Case study on Evaluation of Vulnerability to Earthquake of High Rise Buildings in Goa

Herrick Caldeira, Sonia Vasco Da Gama, Godwin Fernandes, Yash Dessai, Ray Cortez
Department of Civil Engineering, Don Bosco College of Engineering,
Fatorda-Margao, Goa, India 403602

***Abstract*— The aim of this study is to assess the seismic performance of the Reinforced Concrete (RC) framed structure designed as per the latest Codal provisions.**

The study aims at evaluating the effect of torsion, eccentricity, geometric configuration,mass and stiffness irregularities on various parameters like percentage of steel ,inter storey drift, storey, displacement, lateral force, storey acceleration(in x, y, z) ,shear, storey stiffness and overturning moments .

At the end of this study, a comparison of two RC buildings with respect to the above mentioned parameters will be presented to assess the vulnerability of respective structures

I. INTRODUCTION

1.1 GENERAL

Buildings are subjected to dynamic forces like earthquake. In earthquake design, the building is subjected to random motion of the ground at its base which induces inertia force in the building that in turn causes stresses, this is displacement type loading. The motion of the ground during an earthquake is cyclic about the neutral position of the structure hence complete reversal of stresses can take place over a small duration of time.

1.2 DESIGN PHILOSOPHY

Buildings are designed only for a fraction of the forces they would experience, if we were to design a building which will remain elastic during an earthquake it would be too costly. Buildings should be able to withstand -

A] Slight tremor with no damage to structural and non-structural elements.

B] Medium tremors with slight damage to structural elements, and some damage to nonstructural elements.

C] Serious (rare) tremors with damage to structural elements, but with no collapse (to save life and property inside/surrounding the building).

Keeping this in mind structures are made resistant by incorporating four desirable characteristics in them which are:

1. It should have good seismic arrangement, with no architectural feature that is detrimental to good earthquake performance. The features present should not introduce newer complexities in the building behavior than what the earthquake is already imposing;

2. At least a little lateral stiffness in each of its plan directions (distributed evenly on both sides of the building plan), so that there is no inconvenience to occupants of the building and no damage to contents of the building;

3. At least a small lateral strength on each of its plan directions (distributed evenly on both plan building directions), to resist low intensity ground tremors with no damage and not too strong to keep construction costs in check, along with a minimum vertical strength to be able to continue to support the gravity load and thereby prevent collapse under strong Earthquake shaking;

4. Good overall ductility in it to accommodate the imposed lateral deformation between the base and the roof of the building, along with the desired mechanism of behavior at the ultimate stage. Behavior of buildings during earthquakes depend critically on these four virtues. Even if any one of these is not checked, the performance of the building is expected to be poor.

The seismic vulnerability of a structure is a quantity associated with its weakness in the case of earthquakes of given intensity, so that the value of this quantity and the knowledge of seismic hazard allows us to evaluate the expected damage from future earthquakes

1.3 HOW IS VULNERABILITY ASSESSED?

A source-path-site-structure is used for vulnerability assessment. Assuming the magnitude and fault distance of an offshore or inland earthquake, the earthquake intensity at bedrock is determined by an attenuation curve. Site response is calculated by multiplying the seismic momentum by site transfer function measured by micro-tremor measurements, taking into account the frequency dependent condition of soil. Structural response is calculated by repeating the site's response to the built-in transfer function measured by micro-tremor measurements and translated into an inelastic response with equal force Sense, if necessary. In order to assess vulnerability these parameters must also be found -effect of torsion, eccentricity, geometric configuration, mass and stiffness irregularities on various parameters like steel, storey drift, storey displacement, lateral force, acceleration (in x,y,z) ,shear and overturning.

II. LITERATURE REVIEW

A. A.Masi, V. Manfredi, A. Digrisolo (2012), "Seismic assessment of RC Existing Irregular building."

In this paper the structures with an asymmetric distribution of stiffness and strength were subjected to lateral and torsional movements during an earthquake. The inelastic earthquake behaviour of asymmetric structures is considered using base shear and torque histories. The results showed that the earthquake response of the restricted system was much better than the unrestrained one. In this case more uniform displacement demands are expected for the lateral load resting planes.

B. Dj.Z. Ladjinovic and R. J. Folic (2008),"Seismic Analysis of asymmetric in Plan Building" .

In this paper a seismic test was performed of a group of reinforced concrete structures representing existing structures designed for vertical loads only. The role of stair construction was considered as varied in its place in order to analyze the different e-eccentricity values of the plan. In particular, types of central and eccentric stairs have been considered. The results are compared with buildings without stairs, i.e. buildings where the contribution of stairs to the stiffness and strength can be neglected. CS and ES values are lower than those of NS.

C. Takuji HAMAMOTO And Yusuke OZ (2000),"Vulnerability assessment of reinforced concrete building using micro-tremor measurement " .

In this paper the severity of the earthquake was tested using stochastic-fuzzy Integrated method. Micro-tremor measurements are used to identify basic periods as well as estimates for the reduction of building structures and subsoil. Eccentricity and inter-storey drift techniques are calculated from the point of view of random vibrations, taking into account the inelastic response of structures and soils and variations of model parameters. Earthquake damage activities associated with Inter-story drift and eccentricity to the damage measures are obtained using previous earthquake damage data. Demonstrating the effectiveness of earthquake risk assessments, future damage conditions of reinforced concrete structures are predicted.

III. MODELING DATA

Model 1

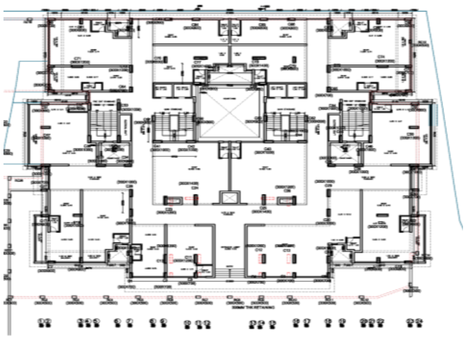

Fig 3.1: Ground and First Floor Plan

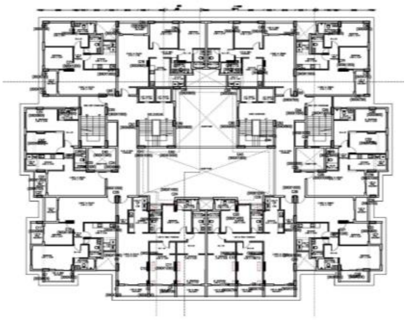

Fig 3.2 Second floor to Fifth floor

Frame Sections			
Object type	Section	Material Concrete	Material Steel
Beams	150x250	M25	Fe415
	230x500	M25	Fe415
	230x600	M25	Fe415
	230x700	M25	Fe415
	300x500	M25	Fe415
	300x700	M25	Fe415
	300x750	M25	Fe415
	400x850	M25	Fe415
Columns	350x700	M25	Fe415
	350x800	M25	Fe415
	350x1000	M25	Fe415
	350x1200	M25	Fe415
	450x700	M25	Fe415
	450x1000	M25	Fe415
	450x1200	M25	Fe415

Shell Sections			
Object type	Section	Material Concrete	Material Steel
Slab	120mm	M25	Fe415
	150mm	M25	Fe415
	170mm	M25	Fe415
Lift Core	230mm	M25	Fe415
Retaining Wall	300mm	M25	Fe415

Damping	5%
Importance Factor	1.2
Response Reduction Factor	5
Zone Factor	0.16
Soil type	Medium Stiff
Percentage of Imposed Load	25%

Model 2

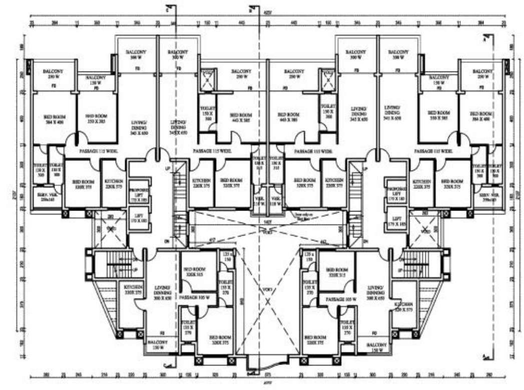

Fig 3.4 Ground Floor to Fifth Floor Plan

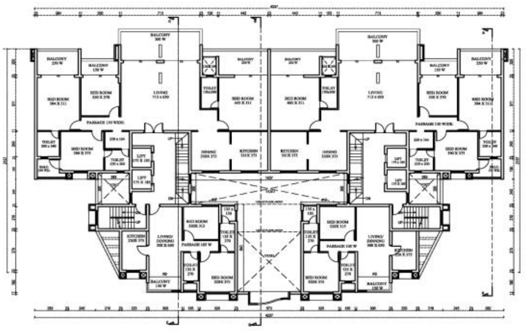

Fig 3.5 Sixth floor to seventh floor Plan

Frame Sections			
Object Type	Section	Material Concrete	Material Steel
Beams	350X800	M25	Fe500
	500X600	M25	Fe500
	500X700	M25	Fe500
	230X800	M25	Fe500
	300X350	M25	Fe500
	300X450	M25	Fe500
	300X550	M25	Fe500
	300X600	M25	Fe500
	300X800	M25	Fe500
	500X750	M25	Fe500
	500X800	M25	Fe500
	550X700	M25	Fe500
	550X750	M25	Fe500
	600X800	M25	Fe500
Columns	500X1200	M25	Fe500
	300X1200	M25	Fe500
	350X500	M25	Fe500
	350X800	M25	Fe500
	350X900	M25	Fe500
	450X600	M25	Fe500
	450X700	M25	Fe500
	450X1000	M25	Fe500
	450X1100	M25	Fe500
	450X1200	M25	Fe500
	450X1300	M25	Fe500
	450X1400	M25	Fe500

Shell Sections			
Object Type	Section	Material Concrete	Material Steel
Slab	120 mm	M25	Fe500
	140 mm	M25	Fe500
	150 mm	M25	Fe500
Lift Core	230 mm	M25	Fe500

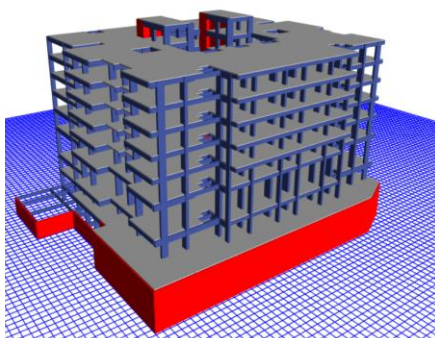

Fig 3.5: Model 1

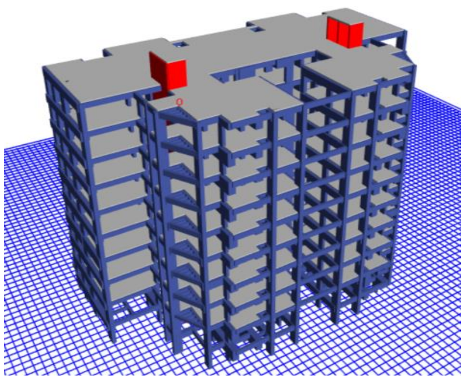

Fig 3.6: Model 2

MODE SHAPES

Model 1

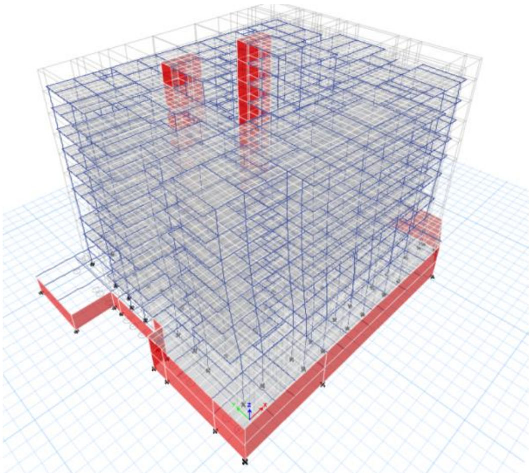

Fig. 3.7: Mode 1, Period: 1.04secs (Rotational)

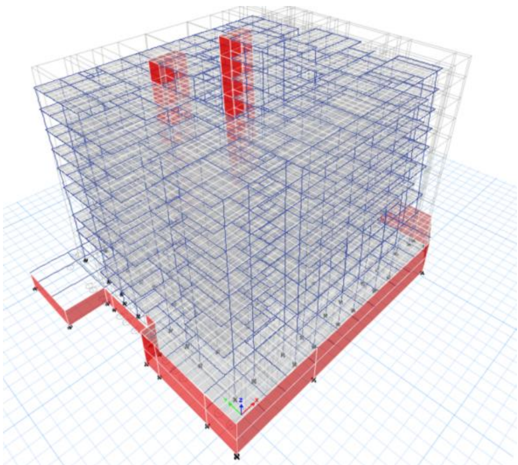

Fig. 3.8: Mode 2, Period: 0.858secs (Transitional)

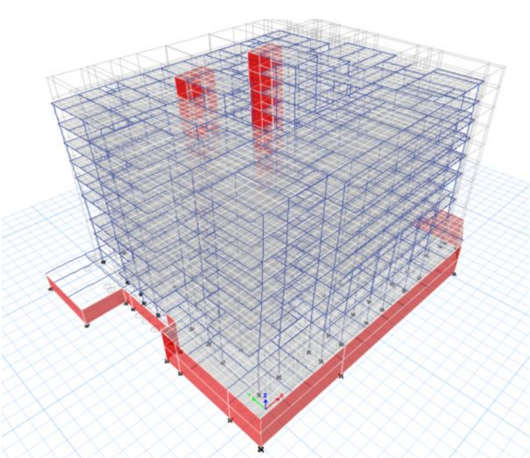

Fig. 3.9: Mode 3, Period: 0.842secs (Rotational)

Model 2

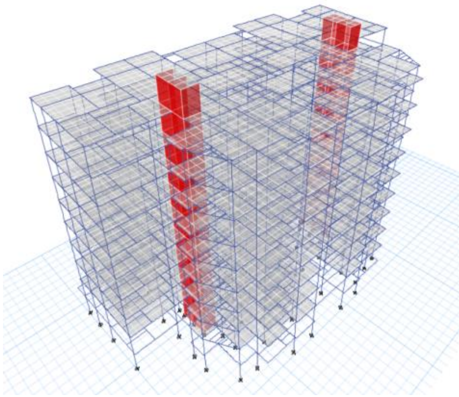

Fig 3.10: Mode 1, Period: 1.06secs (Transitional)

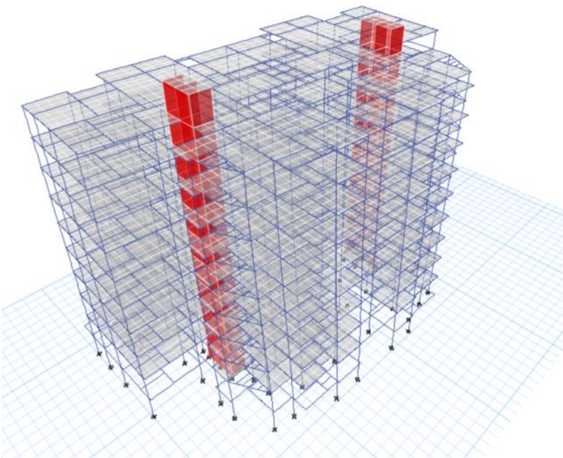

Fig. 3.11: Mode 2, Period: 0.703secs (Rotational)

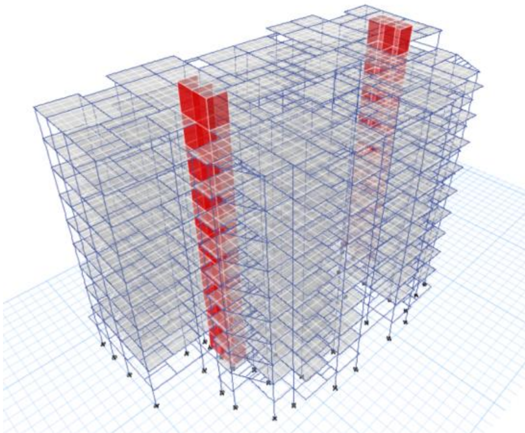

Fig. 3.12: Mode 3, Period: 0.622secs (Rotational)

IV. RESULT AND DISCUSSION

4.1 LATERAL FORCES

4.1.1 Model 1

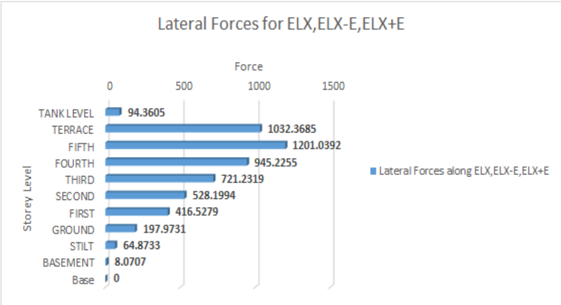

Fig 4.1: Lateral Force Distribution along X for Model 1

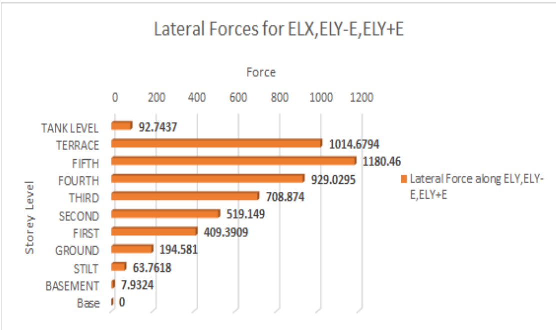

Fig 4.2: Lateral Force Distribution along Y for Model 1

4.1.2 Model 2

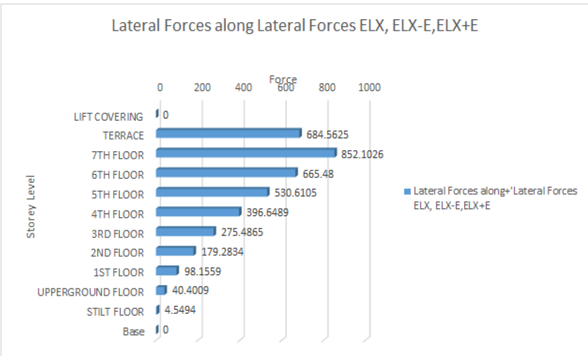

Fig 4.3: Lateral Force Distribution along X for Model 2

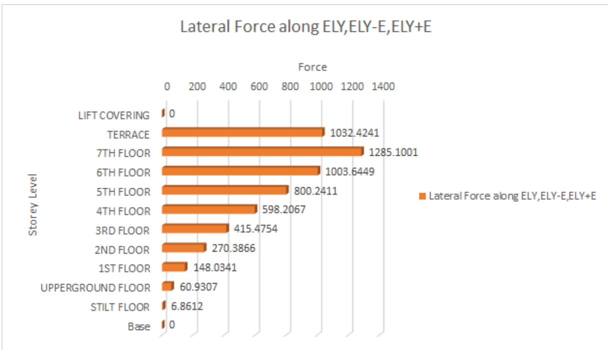

Fig 4.4: Lateral Force Distribution along Y for Model 2

4.2 STOREY SHEAR

Fig 4.5: Storey Shear along X for Model 1

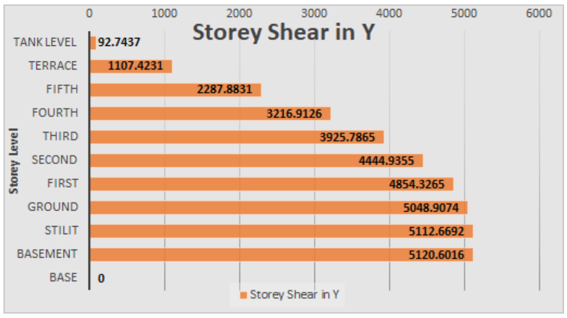

Fig 4.6: Storey Shear along Y for Model 1

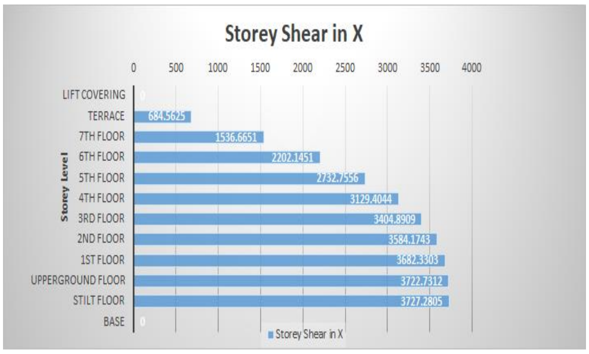

Fig4.7: Storey Shear along X for Model 2

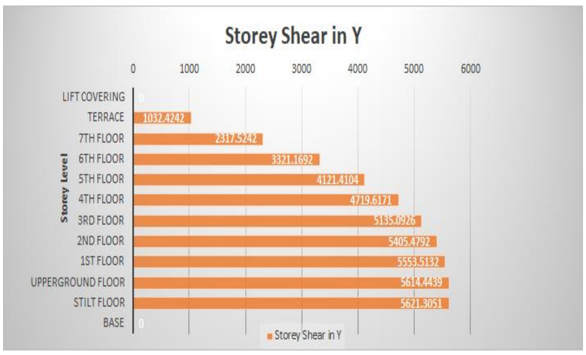

Fig 4.8: Storey Shear along Y for Model 2

4.3 OVERTURNING MOMENTS

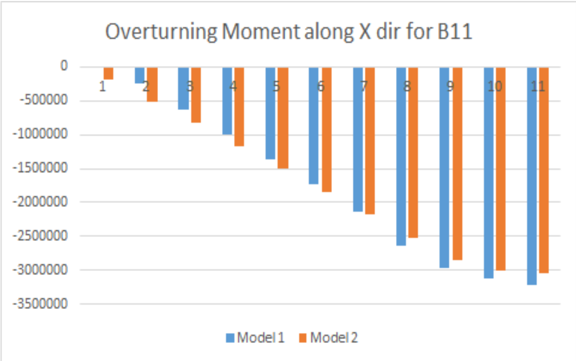

Fig 4.9: Overturning Moment along X dir for B11: 1.0 [DL+SIDL-(ELX-e)]

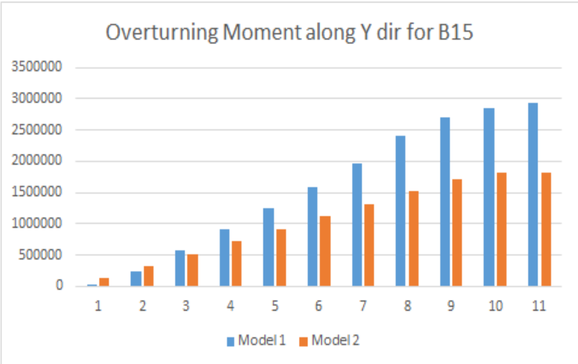

Fig 4.10: Overturning Moment along Y dir for B15:1.0 [DL+SIDL-(ELY+e)]

4.4 STOREY DRIFT

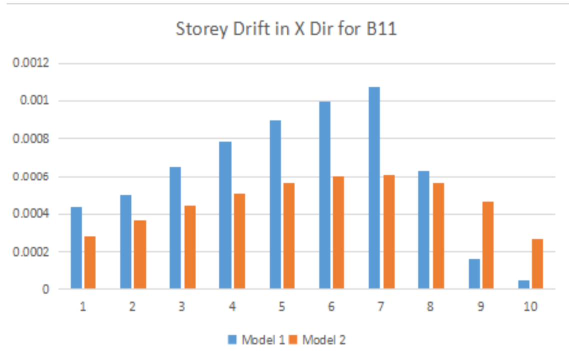

Fig 4.11: For load combination Case: B11: 1.0 [DL+SIDL-(ELX-e)]

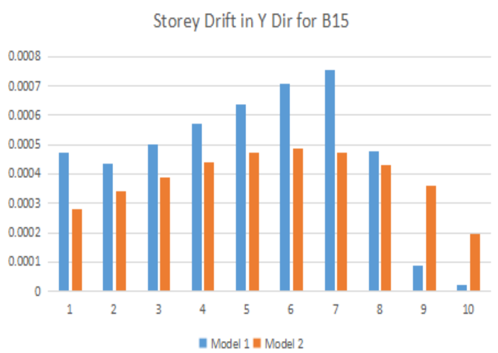

Fig 4.12: For load combination Case: B15: 1.0 [DL+SIDL-(ELY+e)]

4.5 STOREY ACCELERATIONS

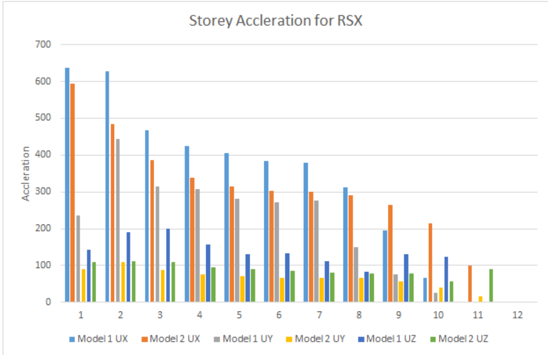

Fig 4.13: Storey acceleration between Model 1 and Model 2 for RSX

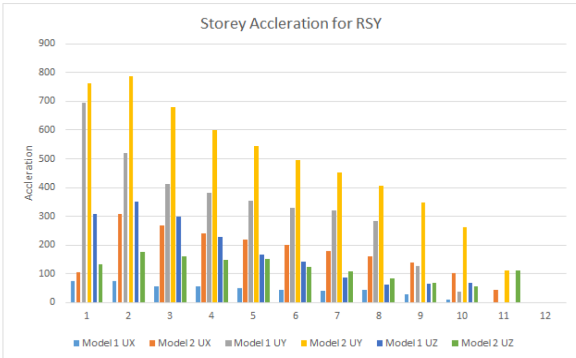

Fig 4.14: Storey acceleration between Model 1 and Model 2 for RSY

4.6 STOREY STIFFNESS

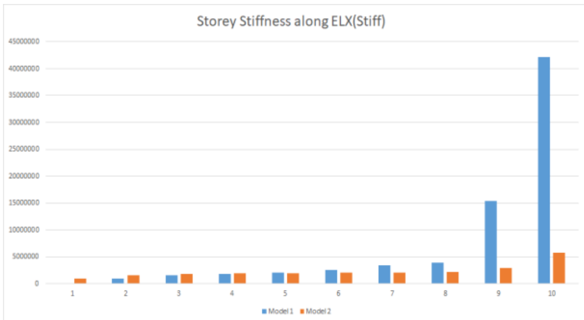

Fig 4.15: Storey Stiffness between Model 1 and Model 2 for ELX (Stiff)

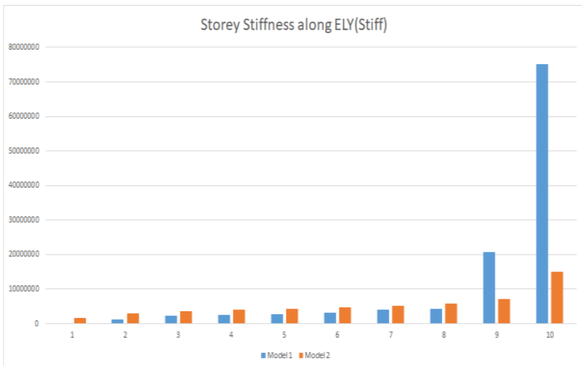

Fig 4.16: Storey Stiffness between Model 1 and Model 2 for ELY(Stiff)

4.7 STOREY DISPLACEMENT

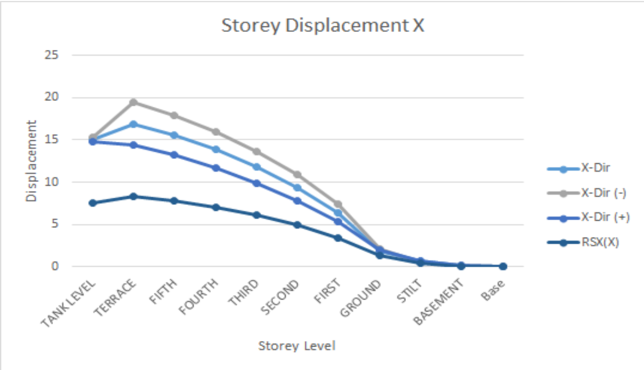

Fig 4.17: Storey Displacement in X direction in Model 1

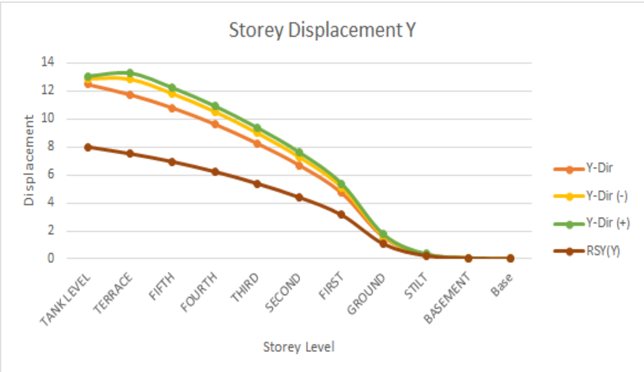

Fig 4.18: Storey Displacement in Y direction in Model 1

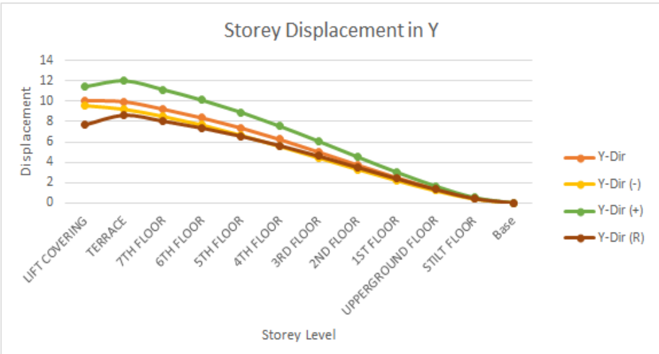

Fig 4.19: Storey Displacement in X direction in Model 2

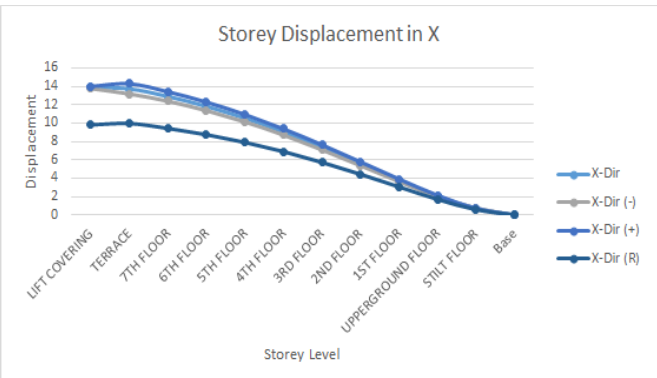

Fig 4.18: Storey Displacement in Y direction in Model 2

4.8 PERCENTAGE REBAR IN COLUMNS

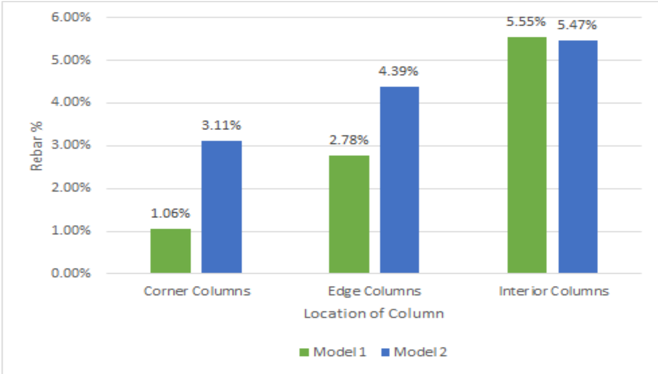

Fig 4.21: Percentage Reinforcement in Columns between Model 1 and Model 2

4.10 MODAL PERIOD AND FREQUENCY

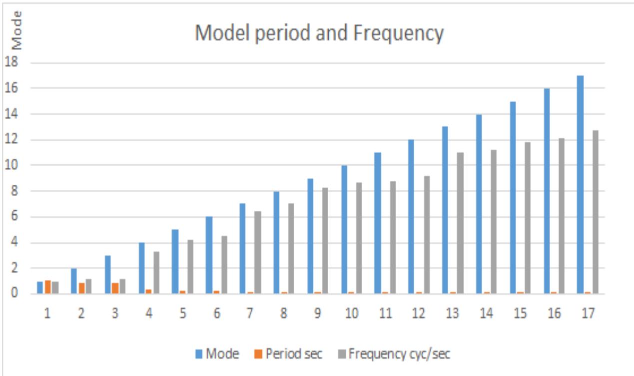

Fig 4.22: Modal Period and Frequency for Model 1

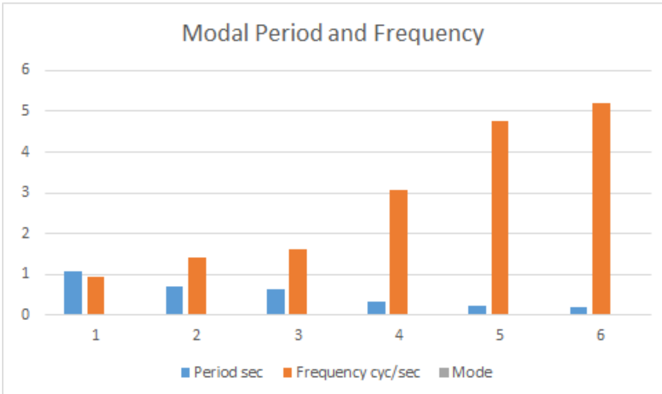

Fig 4.23: Modal Period and Frequency for Model 2

V. CONCLUSION

Based on the response spectra study on multi-storey irregular building, the following points were concluded:

1) The lateral force for model 2 is higher along the Y direction experienced by the 7th floor (1285.10KN)

2) 2) In model 1 the 1st and 3rd mode is torsional while in model 2 the torsional movement is observed in the 2nd and 3rd mode this is due to the placement of the structural wall.

3) The base shear for model 2 is higher in Y direction as it is a function of the base dimension of earthquake force in that direction.(base shear =5621.3051KN)

4) The storey displacement is higher in model 1 in X direction (15mm) as well as Y direction (13mm) at the tank level.

5) Storey drift for model 1 has a maximum value in X direction (0.0009) and Y direction (0.00062) which is well within the limit specified by the code.

6) The storey acceleration is the highest at the rooftop level. Storey acceleration of model 1 at rooftop is higher than model 2 and it is maximum along X direction.

7) Model 2 has a higher chance of overturning along the Y direction at the base.

8) The storey stiffness of model 1 is high at the base in the X and Y direction due to the presence of retaining walls.

9) The percentage of rebar in the column is maximum for the interior columns for model 1.

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