ANALYSIS AND PERFORMANCE BASED EARTHQUAKE RESISTANCE DESIGN OF MULTISTORIED BUILDING IN ETABS

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ABSTRACT

Soft storey is an unavoidable feature in the multi-storey building. It is open for the purpose of parking or reception lobbies and soft storey at different levels of the building for office use. It is also called as stilts storey. Masonry infill's are normally considered as non-structural elements and their stiffness contributions are generally ignored in practice, such an approach can lead to an unsafe design. In the soft storey, the inter storey drifts and seismic demands of the columns are excessive that causes heavy damage or collapse of the buildings during a severe earthquake. The masonry infill walls though constructed as secondary elements behaves as a constituent part of the structural system and determine the overall behavior of the structure especially when it is subjected to seismic loads. In modeling, the masonry infill panels the Finite Element Method is used and the software ETABS is used for the linear dynamic analysis of all the models.
Keywords*; infill walls, multi storied buildings, earth quake resistance*

1.0 Introduction

Linear dynamic analysis of building Models were performed using the software ETABS. The lateral displacements and drift and base shear in soft storey of building, and bare frame are more in infill wall of building. Also from the analysis they concluded that RC frame building with soft storey perform poorly during strong earthquake shaking. The drift and the strength demands in the first storey column are very large for building with soft first storey. The infill components increase the lateral stiffness and serve as a transfer medium of horizontal inertia forces. From this conception the floors that have no infill component has less stiffness regarding other floors.

2.0 Literature review

Hiten and Anuj (2014) investigated many buildings that collapsed during the past earthquake exhibited exactly the opposite strong beam weak column behavior means columns failed before the beams yielded mainly due to soft storey effect. For proper assessment of the storey stiffness of buildings with soft storey building, different Models were analyzed using software. Concluded the displacement estimates of the lateral load patterns are observed to be smaller for the lower stories and larger for the upper stories and are independent of the total number stories of the Models.

Dhadde Santosh (2014)]has carried out nonlinear pushover analysis on building Models using software ETABS and evaluation is carried for non-retrofitted normal buildings and retrofitting methods are suggested like infill wall, increase of ground storey column stiffness and shear wall at central core. Storey drift values for soft storey Models maximum values compare to other storeys and the values of storey drift decreases gradually up to the top.

Rakshith and Shankar (2014) modeled& analyzed RC buildings with soft storey at different level for different load combinations using ETAB the inter storey drift was observed to be maximum in vertically irregular structure when compared to that of regular structure.

Mr.D.Dhandapany (2014) investigated the seismic behavior of RCC buildings with and without shear wall. Analyzed using ETABS software for different soil conditions (hard, medium, soft). The values of Base shear, axial force and Lateral displacement were compared between two frames. Results obtained using STAAD are found to be almost equal results to when compared to obtained using ETABS for all structural members.

3.0 Scope of work-A large number of buildings with soft storey have been built in India in recent year. But it showed poor performance during past earthquake. Therefore it is need of time to take immediate measures to prevent the indiscriminate use of soft first storeys in buildings, the increased displacements and force demands in soft storey at different levels of the building. In this regard, this paper discussed about the storey drifts, lateral displacements and base shears of six models including bare frame and bare frame with slab element in all zones. Also this study has been carried out to compare modified first soft storey, second soft storey, and third soft storey provisions with complete infill wall frame, bare frame models, and bare frame with slab element. Results shows a general changing pattern in storey drifts, lateral displacements and base shear irrespective to building height and maximum inter-storey drift was obtained where the soft storey was located at different levels of the building.

4.0 Objectives:

Following are some objectives of this dissertation work.

1. The main objective of this dissertation is focus on the behavior of RC frame buildings with bare frame, bare frame with slab element, first soft storey, second soft storey, third soft storey in seismic zones II, III, IV, and zone V.
2. To study the effect of storey drifts, lateral displacement and base shear in the seismic zones II, III, IV and zone V of bare frame, bare frame with slab element, full infills, and soft storey at different levels of buildings.
3. To check the applicability of the multiplication factor of 2.5 as given in the Indian Standard IS 1893:2002 for design of bare frame, bare frame with slab element, full infills, and soft storey at different levels of building in zones II,III,IV& zone V.
4. To analyze the RC frame for dynamic analysis in relation to the storey drift and lateral displacements, base shear using software ETABS.
5. To study the comparison between the storey drifts, lateral displacements, base shear of all Models in seismic zones II, III, IV and zone V.
6. To investigate the bare frame, soft storey behavior at different levels of RC frame building for all cases so as to arrive at suitable practical conclusion for achieving earthquake resistant RC frame building.
7. To identify the storey drift where there is exceeds its permissible values of storey drifts i.e.0.004h, in each zone for different Models.
8. To study failure conditions of six Models at different storey's in each zone for all Model buildings.
9. To promote safety without too much changing the constructional practice of reinforced concrete structures.

5.0 Methodology

As experienced by the engineers at design offices the multiplication factor of 2.5 given by IS 1893:2002, for ground storey beams and columns, is not realistic for low rise buildings. This calls for a critical assessment and review of the code recommended multiplication factor. Assessment of the multiplication factor (MF) requires accurate dynamic analysis of soft storey buildings considering infill stiffness and strength. The presence of infill walls in upper storey of soft storey at different levels of buildings accounts for the following issues:1)Increases the lateral stiffness of the building frame. 2)Increases the base shear. 3)Increases the shear forces and bending moments in the ground storey columns. There is a clear need to assess the design guidelines recommended by the IS code 1893:2002.

5.1 Analyzing the data: Linear dynamic analysis has been performed as per IS 1893 (Part 1): 2002 for each model using ETABS analysis package. Lateral load calculation and its distribution along the height are done. The seismic weight is calculated using full dead load plus 25% of live load. Following data is used in the analysis of the RC frame building Models **Data relation to the RC frame building Models**

Type of frame	Ordinary moment resisting RC frame OMRF) fixed at the base
Seismic zones	II,III,IV,&V
Number of storey	G+10 storey
Floor height	3 m
Depth of Slab	150 mm
Size of beam	(230 × 600) mm
Size of column	(230 × 750) mm
Spacing between frames in x-direction	8 m
Spacing between frames in y-direction	7 m
Materials	M 25 concrete, Fe 415 steel and
Infill	Brick
Thickness of external infill walls	230 mm
Thickness of external infill walls	115 mm
Density of concrete	24kN/m^3
Density of infill	20 kN/m^3
Type of soil	Medium soil
Seismic zone	As per IS (1893-2002)
Seismic zone factor, Z	For zone II: 0.10 For zone III: 0.16 For zone IV: 0.24 For zone V: 0.36
Importance Factor, I	1
Response spectrum analysis	Linear dynamic analysis
Damping of structure	5 percent
Plinth height above ground level	1.8 m
Type of the building	OMRF(Ordinary moment resisting RC frame)
Wall load for the outer side for (3 m height wall)	12.42 kN/m
Wall load for the inner side for (3 m height wall)	6.21 kN/m
Wall load for the outer side for (1.8 m height wall)	6.90 kN/m
Wall load for the inner side for (1.8 m height wall)	3.45 kN/m
Total Dead load of slab	5.75 kN/ m^2
Live load	2 kN/ m^2
For Seismic zone loading only 50% of the imposed load is considered the structure is analyzed for all seismic zone by considering Medium for each seismic zone	

5.2 Materials used:

a) Concrete

Concrete with following properties is considered for study.

- Characteristic compressive strength (f_{ck}) = 25 MPa
- Poisons Ratio= 0.2
- Density= 24 kN/m^3
- Modulus of Elasticity (E) = 5000 x $\sqrt{f_{ck}}$= 25000 MPa

b)Steel

Steel with following properties is considered for study.

- Yield Stress (f_y)= 415 MPa
- Modulus of Elasticity (E) = $2x10^5$MPa

c) Masonry infill

- Clay burnt brick, Class A, confined unreinforced masonry
- Compressive strength of Brick, f_m= 10 MPa
- Modulus of Elasticity of masonry (E_i) = 550 x f_m = 5500 MPa
- Poisons Ratio = 0.15

5.3 Load Calculations:

1. **Gravity loading:**

(As per IS: 456 – 2000 & IS: 875 (Part II)-1987) For Dead Load (DL)
Intensity of external wall (for 3m height) = 12.42 kN/m
Intensity of internal wall (for 3m height) = 6.21 kN/m
Intensity of external wall (1.8 m height) = 6.90 kN /m
Intensity of internal wall (1.8 m height) = 3.45 kN/m
Intensity of slab load= 3.75 kN /m^2
Intensity of floor finish load =1 kN /m^2

3.11 RC frame building Models considered in the thesis:

1) Model 1: Bare frame
2) Model 2: Bare frame with slab element.

Intensity of roof treatment load = 1.5 kN /m^2
Intensity of live load (LL)= 2 kN /m^2.

5.4 Lateral loading:

(As per IS1893-2002) Lateral loading consists of earthquake loading. Earthquake loading has been calculated by the program and it has been applied to the mass center of the building. Since the building under consideration was in Zones II, III, IV, & zone V with standard occupancy so the result was computed for the worst case of load combination i.e. (0.9DL+1.5EQX) by Code. The Response reduction factor, R = 3 for OMRF (Ordinary moment resisting RC frame). Importance factor, I = 1, Soil Type = II (Medium Soil), Seismic zone factor, Z = 0.10 for zone II, Z = 0.16 for zone III, Z = 0.24 for zone IV, & Z = 0.36 for zone V.

5.5 Load combination:

The multi-storey building under consideration was in Zones II, III, IV, and zone V with standard occupancy so the result was computed for the worst case of load combination have been taken i.e. (0.9DL+1.5EQX) by Code.

The Plan area of building is 32m x 21m, the Models having 4 bays at 8m distance in x-direction and 3 bays at 7m distance in y- direction.

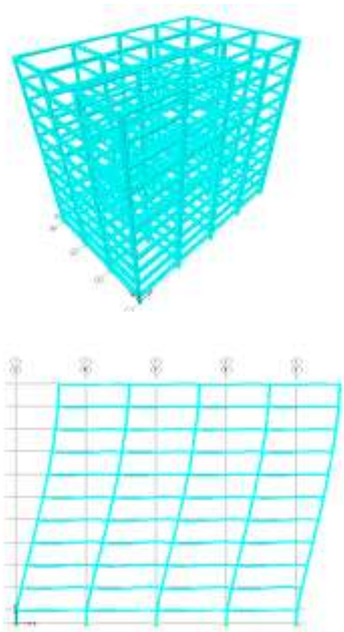
Fig: 3.1 Plan for G+10 storey building

3) Model 3: Building has full walls with external walls (230mm thick) and internal walls (115mm thick).

4) Model 4: Building has first soft storey with external walls (230mm thick) and internal walls (115mm thick).

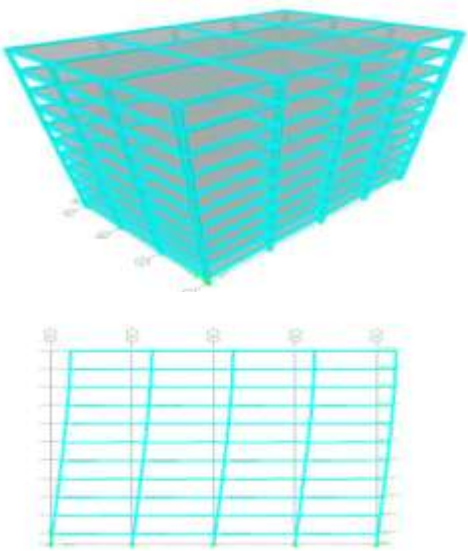
5) Model 5: Building has two stories soft storey with external walls (230mm thick) and internal walls (115mm thick) from ground level.

6) Model 6: Building has three stories soft storey with external walls (230mm thick) and internal walls (115mm thick) from ground level



a) 3D view
b) Lateral displacement

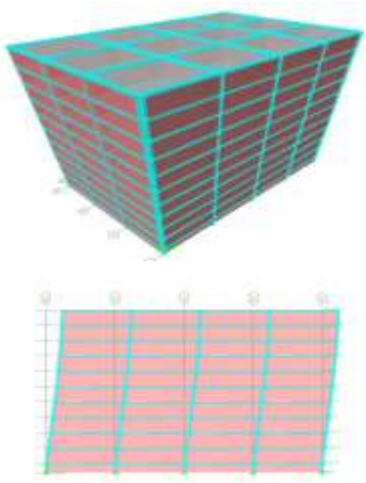
Fig 3.2: Model 1: G+10 RC bare frame building



a) 3D view b) Lateral displacement

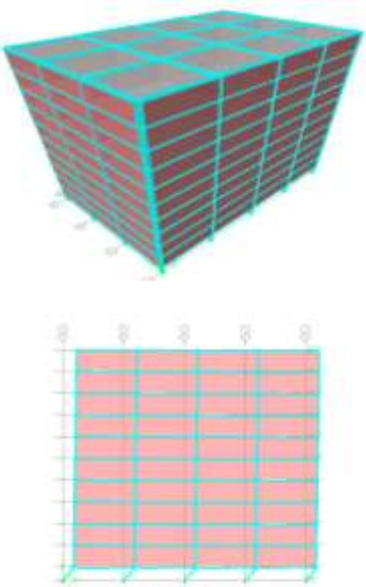
Prepared Models

Fig 3.3: Model2: G+10 RC bare frame building with slab element



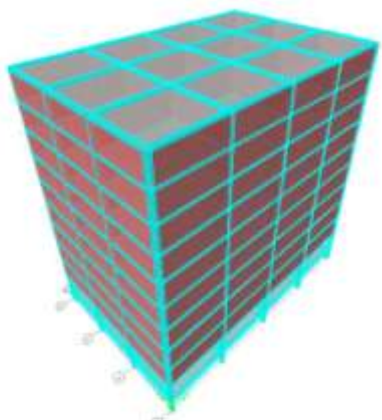
a) 3D view b) Lateral displacement

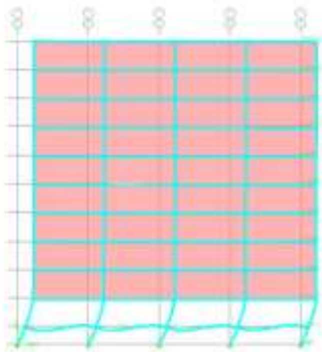
Fig 3.4: Model 3: G+10 RC building of full infill wall with slab element



a) 3D view b) Lateral displacement

Fig 3.5: Model 4: G+10 RC first soft storey building with slab element

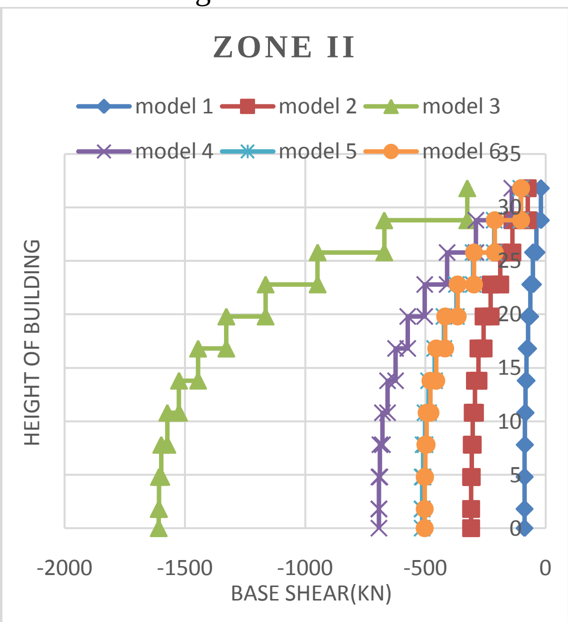


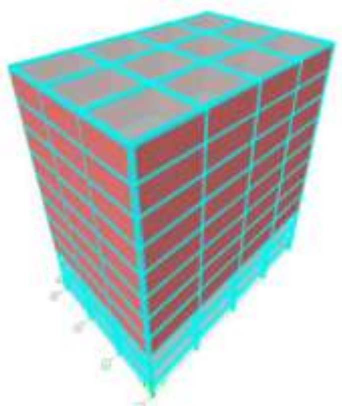


3Dview

Lateral displacement

Fig 3.6: Model5: G+10 RC two soft storey building with slab element





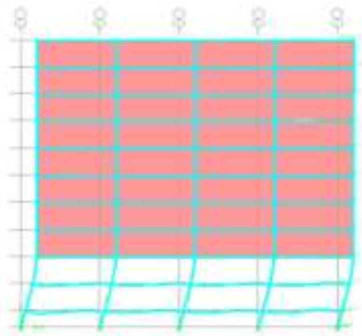
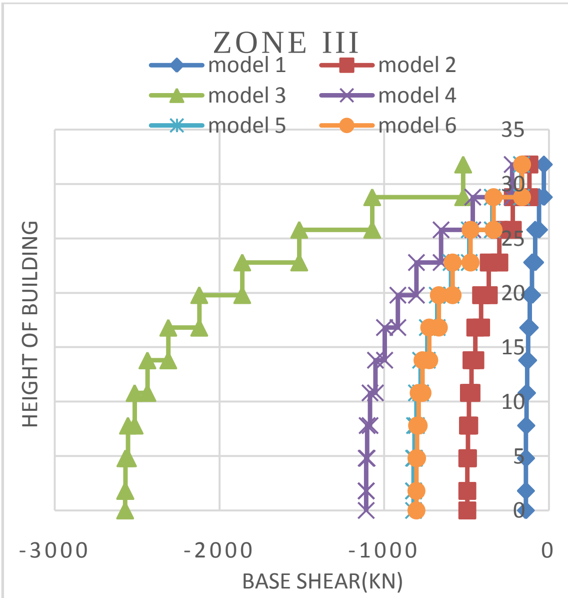


Fig 3.7.1: Model6: G+10 RC three soft storey building with slab element

Fig 3.7.2: Model6: G+10 RC three soft storey building with slab element

Lateral displacement



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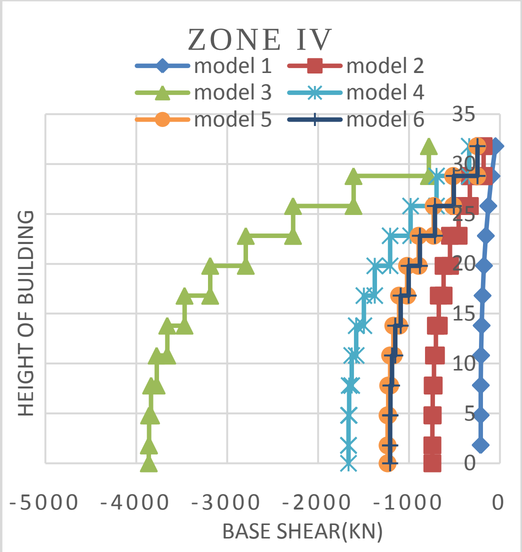

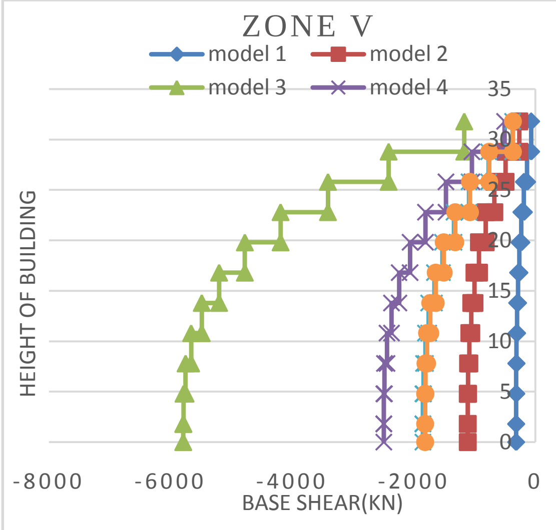

It is observed that the base shear is varying in each Model of zone II due to the lateral load at all floor levels. It is observed that the base shear is varying drastically as per the arrangement of infills at different levels of the building. The maximum base shear occurred at first soft storey due to presence of infill's at remaining portion of the building, next maximum base shear occurred at second soft storey level(Model 5) due to less amount of infill's occupied the frame as compared to the first soft storey (Model 4) for zone II. The base shear was increased to 71.64%, 94.54%, 87.34%, 82.93%, and 82.56% in model 2, model 3, model 4, model 5, and model 6 respectively when compared to the model 1 in zone II
According to zone wise comparison of the base shear is found to be more in zone V in all Models when compared to the remaining zones. Further it is observed that base shear is found to be less in Zone II in all Models as compared to the other zones. When compared to zone II, the increase in base shear in zones III, IV and V was 36.87%, 57.66%, and 71.67% respectively

Conclusion:

The IS code methods describing very insufficient guidelines about infill wall design procedures. Software like ETABS is used as a tool for analyzing the effect of infill on the structural behavior. It is observed that ETABS provide overestimated values of storey drift, lateral displacement and base shear. According to relative values of all parameters, it can be concluded that provision of infill wall enhances the performance in terms of displacement, storey drift and lateral stiffness.RC framed buildings with soft storey are known to perform poorly during in strong earthquake shaking. Because the stiffness at lower floor is 70% lesser than stiffness at storey above it causing the soft storey to happen. For a building that is not provided any lateral load resistance component such as shear wall or bracing, the strength is consider very weak and easily fail during earthquake. In such a situation, an investigation has been made to study the seismic behavior of such buildings subjected to earthquake load so that some guideline could be developed to minimize the risk involved in such type of buildings. It has been found earthquake forces by treating them as ordinary frames results in an underestimation of base shear. Investigators analysis numerically and use various computer programs such as STAAD Pro., ETABS, SAP2000 etc. Calculations shows that, when RC framed buildings having brick masonry infill on upper floor with soft ground floors subjected to earthquake loading, base shear can be more than twice to that predicted by equivalent earthquake force method with or without infill or even by response spectrum method when no infill in the analysis Model. This document highlights the poor seismic performance of RC bare frame buildings, bare frame with slab element, first soft storey second soft storey, and third soft storey from ground level and the documents analyzing the variation of storey drifts, lateral displacements and base shear in all zones.

The storey drifts observed of the structure are found within the limit as specified by code (IS: 1893-2002, part-1) in linear dynamic analysis.

Storey drift value is more in the storey 11 of bare frame as compared to the soft storey at different levels of building.

The presence of masonry infill influences the overall behavior of structures when subjected to lateral forces. Lateral displacements and storey drifts are considerably reduced while contribution of the infill brick wall is taken into account.

Infilled frames should be preferred in seismic zones more than the open first storey frame, because the storey drift of first storey of open first storey frame is very large than the upper storey's, this may probably cause the collapse of structure.

Lateral displacement of bare frame Model is higher than other Models because of less lateral stiffness of storey, due to absence of infill walls. The lateral displacements were observed in model 2 are reduced to 13.14%, 20.68% 30.74% and 45.82% as compared to the model 1 in zone II, III, IV and zone V respectively

First storey displacement of soft first storey Model is maximum than other Models due to absence of infill in the first storey. In soft first storey frame, there is sudden change in drifts between first and second storey in all seismic zones.

Concluded that the providing of infill wall in RC building controlled the displacement, storey drifts and lateral stiffness.

The increase in base shear in models III, IV and V was 71.64%, 94.54%, 87.34%, 82.93%, and 82.56% respectively when compared to the model 1 in all zones.

Base shear is more in full infilled Model (model 3) as compared to the other R.C building models.

Bare frame has a lesser value of base shear as compared to the other R.C building Models.

Base shear was more in the zone V for bare frame and that in the medium soil, the increase in base shear in zones III, IV and zone V was 36.87%, 57.66%, and 71.67% respectively as that of Zone II.

Future scope

Earthquake vulnerability of buildings with open ground floor is well known around the world. In such a situation, an investigation has been performed to study the behavior of such buildings subjected to earthquake load so that some guidelines could be developed to masonry infill's the risk involved in such type of buildings.

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Annexure-1 table results of zones

Zone II						
Base Shear(kN)						
Height of buildings(m)	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
31.8	-19.48	-74.3	-325.14	-140.27	-103.89	-102.29
28.8	-19.48	-74.3	-325.14	-140.27	-103.89	-102.29
28.8	-37.8	-137.56	-670.54	-289.29	-214.25	-210.95
25.8	-37.8	-137.56	-670.54	-289.29	-214.25	-210.95
25.8	-52.51	-188.33	-947.73	-408.88	-302.81	-298.16
22.8	-52.51	-188.33	-947.73	-408.88	-302.81	-298.16
22.8	-63.99	-227.98	-1164.21	-502.27	-371.98	-366.26
19.8	-63.99	-227.98	-1164.21	-502.27	-371.98	-366.26
19.8	-72.74	-257.88	-1327.46	-572.7	-424.14	-417.62
16.8	-72.74	-257.88	-1327.46	-572.7	-424.14	-417.62
16.8	-79.05	-279.4	-1444.99	-623.41	-461.7	-454.6
13.8	-79.05	-279.4	-1444.99	-623.41	-461.7	-454.6
13.8	-83.25	-293.93	-1524.3	-657.62	-487.04	-479.55
10.8	-83.25	-293.93	-1524.3	-657.62	-487.04	-479.55
10.8	-85.83	-302.82	-1572.87	-678.58	-502.56	-494.83
7.8	-85.83	-302.82	-1572.87	-678.58	-502.56	-494.83
7.8	-87.17	-307.46	-1598.21	-689.51	-510.65	-501.16
4.8	-87.17	-307.46	-1598.21	-689.51	-510.65	-501.16
4.8	-87.68	-309.22	-1607.8	-692.79	-513.72	-502.93
1.8	-87.68	-309.22	-1607.8	-692.79	-513.72	-502.93
1.8	-87.75	-309.46	-1608.86	-693.13	-514.11	-503.17
0	-87.75	-309.46	-1608.86	-693.13	-514.11	-503.17

Zone III						
Base Shear(kN)						
Height of buildings(m)	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
31.8	-31.17	-118.88	-520.22	-224.44	-166.22	-163.66
28.8	-31.17	-118.88	-520.22	-224.44	-166.22	-163.66
28.8	-60.49	-220.1	-1072.9	-462.86	-342.79	-337.53
25.8	-60.49	-220.1	-1072.9	-462.86	-342.79	-337.53
25.8	-84.01	-301.32	-1516.4	-654.2	-484.5	-477.05
22.8	-84.01	-301.32	-1516.4	-654.2	-484.5	-477.05
22.8	-102.39	-364.76	-1862.7	-803.63	-595.17	-586.02
19.8	-102.39	-364.76	-1862.7	-803.63	-595.17	-586.02
19.8	-116.39	-412.6	-2123.9	-916.32	-678.63	-668.2
16.8	-116.39	-412.6	-2123.9	-916.32	-678.63	-668.2
16.8	-126.47	-447.04	-2312	-997.45	-738.71	-727.36
13.8	-126.47	-447.04	-2312	-997.45	-738.71	-727.36
13.8	-133.2	-470.28	-2438.9	-1052.2	-779.26	-767.28
10.8	-133.2	-470.28	-2438.9	-1052.2	-779.26	-767.28
10.8	-137.33	-484.52	-2516.6	-1085.7	-804.09	-791.73
7.8	-137.33	-484.52	-2516.6	-1085.7	-804.09	-791.73
7.8	-139.48	-491.94	-2557.1	-1103.2	-817.04	-801.85
4.8	-139.48	-491.94	-2557.1	-1103.2	-817.04	-801.85
4.8	-140.29	-494.75	-2572.5	-1108.5	-821.95	-804.69
1.8	-140.29	-494.75	-2572.5	-1108.5	-821.95	-804.69
1.8	-140.4	-495.14	-2574.2	-1109	-822.57	-805.08
0	-140.4	-495.14	-2574.2	-1109	-822.57	-805.08

Zone IV						
Base Shear(kN)						
Height of building (m)	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
31.8	-46.75	-178.32	-780.33	-336.65	-249.33	-245.49
28.8	-46.75	-178.32	-780.33	-336.65	-249.33	-245.49
28.8	-90.73	-330.15	-1609.3	-694.29	-514.19	-506.29
25.8	-90.73	-330.15	-1609.3	-694.29	-514.19	-506.29
25.8	-126.02	-451.99	-2274.6	-981.3	-726.75	-715.58
22.8	-126.02	-451.99	-2274.6	-981.3	-726.75	-715.58
22.8	-153.58	-547.14	-2794.1	-1205.5	-892.75	-879.03
19.8	-153.58	-547.14	-2794.1	-1205.5	-892.75	-879.03
19.8	-174.59	-618.9	-3185.9	-1374.5	-1017.9	-1002.3
16.8	-174.59	-618.9	-3185.9	-1374.5	-1017.9	-1002.3
16.8	-189.71	-670.56	-3468	-1496.2	-1108.1	-1091
13.8	-189.71	-670.56	-3468	-1496.2	-1108.1	-1091
13.8	-199.8	-705.42	-3658.3	-1578.3	-1168.9	-1150.9
10.8	-199.8	-705.42	-3658.3	-1578.3	-1168.9	-1150.9
10.8	-205.99	-726.77	-3774.9	-1628.6	-1206.1	-1187.6
7.8	-205.99	-726.77	-3774.9	-1628.6	-1206.1	-1187.6
7.8	-209.21	-737.91	-3835.7	-1654.8	-1225.6	-1202.8
4.8	-209.21	-737.91	-3835.7	-1654.8	-1225.6	-1202.8
4.8	-210.44	-742.13	-3858.7	-1662.7	-1232.9	-1207
1.8	-210.44	-742.13	-3858.7	-1662.7	-1232.9	-1207
1.8	-210.6	-742.71	-3861.3	-1663.5	-1233.9	-1207.6
0	-210.6	-742.71	-3861.3	-1663.5	-1233.9	-1207.6

Zone V						
Base Shear(kN)						
Height of building (m)	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
31.8	-70.13	-267.48	-1170.5	-504.98	-373.99	-368.24
28.8	-70.13	-267.48	-1170.5	-504.98	-373.99	-368.24
28.8	-136.09	-495.22	-2413.9	-1041.4	-771.29	-759.43
25.8	-136.09	-495.22	-2413.9	-1041.4	-771.29	-759.43
25.8	-189.03	-677.98	-3411.8	-1472	-1090.1	-1073.4
22.8	-189.03	-677.98	-3411.8	-1472	-1090.1	-1073.4
22.8	-230.37	-820.71	-4191.1	-1808.2	-1339.1	-1318.6
19.8	-230.37	-820.71	-4191.1	-1808.2	-1339.1	-1318.6
19.8	-261.88	-928.35	-4778.9	-2061.7	-1526.9	-1503.4
16.8	-261.88	-928.35	-4778.9	-2061.7	-1526.9	-1503.4
16.8	-284.56	-1005.9	-5202	-2244.3	-1662.1	-1636.6
13.8	-284.56	-1005.9	-5202	-2244.3	-1662.1	-1636.6
13.8	-299.71	-1058.1	-5487.5	-2367.4	-1753.3	-1726.4
10.8	-299.71	-1058.1	-5487.5	-2367.4	-1753.3	-1726.4
10.8	-308.98	-1090.2	-5662.3	-2442.9	-1809.2	-1781.4
7.8	-308.98	-1090.2	-5662.3	-2442.9	-1809.2	-1781.4
7.8	-313.82	-1106.9	-5753.5	-2482.2	-1838.3	-1804.2
4.8	-313.82	-1106.9	-5753.5	-2482.2	-1838.3	-1804.2
4.8	-315.65	-1113.2	-5788.1	-2494.1	-1849.4	-1810.5
1.8	-315.65	-1113.2	-5788.1	-2494.1	-1849.4	-1810.5
1.8	-315.9	-1114.1	-5791.9	-2495.3	-1850.8	-1811.4
0	-315.9	-1114.1	-5791.9	-2495.3	-1850.8	-1811.4