Seismic Assessment of Multistory Symmetric and Asymmetric Buildings Using Equivalent Static and Response Spectrum Analysis

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Abstract- *In the current study we have modeled symmetric and asymmetric buildings such as H-shape, L-shape, Long slender shape, Rectangular shape and T-shape buildings for G+5, G+10 and G+15 stories using ETABS 9.7 non-linear version software. We have compared base shear, lateral displacement and story drift values for Equivalent static and Response spectrum analysis. And we have observed that symmetric buildings are comparatively more suitable to take earthquake load compared to asymmetric buildings*

Keywords- About Equivalent Static,Response Spectrum, base shear, story drift and lateral displacement.

I. INTRODUCTION

Static linear analysis defines a series of forces acting on a building to represent the effect of earthquake ground motion, typically defined by a seismic design response spectrum. It assumes that the building responds in its fundamental mode. In this method, mass of the structure multiplied by design seismic coefficient, acts statically in a horizontal direction. It is also assumed here that the magnitude of the coefficient is uniform for the entire members of the structure. Design shears at different levels in a building shall be computed from the assumption of linear distribution horizontal accelerations, varying from zero at the base of the structure to a maximum at the top. For important and complicated structures this method is not adequate.

The total design lateral force or design base shear along any principal direction is given in terms of design horizontal Seismic coefficient and seismic weight of the structure. Design horizontal seismic coefficient depends on the zone factor of the site, importance of the structure, response reduction factor of the lateral load resisting elements and the fundamental period of the structure.

Following procedure is generally used for the equivalent static analysisaccording to IS 1893 – 2002.

i) Calculation of lumped weight.
ii) Calculation of fundamental natural period.

The fundamental natural period of vibration (Ta) in seconds of a moment resisting frame building,

$Ta = 0.075\ h^{0.75}$ (without brick infill panels)
$Ta = 0.09\ h/\sqrt{d}$(with brick infill panels)

Where

h = Height of the building
d = Base dimension of the building at the plinth level in m, along the considered direction of the lateral force.

iii) Determination of base shear (VB) of the building.

VB = Ah x W

$$A_h = \frac{Z}{2}\frac{I}{R}\frac{S_a}{g}$$

Where,

A_h is the design horizontal seismic coefficient, which depends on the seismic zone factor (Z), importance factor (I), response reduction factor (R) and the average response acceleration coefficient (Sa/g). Sa/g in turn depends on the nature of foundation soil (rock, medium or soft soil sites), natural period and the damping of the structure.

iv) Lateral distribution of design base shear;

The design base shear VB thus obtained is then distributed along the height of the building using a parabolic distribution expression:

$$Q = V_B \frac{W_1 h_1}{\sum_{j=1}^{n} W_j h_k^{\ 2}}$$

Where Q_1 is the design lateral force, W_1 is the seismic weight, h_1 is the height of the i^{th} floor measured from base and n is the number of stories in the building.

Response spectrum analysis permits the multiple modes of response of a building to be taken into account (in the frequency domain). This is required in many building codes for all except for 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 "harmonics".It is a dynamic method of analysis. In the calculation of structural response (whether modal analysis or otherwise), the structure should be so represented by means of an analytical or computational model that reasonable and rational results can be obtained by its behaviour. When response spectrum method is used with modal analysis procedure. At least 3 modes of response of the structure should be considered except in those cases where it can be shown qualitatively that either third mode or the second mode produces negligible response. When appropriate. The model maxima should be combined using the square root of the sum of the squares of the individual model values. In this method the building is considered as a flexible structure with lumped masses concentrated at floor levels, with each mass having one degree of freedom that of lateral displacement in the direction under consideration.

II. MODELLING AND ANALYSIS

The following load combinations are considered in the current study.

Types of analysis	Load factors	
EQUIVALENT STATIC ANALYSIS	X- Direction	0.9 DL+1.5 EQX
		1.5 (DL+EQX)
		1.2 (DL+LL+EQX)
	Y-Direction	0.9 DL+1.5 EQY
		1.5 (DL+EQY)
		1.2 (DL+LL+EQY)
RESPONSE SPECTRUM ANALYSIS	X- Direction	0.9 DL+1.5 RESX
		1.5 (DL+RESX)
		1.2 (DL+LL+RESX)
	Y-Direction	0.9 DL+1.5 RESY
		1.5 (DL+RESY)
		1.2 (DL+LL+RESY)

Among all the load combinations considered, the maximum response is observed in 1.5 (DL + EQL) combination. Therefore those values are tabulated and compared.

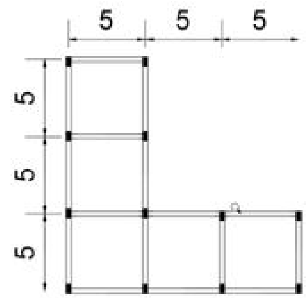

Fig. : L-shape plan.

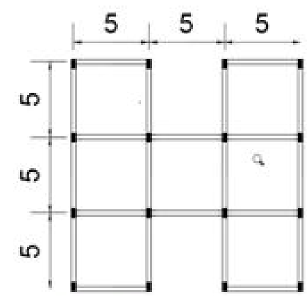

Fig. : H-shape plan.

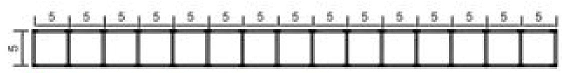

Fig.:Long slender shape plan.

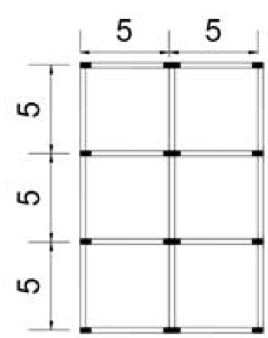

Fig. : Rectangular shape plan.

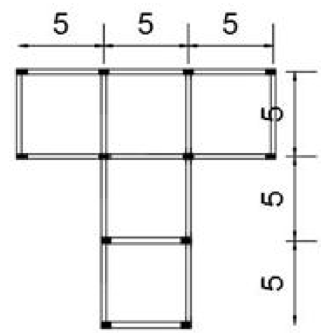

Fig. : T-shape plan.

The entire analysis has done for all the 3D models using ETABS 9.7 non-linear version software. The results are tabulated in order to focus the parameters such as time period, story shear, story drift and lateral displacement.

Input parameters

Type of building G+5, G+10 and G+15story reinforced structure.

Height b/w the floor	3.0 m
Ground floor height	3.0 m
Wall thickness	300 mm
Unit weight of R.C.C **(IS 875-1987, P-1)**	25 kN/m^3
Unit weight of bricks **(IS 875-1987, P-1)**	18 kN/m^3
Grade of concrete (M20)	20 N/mm^2
Grade of steel (Fe415)	415 N/mm^2
Size of beam	230x450 mm
Size of column	900x900 mm
Thickness of slab	150 mm
Live load	3 kN/m^2
Floor finishes	1.25 kN/m^2

III. RESULTS AND DISCUSSIONS

BASE SHEAR

Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure.

Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure. Calculations of base shear (**V**) depend on proximity to potential sources of seismic activity, probability of significant seismic ground motion, the level of ductility and overstrength associated with various structural configurations and the total weight of the structure and the fundamental (natural) period of vibration of the structure when subjected to dynamic loading.

Table : Base shears for H-shaped buildings.

No. of stories	EQX (kN)	EQY (kN)	RESX(kN)	RESY(kN)
G+5	452.486	398.261	332.005	303.261
G+10	606.269	665.26	522.302	566.915
G+15	766.245	697.279	645.586	597.302

Table : Base shear for T-shaped buildings

No. of stories	EQX (kN)	EQY (kN)	RESX(kN)	RESY(kN)
G+5	480.771	494.56	360.29	374.079
G+10	634.554	648.343	550.587	564.376
G+15	794.53	808.319	673.871	687.66

Table: Base shear for Rectangular shaped buildings.

No. of stories	EQX (kN)	EQY (kN)	RESX(kN)	RESY(kN)
G+5	328.886	383.111	233.886	262.63
G+10	595.885	536.894	497.54	452.927
G+15	627.904	696.87	527.927	576.211

Table : Base shear for L-shaped buildings.

No. of stories	EQX (kN)	EQY (kN)	RESX(kN)	RESY(kN)
G+5	409.236	409.236	288.755	288.755
G+10	563.019	563.019	479.052	479.052
G+15	722.995	722.995	602.336	602.336

Table:Base shear for Long slender shaped buildings.

No. of stories	EQX (kN)	EQY (kN)	RESX(kN)	RESY(kN)
G+5	2160.325	2106.1	2039.844	2011.1
G+10	2314.108	2373.099	2230.141	2274.754
G+15	2474.084	2405.118	2353.425	2305.141

The above tables provides the comparison of Base Shear for G+5, G+10 and G+15 storied building in X and Y direction for both Equivalent static and Response spectrum analysis.

We can observe that Base Shear obtained from the Equivalent Static method is larger than the dynamic response method because, The Base Shear is a function of mass, stiffness, height and Natural period of building structure. But the Equivalent static method considers only the mass and natural period of the building. Moreover the basic assumption in the Equivalent Static method is that only first mode of vibration of building governs the dynamics.

In dynamic response spectrum, all the modes of the building are considered, and first mode governs in the shorter buildings and as the story increases for tall buildings, the flexibility increases and higher modes come in to picture.

LATERAL DISPLACEMENT

Lateral displacement or drift of a reinforced concrete frame building under earthquake loading is a critical parameter for structural evaluation or design. The magnitude of lateral displacement indicates the damage state and the vulnerability of the building.

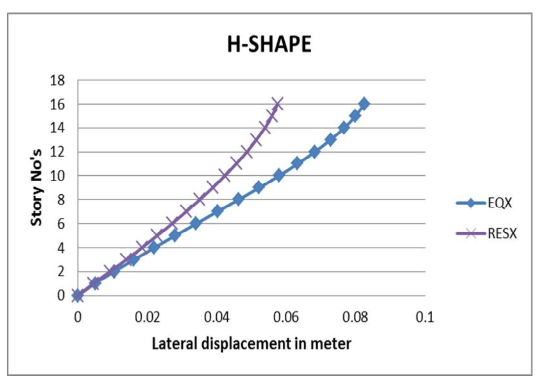

Fig.: Lateral displacement for H-shaped building for1.5(DL+EQL) combination.

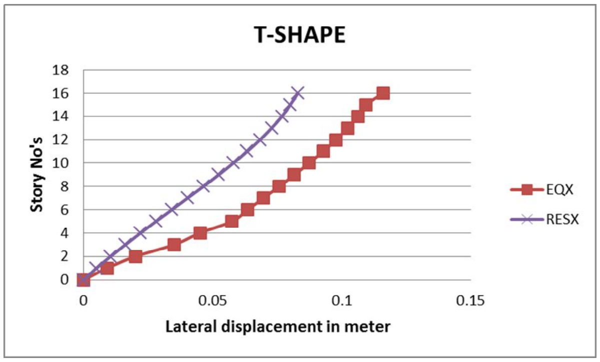

Fig.: Lateral displacement for T-shaped building for1.5(DL+EQL) combination.

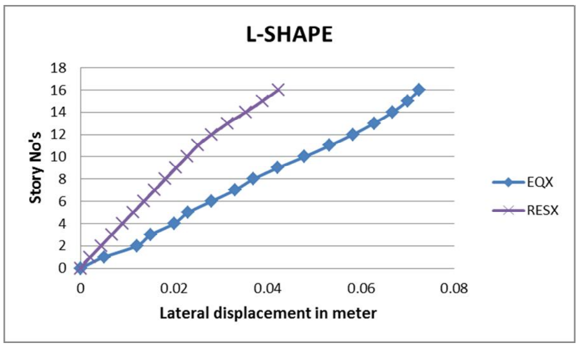

Fig.: Lateral displacement for L-shaped building for 1.5(DL+EQL) combination.

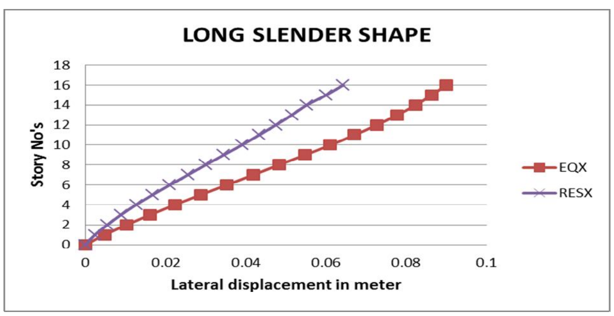

Fig.: Lateral displacement for Longslender-shaped building for1.5(DL+EQL) combination.

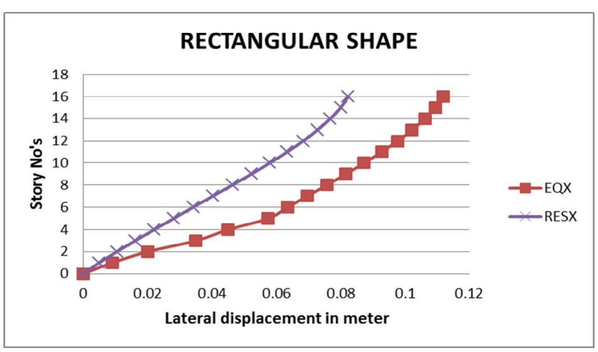

Fig.: Lateral displacement for Rectangular-shaped building for 1.5(DL+EQL) combination.

The lateral displacement obtained for H-shape, L-shape, Long slender shape, Rectangular shape and T-shape buildings for equivalent static method and response spectrum method are plotted in graphs above.

From the above graphs, for H-shape we notice that Lateral displacement of the roof is 0.06 m for Response Spectrum method whereas for Equivalent static method it is 0.09 m, for L-shape we notice that Lateral displacement of the roof is 0.04 m for Response Spectrum method whereas for Equivalent static method it is 0.075 m, for Long slender-shape we notice that Lateral displacement of the roof is 0.07 m for Response Spectrum method whereas for Equivalent static method it is 0.095 m, for Rectangular-shape we notice that Lateral displacement of the roof is 0.08 m for Response Spectrum method whereas for Equivalent static method it is 0.11 m, for T-shape we notice that Lateral displacement of the roof is 0.08 m for Response Spectrum method whereas for Equivalent static method it is 0.12 m

It is observed that, the maximum displacement is increasing from first story to last one.It's clear that the static analysis gives higher values for lateraldisplacement of the stories rather than Response spectrum methods of analysis, especially in higher stories.

STORYDRIFT

Story drift is the drift of one level of a multistory building relative to the level below. Story drift is the difference between the roof and floor displacements of any given story as the building sways during the earthquake, normalized by the story height.

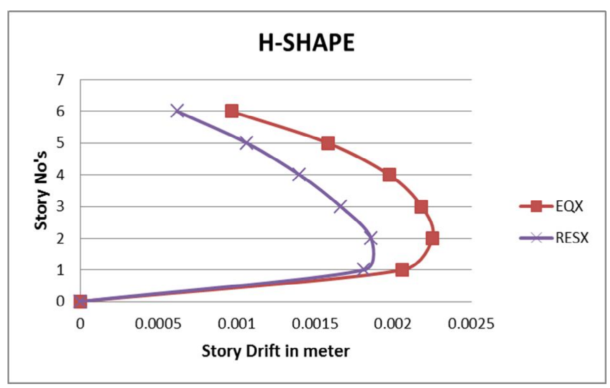

Fig.: Story Drift for H-shaped building for1.5(DL+EQL) combination.

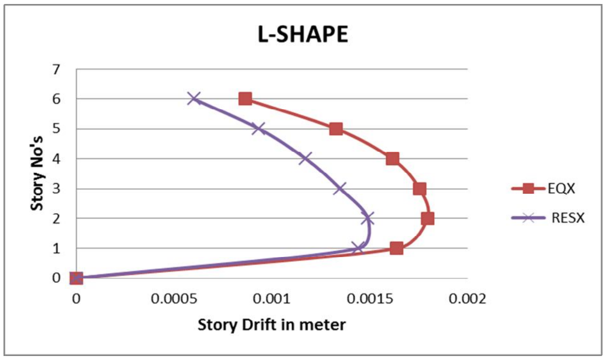

Fig.: Story Drift for L-shaped building for1.5(DL+EQL) combination.

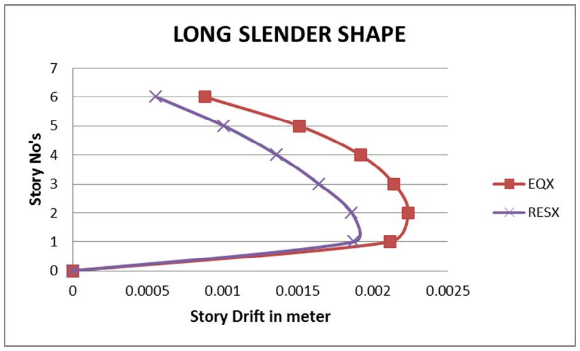

Fig.: Story Drift for Long slender-shaped building for 1.5(DL+EQL) combination.

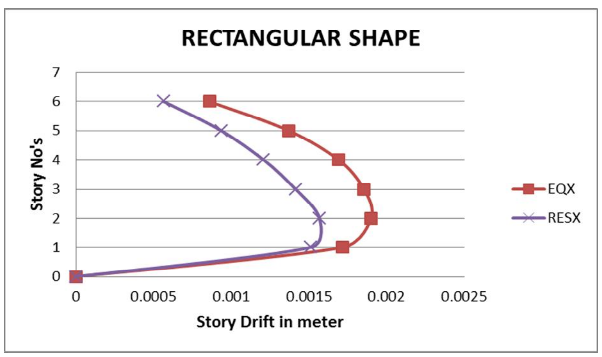

Fig.: Story Drift for Rectangular-shaped building for 1.5(DL+EQL) combination.

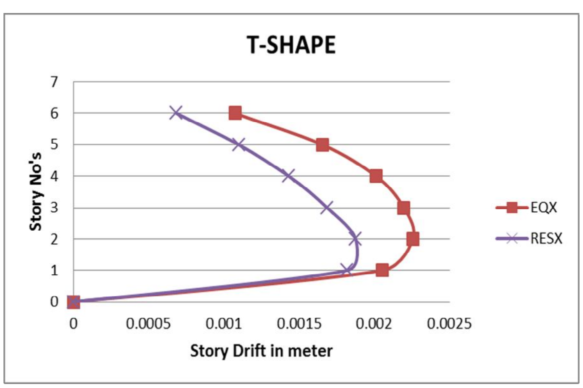

Fig.: Story Drift for T-shaped building for 1.5(DL+EQL) combination.

The Story Drift obtained for Equivalent static method and response spectrum for H-shape, L-shape, Rectangular shape, Long slender shape and T-shapebuildings are plotted in graphs above.

From the above graphs, for H-shape we notice that Story drift of the roof is 0.0005 m for Response Spectrum method whereas for Equivalent static method it is 0.001 m, for L-shape we notice that Story drift of the roof is 0.0006 m for Response Spectrum method whereas for Equivalent static method it is 0.0008 m, for Long slender-shape we notice that Story drift of the roof is 0.0005 m for Response Spectrum method whereas for Equivalent static method it is 0.0008 m, for Rectangular-shape we notice that Story drift of the roof is 0.0006 m for Response Spectrum method whereas for Equivalent static method it is 0.0009 m, for T-shape we notice that Story drift of the roof is 0.0007 m for Response Spectrum method whereas for Equivalent static method it is 0.0012 m
It's clear that the static analysis gives higher values of Story Drift rather than Response spectrum methods of analysis. Static analysis provides almost real results hence we have to consider them during design.
According to IS 1893 : 2002 (part 1) clause 7.11.1 the story drift in any story due to the minimum specified design lateral force, with partial load factor of 1.0 shall not exceed 0.004 times the story height. And the values we got are well within the limits.

VI. CONCLUSION

1. Since Base shear values of equivalent static analysis are lower than Response spectrum analysis ,we should take Base shear values of Response spectrum for the design.
2. Lateral Displacement of Response Spectrum analysis is lesser than Equivalent Static analysis.
3. Story Drift of Response Spectrum analysis is lesser than Equivalent Static analysis.
4. Lateral displacement of L-shaped building is less among all and Lateral displacement of T-shape building is more among all.
5. Story drift of H-shaped building is less among all and Story drift of T-shape building is more among all.

REFERENCES

[1] Dr. H Eramma, pulakeshi H L (2015), "Seismic Performance Evaluation of RC Building Connected With and Without X-Braced Friction Dampers", International Journal of Research in Engineering and Technology.
[2] Avtar S Pall, Rashmi Pall (1996), "Friction Dampers For Seismic Control of Buildings, A Canadian Experience",

Eleventh World Conference on Earthquake Engineering, Paper No. 497.

[3] Shilpa G, Nikam, S. K. Wagholikar, G. R. Patil (2014), "Seismic Energy Dissipation of a Building Using Friction Damper", International Journal Of Innovative and Exploring Engineering (IJITEE).

[4] NaveetKaur, V. A. Matsagar, A. K. Nagpal (2012), "Earthquake Response of Mid-Rise to High-Rise Buildings With Friction Dampers", Council of Tall Buildings and Urban Habitat (CTBUH).

[5] Chiara PASSONI, Andrea BELLERI, Alesandra MARINI, Paolo RIVA (2014), "Existing Structure Connected With Dampers: State of The Art and Future Developments", Second European Conference on Earthquake Engineering and Seismology, Istanbul.

[6] F. Bharatia, A. Esfandiari (2012), "Exploring the Efficiency of Dampers for Repair and Strengthing of Existing Buildings ", Journal of Structural Engineering and Geotechnics.

[7] ZbigniewSkup (2010), "Analysis of Damping of Vibrations Through A Frictional Damper", Journal of Theoretical and Applied Mechanics.

[8] Ramesh Chandra, MotiMasand, S. K. Nandi, C. P. Tripathi, Rashmi Pall, Avtar Pall (2008), "Friction-Dampers for Seismic Control of La Gardenia Towers South City, Gurgaon, India",WCEE.

[9] P. Dupont, P. Kasturi, S. Stokes (1997),"Semi-Active Control of Friction Dampers", Journal of Sound and Vibration.

[10] KishorBajad, Rahul Watile (2014),"Application of Dampers for RCC Building to Reduce Seismic Risk", International Journal of Research in Advent Technology.

[11] A.V. Bhaskararao, R. S. Jangid(2003), "Seismic Analysis of Structures connected With Friction Dampers",Departement of Civil Engineerinfg, IIT Bombay, Powai, Mumbai.