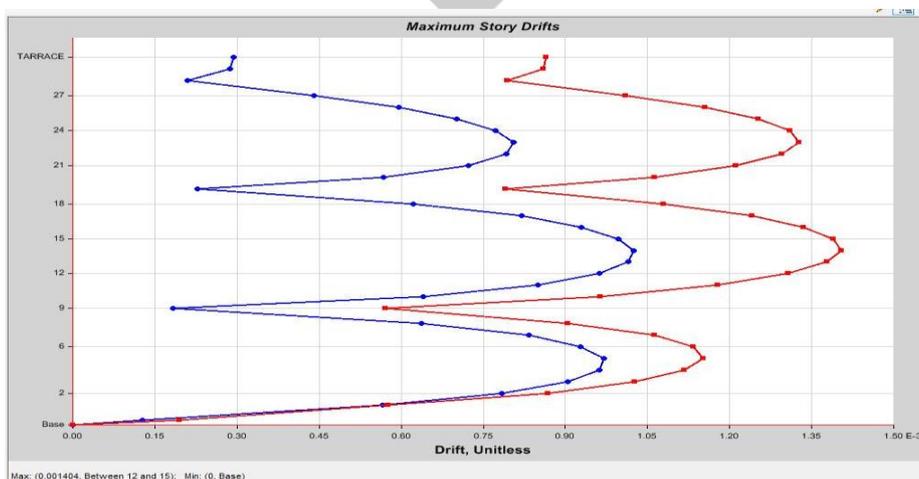
3.8.3.2 DRIFT FOR STATIC EARTHQUAKE IN Y DIRECTION

GRAPH: 12

3.8.3.3 DRIFT FOR DYNAMIC EARTHQUAKE IN X DIRECTION

GRAPH: 13

3.8.3.4 DRIFT FOR DYNAMIC EARTHQUAKE IN Y DIRECTION

GRAPH: 14

4. CONCLUSION

From the study it is clear that now a day soft storey buildings are becoming more useful and can be used as commercial as well as residential proposes. So in current paper an attempt was made to study the effect of soft storey on high rise building under earthquake and wind loads. Two models were prepared, one is bare frame and other is braced frame and stiffness of both models were checked under the effect of earthquake and wind load. And following conclusions are drown out.

- Time duration of the structure is more in bare frame, whereas it reduces in case of braced frame.

- Base shear in case of bare frame is more, whereas after the provision of bracings it is observed that base shear reduces.

- Drift and displacement of the structure are more in case of bare frame. And these can be lowered by making the provision of bracings at the level of soft storey.

- Stiffness of the soft storey in case of bare frame is less than the upper storey. And it is seen that stiffness of the storey increases by providing the bracings at soft strey level.

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