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Earthquake Analysis of Multi-storeyed Residential Buildings by Equivalent Static Method and Response Spectrum Method and Comparative Study between them

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ABSTRACT

When a powerful, damaging earthquake strikes, it primarily affects the structures that weren't sufficiently well designed assessed as well as having insufficient strength to withstand it. Must need to learn about seismic analysis in order to develop and assess earthquake-resistant structure in order to assure safety against seismic force brought on by earthquake. The techniques used in structure for the earthquake analysis are Equivalent Static Analysis and Response Spectrum Analysis. The G+10 story residential building in zone V is analyzed by STADD PRO software. The primary goal of this thesis is to investigate seismic structure analysis for static and dynamic analysis in a special moment resistant frame and it's effective in withstand earthquake loads. Construction of buildings is major concern, as per the recent Gorkha Earthquake, which happened on April 25, 2015 in Nepal. The analysis of the building is therefore centred on enhancing the seismic capacity through suitable configuration as well as proper planning and detailing of structural parts and the selection of building site is necessary.

Keywords: Equivalent static analysis, Response spectrum analysis, Special moment resisting frame, STADD Pro V8i, Base shear, Story Shear, Story drift, Story displacement

1. INTRODUCTION

Urbanization effects are quite widespread, and people are currently dealing with a lack of available land and high land prices. Nowadays development of high rise buildings as the solution to this problem, however these structures are extremely vulnerable to earthquake damage and the structures completely fail as a result. After 2015 April earthquake in Nepal, often known as the Gorkha earthquake in Nepal which happened at 11: 56 NST, and it has drawn special attention to the structural design. The epicentre of the 7.8 Richter magnitude earthquake, with a focal point 8.2 km below and a Mercalli intensity of category ix (intense), was only 60Km to the northwest of Kathmandu, the country's capital. Different earthquakes occur at various locations with varying intensities, magnitudes and accelerations and at these locations, the damage they produce varies as well. As a result, it is crucial to research how seismic activity affects RC structures for a variety of reactions, including base shear, story shear, story drift, story displacement, axial force, bending moment, torsion etc. The calculation of the building seismic reaction requires seismic analysis, which is a common step in the structural design.

2. Literature Review

- Anirudh Gottala, et al (2015)[1] has published a journal on "Comparative Study of Static and Dynamic Seismic Analysis of a Multi-storeyed Building". The (G+9) pattern multi-story framed construction was chosen and its lies zone in II and III of Andhra Pardesh. According to IS-1893-2002-Part-1, STADD PRO was used to perform static (Seismic Coefficient Method) and dynamic (Response Spectrum Method) linear seismic analysis on the building. The findings of the static and dynamic analyses, such as the bending moment, nodal displacements, and mode shapes, were compared and reported for the beams, columns, and structure as a whole.

- Giru Mindaye, Dr. Shaik Yajdani, (2016) has published journal on "Seismic Analysis of a Multi-storey RC Frame Building in Different Seismic Zones", the seismic response of a residential G+10 RC frame is the main topic of this academic paper. It is done for various seismic Zones and medium soil type for all Zones. Zones II and III are done using only OMRF frame types, whereas Zones I, II, and III are done using both OMRF and SMRF frame types. In order to compare the outcomes of the static and dynamic analyses, several responses, such as lateral force, overturning moment, narrative drift, displacements, and base shear are shown.

- Bahador Bagheri (2013) has published a journal on "Comparative Study of Seismic Response for Seismic Coefficient and Response Spectrum Methods" the time periods, natural frequencies and mode shape coefficients were calculated by MATLAB program then remaining process was done by manually. The modal combination rule for Response Spectrum Analysis was SRSS. The main parameters considered in that study was to compare the seismic performance of different Zones i.e. II and V were Base Shear, Story Moment and lateral force.

- Kurapati Manasa, A Srikanth (2017) has published a journal on "Comparison of Equivalent Static Analysis and Response Spectrum Analysis on G+10 storied Building in All Seismic Zones and Soil Types" a multi-storied framed structure of (G+10) pattern is selected and linear seismic analysis is done for the building by static method (Seismic Coefficient Method) and the dynamic method (Response Spectrum Method) using STAAD-Pro as per the IS- 1893-2002-Part-1. Comparison is done between both methods results such as bending moment, nodal displacements.

3. Method of Analysis

3.1. Equivalent Static Analysis

One of the streamlined methods, known as the equivalent static analysis method, was created to replace the dynamic loading caused by an anticipated earthquake with a static force distributed laterally on a structure. By only using horizontal forces, the structure is analysed and designed. The analogous static technique is frequently utilised in design and analysis for low-rise structures.

3.2. Response Spectrum Analysis

For a given damping, the response spectrum is a plot of the maximum response of linear single degree of freedom system oscillations as a function of natural period. Response Spectrum Analysis indicates the dynamic behaviour of structure under peak ground acceleration and is useful to assess the performance of structure under peak ground acceleration and is useful to assess the performance of structure under dynamic excitation.

4. General Building Description

Particulars	**Details**
Country	Nepal
Region	Central Development Region
State	Bagmati Province
District	Kathmandu
Zone	Bagmati
Type of Building	Residential Buildings
Structural System	Special moment resisting frame
Plan Size	32.613m×29.565m
Type of Staircase	Open well
Type of lift	Box lift
Soil type	Medium soil (II)
Seismic Zone	V
No of storey	G+10 floors + staircase cover +2 box lift
Main wall	0.229m
Partition wall	0.102m
Parapet wall	0.102m
Floor height	3.048m
Staircase cover	3.048m
Beams	457.2mm ×609.6mm
Columns	700mm×700mm
Shear wall	25mm, 30mm, 35mm
Imposed load	2.5KN/m^2
Concrete	M30 grade
Steel	Fe415 grade
Specific wt of masonry	20KN/m^3
Particulars	**Details**
Specific wt of RCC	25KN/m^3

5. Results

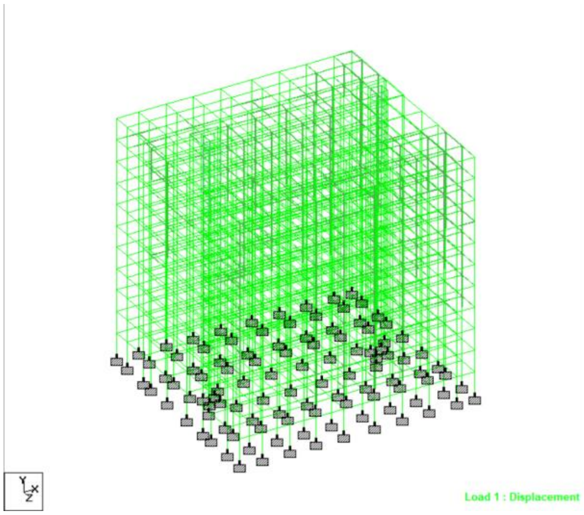


Fig: Displacement in Equivalent Static Analysis

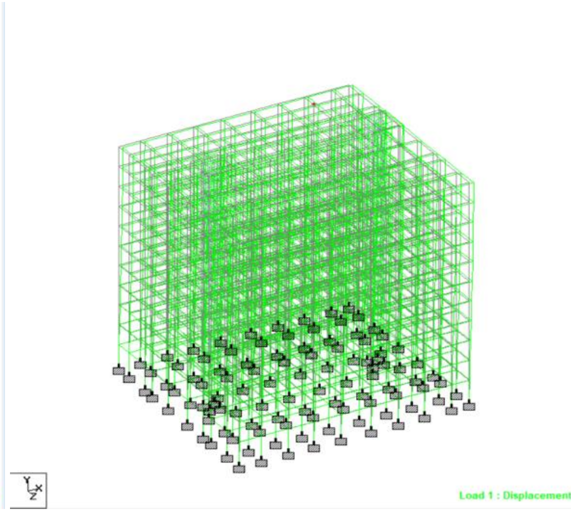


Fig: Displacement in Response Spectrum Analysis

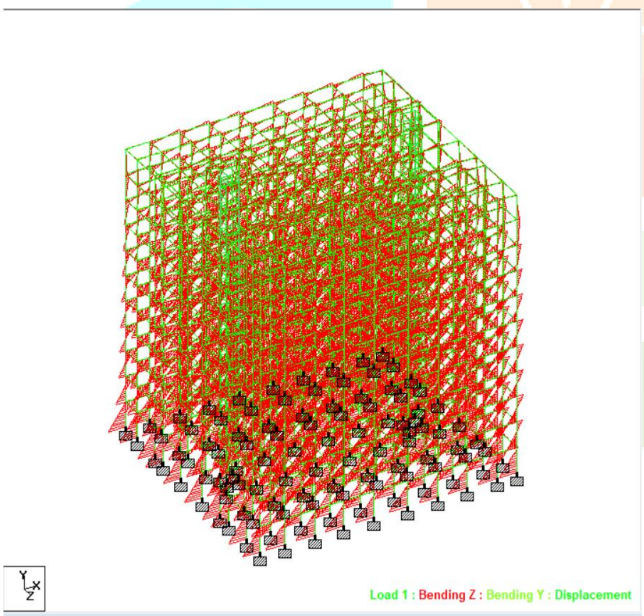


Fig: Displacement, Bending Y and Z in Equivalent Static Analysis

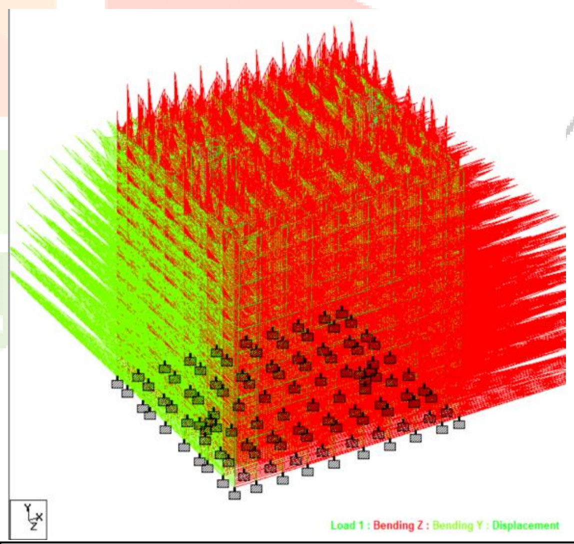
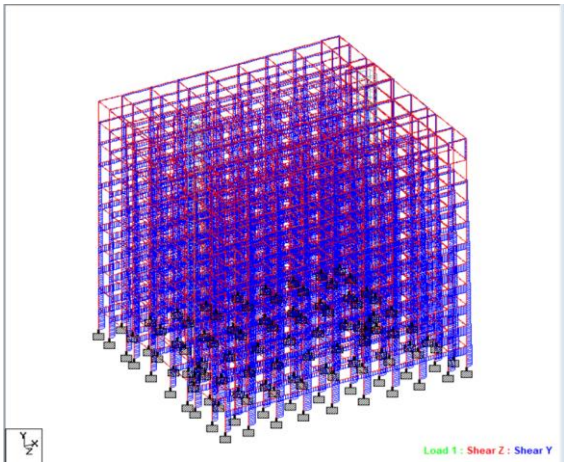


Fig: Displacement, Bending Y and Z in Response Spectrum Analysis



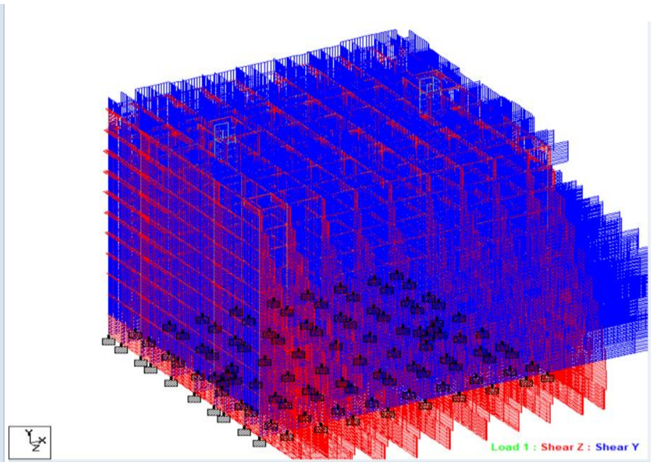
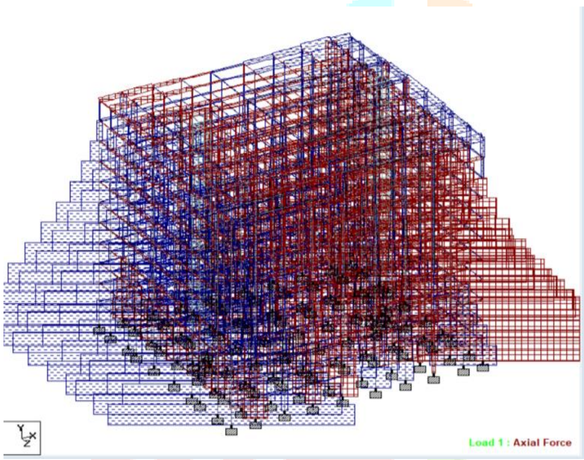


Fig: Shear Y and Z in Equivalent Static Analysis

Fig: Shear Y and Z in Response Spectrum Analysis



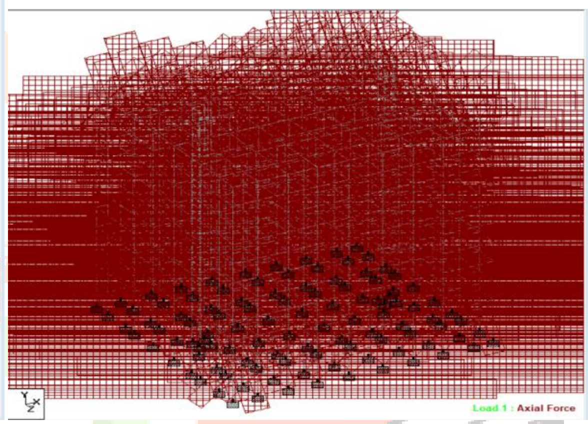
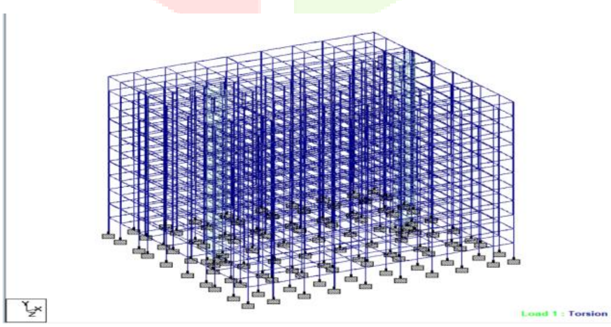


Fig: Axial force in Equivalent Static Analysis

Fig: Axial force in Response Spectrum Analysis



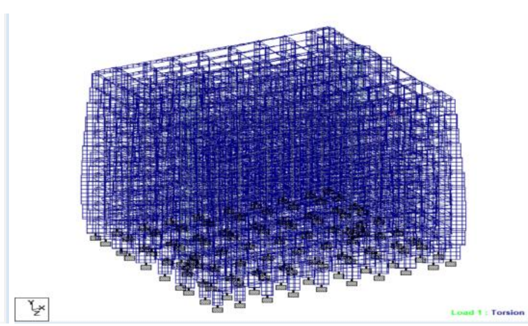


Fig: Torsion in Equivalent Static Analysis

Fig: Torsion in Response Spectrum Analysis

➢ Base Shear

Base shear is a calculation of the greatest lateral force that seismic activity is projected to have on the foundation of the structure. It is estimated using lateral force formulae for the seismic zone, the soil type, and the building code. The symbol for it is "VB".

Table 1: Base shear for ESA and RSA method

	ESA		RSA	
	X(KN)	Z(KN)	X(KN)	Z(KN)
Without Shear wall	5432.22	5518.04	149453.23	149778.10
After getting safe with Shear wall 35mm in lift portion for ESA and RSA methods	230.451	248.522	1066.273	1069.645
With Shear wall of 45mm in lift portion for ESA and RSA methods	40.529	42.738	235.621	239.424

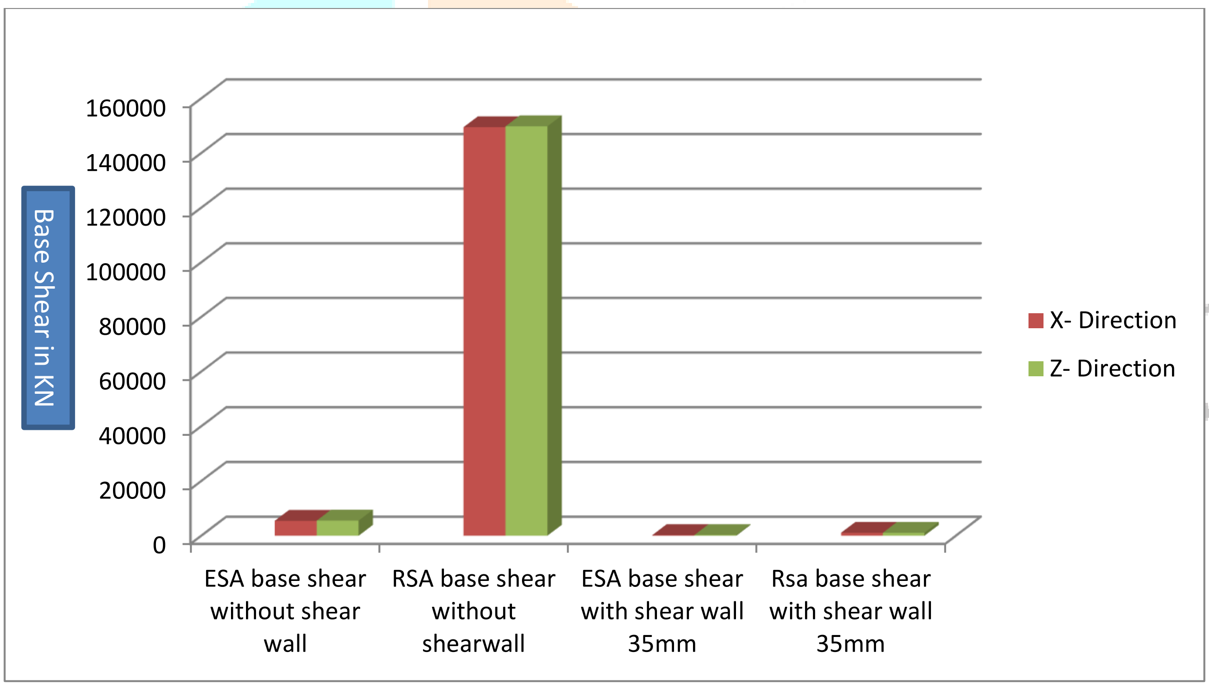


Fig Base shear for ESA and RSA method

➢ Story Shear

The total design lateral forces at all storey levels above the one under consideration make up storey shear. “Vi” is used to indicate it.

Table 2: Story Shear for ESA and RSA method without shear wall

Story	Level in meter	Story shear in ESA		Story shear in RSA	
		X(KN)	Z(KN)	X(KN)	Z(KN)
1	3.05	5210.288	5302.46	148627.68	149036.43
2	6.10	5204.327	5207.45	144245.05	144752.95
3	9.14	5180.988	5199.84	136762.65	137430.96
4	12.19	5078.66	5142.88	126224.97	127076.31
5	15.24	4954.07	4928.39	112820.27	113846.37
6	18.29	4650.104	4795.73	96806.30	97939.44
7	21.34	4247.13	4398.22	78521.29	79668.15
8	24.38	3757.98	3925.55	58352.77	59390.90
9	27.43	3122.59	3357.62	36727.42	37509.90
10	30.48	2265.59	2458.62	14085.92	14444.01
11	33.58	570.86	597.89	762.20	798.21

Table 3: Story Shear for ESA and RSA method for shear wall 35mm in lift portion for ESA and RSA methods after getting safe

Story	Level in meter	story shear in ESA		Story shear in RSA	
		X(KN)	Z(KN)	X(KN)	Z(KN)
1	3.05	208.779	209.326	1045.446	1047.282
2	6.10	194.440	195.754	1027.269	1027.269
3	9.14	193.589	193.824	1020.274	1021.924
4	12.19	187.090	188.162	984.104	985.257
5	15.24	179.040	180.528	942.282	944.852
6	18.29	161.993	164.257	856.232	857.042
7	21.34	143.679	144.282	798.042	799.246
8	24.38	111.787	112.437	622.831	622.517
9	27.43	86.873	88.243	497.552	499.549
10	30.48	63.370	64.108	358.459	359.547
11	33.58	29.225	29.892	162.261	165.022

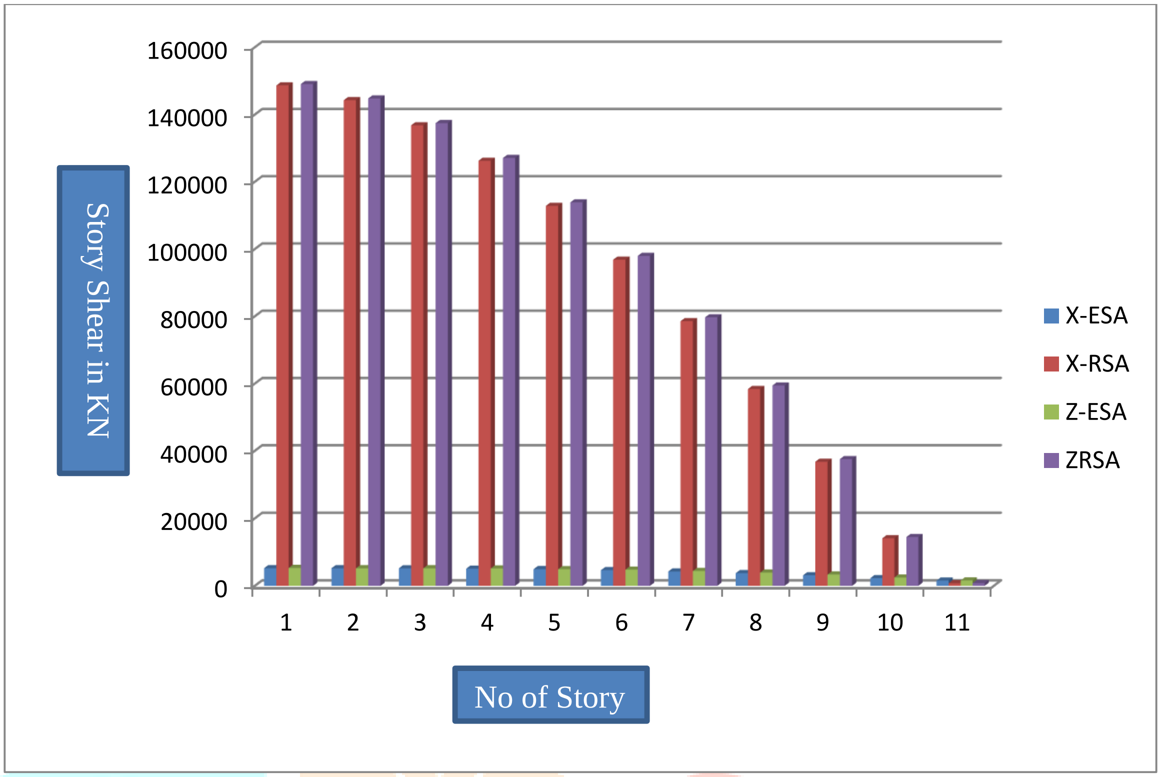


Fig: Story Shear at different story without Shear wall

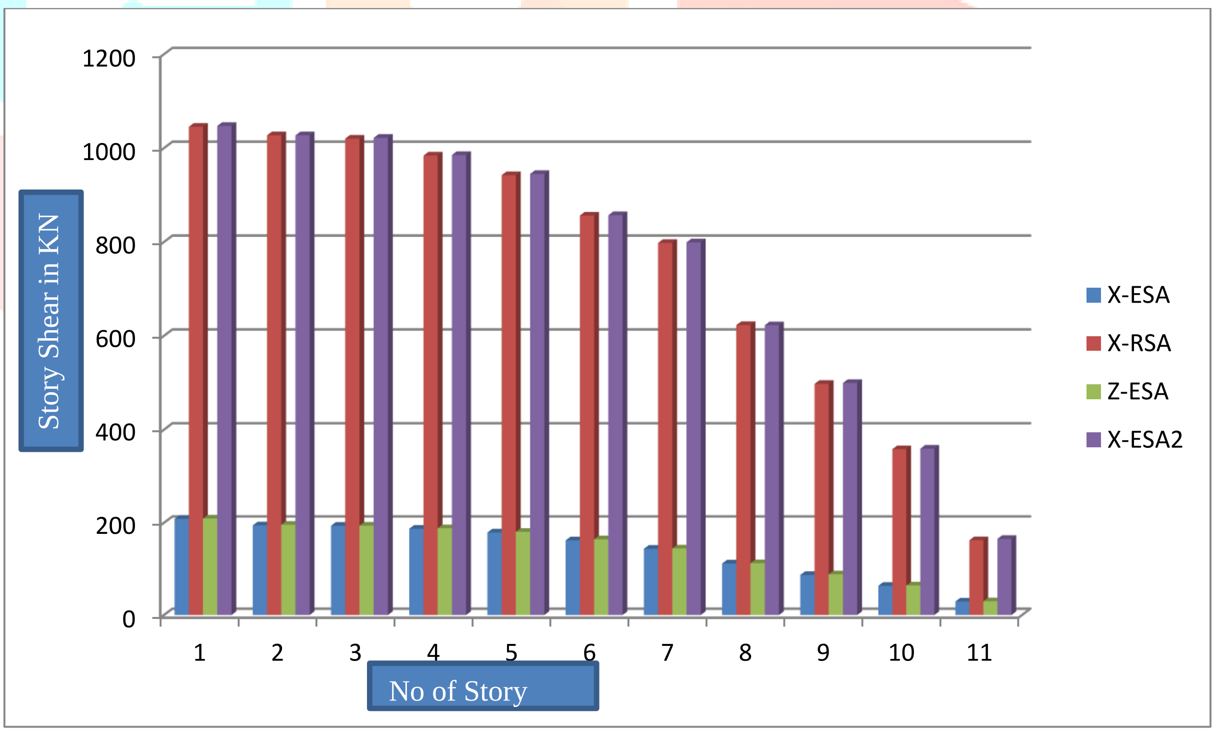


Fig: Story Shear at different story after getting safe providing 35mm shear wall in lift portion in ESA and RSA methods

Table 4: Story Shear for ESA and RSA method with shear wall of 45mm thickness in lift portion for ESA and RSA methods to achieve minimum value

Story	Level in meter	Story Shear in ESA		Story Shear in RSA	
		X(KN)	Z(KN)	X(KN)	Z(KN)
1	3.05	35.525	35.920	198.634	199.362
2	6.10	33.787	34.071	195.181	195.275
3	9.14	33.015	33.279	193.852	194.748
4	12.19	32.231	32.621	186.787	187.594
5	15.24	30.436	30.874	177.133	178.526
6	18.29	27.538	27.962	162.680	162.934
7	21.34	24.425	25.269	149.157	150.168
8	24.38	20.127	21.213	118.337	120.236
9	27.43	15.637	15.827	94.534	95.475
10	30.48	11.406	13.282	68.107	69.285
11	33.53	5.260	6.105	30.829	31.342

➢ Story Drift

Story drift is the displacement (shifting) of a story in relation to another level. As per IS 1893 part 1:2002 cl.7.11.3, story drift shall not exceed 0.04 times storey height with partial load factor 1.0.

Table 5: Story Drift after getting safe providing 35mm shear wall in lift portion in ESA and RSA methods

Story	Level in meter	Story Drift in ESA		Story Drift in RSA	
		X(cm)	Z(cm)	X(cm)	Z(cm)
1	3.05	0.0079	0.0049	0.0530	0.0450
2	6.10	0.0139	0.0135	0.0933	0.0968
3	9.14	0.0203	0.0182	0.1359	0.1404
4	12.19	0.0268	0.0258	0.1792	0.1844
5	15.24	0.0060	0.0062	0.0430	0.0447
6	18.29	0.0182	0.0173	0.1217	0.1240
7	21.34	0.0435	0.0413	0.2900	0.2956
8	24.38	0.0475	0.0450	0.3168	0.3217
9	27.43	0.0507	0.0478	0.3380	0.3420
10	30.48	0.0566	0.0500	0.3542	0.3572
11	33.53	0.0463	0.0441	0.3093	0.3151

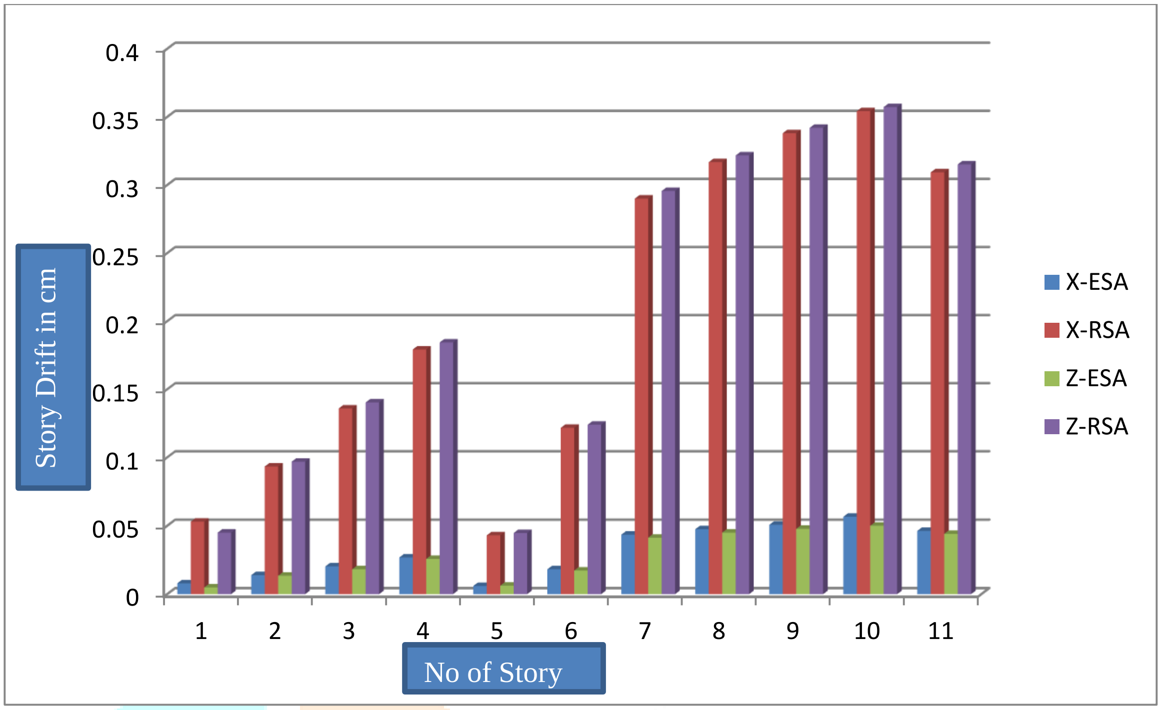


Fig: Story Drift of different story after getting safe providing 35mm shear wall in lift portion in ESA and RSA methods

Table 6: Story Drift after providing 45mm thick shear wall in lift portion in ESA and RSA methods to achieve minimum value

Story	Level in meter	Story Drift in ESA		Story Drift in RSA	
		X(cm)	Z(cm)	X(cm)	Z(cm)
1	3.05	0.000158	0.000196	0.00106	0.0009
2	6.10	0.0018	0.00054	0.001866	0.001936
3	9.14	0.000406	0.000728	0.002718	0.002808
4	12.19	0.000804	0.000103	0.002718	0.003688
5	15.24	0.00018	0.000248	0.003584	0.000894
6	18.29	0.00054	0.000692	0.002434	0.00248
7	21.34	0.001305	0.001652	0.0058	0.005912
8	24.38	0.001425	0.0018	0.006336	0.006434
9	27.43	0.001521	0.001912	0.00676	0.00684
10	30.48	0.001698	0.00200	0.007084	0.007144
11	33.53	0.001389	0.00176	0.006186	0.006302

➢ Story Displacement

Story displacement is the movement of a narrative (story) away from its structural foundation.

Table 7: Story Displacement after getting safe providing 35mm shear wall in lift portion in ESA and RSA methods

Story	Level in meter	Story Displacement in ESA		Story Displacement in RSA	
		X(cm)	Z(cm)	X(cm)	Z(cm)
1	3.05	0.0051	0.0072	0.0469	0.0554
2	6.10	0.0087	0.0125	0.0797	0.0968
3	9.14	0.0123	0.0182	0.1124	0.1404
4	12.19	0.0157	0.0239	0.1436	0.1844
5	15.24	0.0165	0.0179	0.1057	0.1379
6	18.29	0.0195	0.0342	0.1934	0.2636
7	21.34	0.0214	0.0384	0.2094	0.2956
8	24.38	0.0229	0.0418	0.2234	0.3217
9	27.43	0.0237	0.0444	0.2339	0.3420
10	30.48	0.0252	0.0464	0.2405	0.3572
11	33.53	0.0032	0.0052	0.0289	0.0402

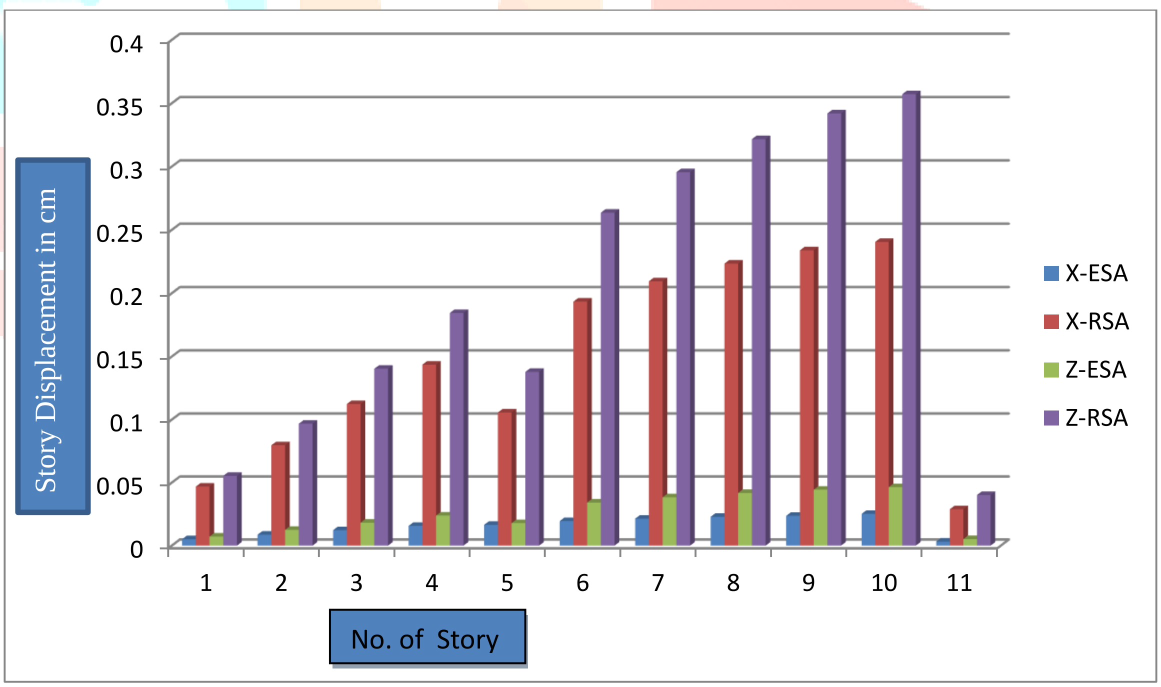


Fig: Story Displacement of different story after getting safe providing 35mm shear wall in lift portion in ESA and RSA methods

Table 8: Story Displacement after providing 45mm thick shear wall in lift portion in ESA and RSA methods to achieve maximum value

Story	Level in meter	Story Displacement in ESA		Story Displacement in RSA	
		X(cm)	Z(cm)	X(cm)	Z(cm)
1	3.05	0.000153	0.000288	0.000938	0.001108
2	6.10	0.000261	0.0005	0.001594	0.001936
3	9.14	0.000369	0.000728	0.00248	0.002808
4	12.19	0.000471	0.000956	0.002872	0.003688
5	15.24	0.000495	0.000716	0.002114	0.002758
6	18.29	0.000585	0.000136	0.003868	0.005272
7	21.34	0.000642	0.000153	0.004188	0.005912
8	24.38	0.000687	0.000167	0.004468	0.006434
9	27.43	0.000711	0.001776	0.004478	0.00684
10	30.48	0.000756	0.001856	0.00481	0.007144
11	33.53	0.000096	0.000208	0.000578	0.000804

6. Conclusion

- The earthquake analysis is done by both methods and the differences are seen that without applying shear wall in lift portion, the base shear in x direction is 96.36% more in RSA than ESA and in z direction 96.31% more in RSA than ESA. After applying shear wall of 35mm thick in lift portion, base shear in x direction is 78.38% more in RSA than ESA and in z direction 77% more in RSA than ESA.
- Story shear in x direction is 83% more in RSA than ESA in 9th story, 25% more in RSA than ESA in 10th story and 91% to 96% more in RSA than ESA in remaining story and in z direction 82% more in RSA than ESA in 9th story, 25% more in RSA than ESA in 10th story and 91% to 96% more in RSA than ESA in remaining story. After providing shear wall in lift portion of 35mm thick, story shear in x direction in average 81% more in RSA than ESA and similarly in z direction in average 82% more in RSA than ESA.
- After providing Shear wall of 35mm in both methods the structure get safe then story drift in x direction in average 85% more in RSA than ESA and in z direction 89% in ground story and 87% in 2nd story more in RSA than ESA and 86% more in RSA than ESA in all other remaining story.
- After providing shear wall of 35mm in both methods the structure get safe then story displacement in x direction is 89% more till 4th story after that 90% more from 5th to last story in RSA than ESA and in z direction 87% more in all story in RSA than ESA.
- The values are less in ESA than RSA method and RSA method gives most crucial results than ESA but results of RSA method is better than ESA that’s why it’s need to take RSA method.
- Thickness of shear wall increases in both methods to get the minimum values and after that further it’s achieved.

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