Comparative Analysis of L-shaped RC frame Structures with and without Shear Wall as per IS1893-2002 and IS1893-2016

Ajay Salimath[1], Rajeeva S. V.[2]

[1]MTech student, Civil Engineering Department, S.J.B. Institute of Technology, Bangalore, Karnataka, India

[2]Professor, Civil Engineering Department, S.J.B. Institute of Technology, Bangalore, Karnataka, India

***Abstract*: Highrise structures are mostly affected by lateral loads and vulnerable to seismic forces. One of the main causes for failure of structures is their irregularity (either plan irregularity or vertical irregularity). In this study, the response of irregular structure with shape L situated in seismic zone V are evaluated. For the analysis, 25 storey building is considered. The analytical methods used in this dissertation work are response spectrum method and time history method. The seismic parameters for earthquake loads and functions are set as per IS1893-2002(1), IS1893-2016(1) and IS 16700-2017 and time history method is carried out using BHUJ earthquake data. The FEA software ETABS v15 is used for analysis. Also, the presence of shear wall and the behavior of structure by its inclusion is studied. For the study, totally eight models are considered whichare L-shaped structures (with and without shear wall analyzed using linear and non-linear dynamic method for IS1893-2002 and IS1893-2016). In this work, various parameters like storey drift, storey displacement, time period, base shear and modal mass participation ratio are obtained for all the models and have been compared. Also, the column forces at re-entrant cornerand interior column is compared.**

***Keywords*: Seismic force, irregularity, response spectrum method, time history method, IS1893-2002(1), IS1893-2016(1), IS16700-2017, BHUJ earthquake, ETABS v15, re-entrant corners.**

I. INTRODUCTION

The rapid growth in industrialization, population explosion and growing urbanization due to which high rise building have become necessary. The onrush of people to the urban areas or cities has resulted in huge demand for commercial buildings and shelter. With cities being the center of development and growth, there is a leading construction in the cities due to which buildings being built close to each other and the demand for land in cities has grown exponentially in association with this and rising inflation there is increase in land cost, raw materials and construction. The high cost for constructing and owning independent dwellings has become costlier, due to which apartment culture and more taller buildings which serve multipurpose utilities ranging from housing to shopping, food catering and recreation. As a result, high rise buildings have become necessary and also, they have become a prestige symbol due to which new and distinct tall buildings are being constructed higher and higher.Highrise structures are slender and are highly endangered to all types of lateral loads ranging from earthquake, wind and blast to wave impact. Among all the various types of lateral loads, the lateral load due to earthquake are drawing attention in the recent years with the increase of seismic activities all around the world and have proved to be dangerous as their impact being fatal and dreadful to the population and infrastructure over the vast area surrounding the epicenter. RC structure is more resistant to wind load due to its mass and slenderness and the same being disadvantage in resistance to seismic loads.Earthquake is the disturbance that happens at some depth below the ground level which causes vibrations at the ground surface. These vibrations happen in all the directions and are totally uncertain. The location, time, duration and magnitude are totally unknown. These are momentary and happen for a short duration. It is completely unpredictable, it is a shaking or trembling caused by the sudden release of energy below the ground. It is usually associated with the faulting or breaking of rocks. It is a sudden tremor or movement of the earth’s crust, which originates naturally at or below the surface. It excludes shock waves caused by nuclear test, manmade explosions etc. About 90% of all earthquakes, result from tectonic events, primarily movement on the faults[9] [10].

The earthquake forces due to the seismic waves produce vertical and horizontal ground motions. The vertical load due to ground motion is of lesser magnitude and can be withstand as the structure is designed for more factor of safety and according to IS1893-2002 the analysis is ignored, but according to IS 1893-2016 design for vertical earthquake effects is to be considered for structures with plan and vertical irregularity situated in seismic zone v or iv and resting on soil type 3 (soft soil). Hence, 2/3rd of the lateral load due to earthquake is considered as vertical load for design. The building designed to resist the vertical gravity and seismic loads cannot resist the horizontal loads or lateral loads and due to lateral seismic loads, the structures are more vulnerable. The design engineer should take into account both the vertical and lateral loads (gravity, seismic, wind, etc.) on the buildings and should design for the worst condition considering the surroundings. The seismic loads are considered as per the IS code IS1893-2002 but recently it has been updated as IS1893-2016. The greatest challenges of the recent days for a design engineer is to design a building seismic resistance.

II. LITERATURE REVIEW

[Bagheri et al., (2012)] modelled a 20 stories irregular building and analyzed using software's ETABS and SAP 2000 for seismic zone V in India. This paper also deals with the effect of the variation of the building height on the structural response of the shear wall building. Dynamic analysis is carried out under the earthquakes EL-CENTRO 1949 and CHI-CHI Taiwan 1999. In this paper the accuracy of the non-linear dynamic method (Time History analysis) is compared with linear static and dynamic methods (Equivalent Static and Response Spectrum method respectively) and the following conclusions were drawn: (i) Static method gave higher displacement values than dynamic method, (ii) Time history method is the most ideal method for the seismic analysis of buildings, (iii) Dynamic analysis should be performed for high rise structures to obtain accurate results, (iv) There is no much difference in displacement values between both methods for the lower stories whereas the higher stories shows higher displacement values, the displacement values increases along the height, (v) As the displacement values obtained from equivalent static analysis are higher, it is not considered as an economical method.**[Wakchaure et al., (2012)]** modeled and analyzed T shape and Oval shape buildings with 35 and 39 stories respectively. Considering the plan irregularity analytical analysis during seismic events is carried out and studied. The seismic performance of high rise buildings and the effects of structural irregularities in stiffness, strength, mass and combination of these factors are considered. The analysis was carried out using ETABS and the results were computed. The shear walls are located in the core and analyzed.**[Rama Raju et al., (2013)]** modelled a 3B+G+40storey reinforced concrete frame structure and designed according to the limit state design under wind and earthquake loads as per described in the IS codes. Safety of the structure is checked against allowable limits prescribed for base shear, roof displacement, inter storey drifts, accelerations prescribed in codes of practice and other relevant references.**[Guleria A. (2014)]** studied the structural behavior of multi-storey building for different plan configurations like rectangular, C, L and I shape and compared. A 15 storey RC frame building is modelled and analyzed using ETABS software. Post analysis of the structure maximum shear forces. bending moments and maximum storey displacement are computed and then compared for all the analyzed cases and from the results it was noticeable that the irregular plan structure had more values compared to regular building. **[Prajapati P. B. and Prof. M. G. Vanaza (2014)]** studied the seismic performance of a(G+10) storey residential building with three different types of plan configuration – rectangular, L shape and C shape. The buildings were analyzed both statically and dynamically using the software SAP 2000. The time history method made use of the previous earthquake data of BHUJ, UTTARKHASI and CHAMOLI. In this work storey shear and top joint deflections were evaluated and it was found that among all the three plan configurations, the L shape building gave higher values of displacement and storey shear.**[Bele K. R. and S. B. Borghate (2015)]** studied the seismic performance of sixmodels (one regular and other five irregular) with (G+12) stories, having 3.1m as the storey height. The models were considered with different projections of re-entrant corners both along X and Y directions. The analysis of models is done both in static and dynamic method for the seismic zone V. The earthquake details of previously occurred ELECENTRO earthquake was considered for the time history analysis. From the results obtained through analysis, base shear, time period, column forces for all the different models were obtained.**[Manilal M. and S. V. Rajeeva (2017)]** studied the horizontal irregularity (re-entrant corners). The paper focuses on the comparison of regular building with re-entrant corner buildings by conducting time history analysis located in seismic zone V. The time history analysis is carried out for BHUJ earthquake. The RC frame multi storied structure are modelled and analyzed using FE software ETABS. The evaluation and comparison of the regular and irregular buildings has been done using the parameters storey displacement, storey drift, time period and base shear. Also, the forces on the columns near the re-entrant corner has been studied.**[Bhattarai et al., (2017)]** studied the behavior of three G+10 storied buildings with different plans have been considered, one square shaped regular model and other two H shaped and hexagonal shaped models with horizontal irregularities. All models are located in Bangalore region with a seismic zone II. Analysis of these models is carried out using ETABS software. linear static method was used in the study of the models and results for various parameters was obtained like storey drift, storey displacement, storey shear, shear force and bending moment with and without shear wall. Comparison between three models with these parameters was done and it was found that the H-shaped model with shear wall gave better resistant to seismic load compared to other models and hence was chosen as the best frame.

III. MODELS CONSIDERED FOR ANALYSIS

Eight models are modelled with L-shape and analyzed. Models M1, M2, M5 and M6 are without shear wall and M3, M4, M7 and M8 are with shear wall. M1, M2, M3 and M4 are analyzed using response spectrum method and M5, M6, M7 and M8 are analyzed using time history method. M1, M3, M5 and M7 satisfy the codal provisions as per IS 1893-2002(1) and the other models are as per IS 1893-2016(1).

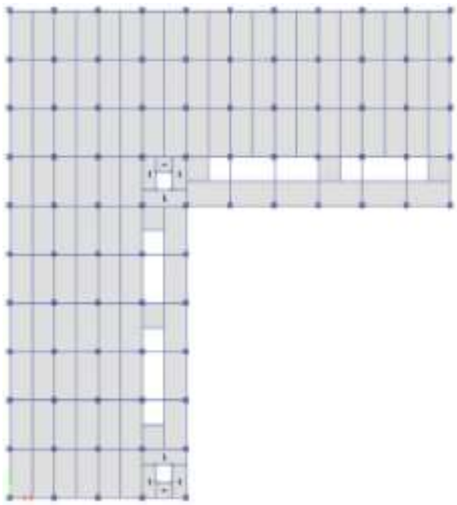


Fig. 1: Plan view of L-shape structure without shear wall

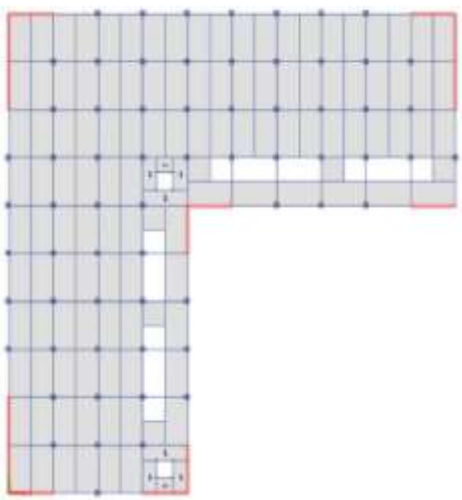


Fig. 2: Plan view of L-shape structure with shear wall

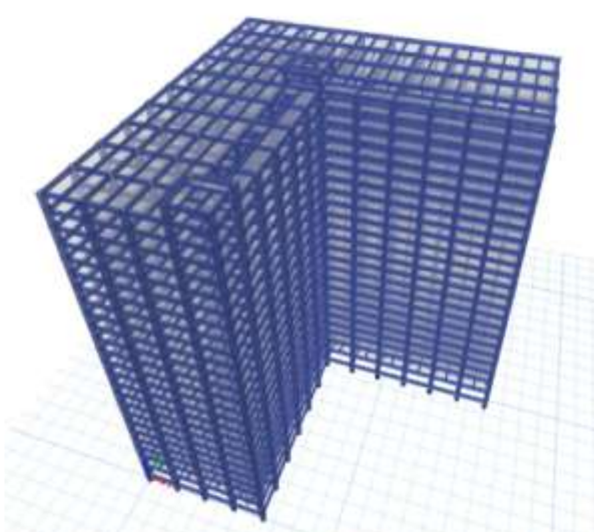


Fig. 3: 3D view of L-shape structure without shear wall

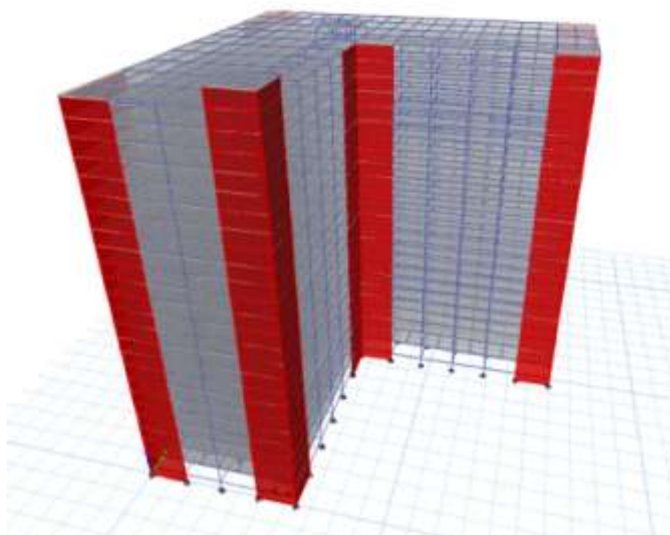


Fig. 4: 3D view of L-shape structure with shear wall

IV. MODEL DETAILS

Bay in both directions: 8m

No. of bays in both direction: 10

Storey height: 4m and 3.2m

Stories: G+25

Concrete grade: M50-M25

Steel grade: Fe500 and Fe415

Beam sizes (in mm): 300x450, 300x600 and 450x750

Column sizes (in mm): 300x600 and 1000x1000

Thickness of slab: 165mm

Thickness of shear wall: 300mm

Density of concrete: 25kN/m^3

Live load: 5kN/m^3

Floor finish: 1.5kN/m^3, 2kN/m^3 and 4kN/m^3

Load on beam: 10kN/m

Seismic Parameters

Seismic Zone, Z: V=0.36

Importance factor, I: 1 and 1.2

Response reduction factor, R: 5

Soil type: 1 (hard soil)

BHUJ earthquake data for time history analysis

Wind load parameters

Wind speed: 50 m/sec

Terrain category: 2

Structural class: C

Risk co-efficient (probability factor), k_1: 1

Terrain, height and structure size factor, k_2: as per height

Topography factor, k_3: 1

V. RESULTS AND DISCUSSIONS

The L-shaped structure with and without shear wall are analyzed as per codal provisions in IS 1893-2002(1), IS 1893-2016(1) and IS 16700-2017 using linear and non-linear dynamic analysis (response spectrum method and time history method respectively) and the results are obtained and compared.

5.1 Response Spectrum method

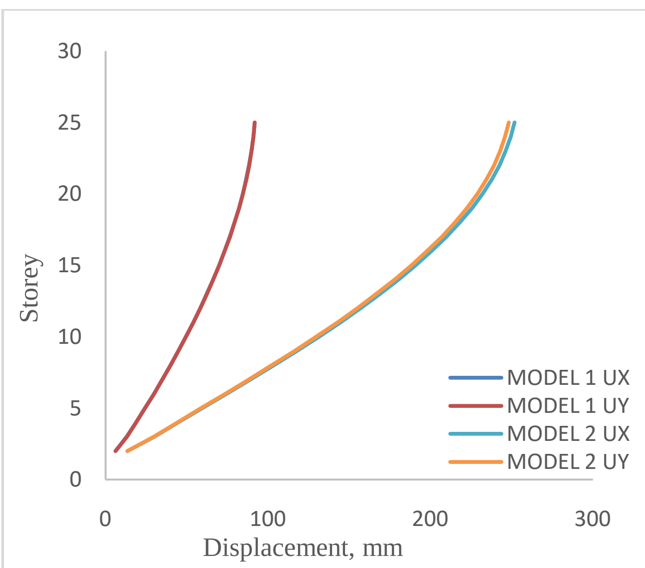
Model M1, M2, M3 and M4 are analyzed using response spectrum method. M1 and M2 are models without shear wall and M3 and M4 are models with shear wall. Models M1 and M3 are analyzed as per IS 1893-2002(1) and M2 and M4 are analyzed as per IS 1893-2016(1).

The storey displacement and storey drift ratio are compared in three cases, case1 models without shear wall, case2 models with shear wall and case3 models with and without shear wall for models analyzed as per IS 1893-2016.

5.1.1 Storey displacement

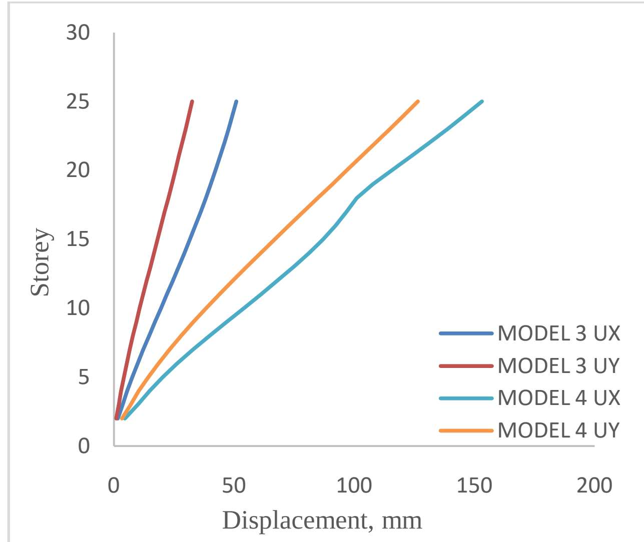
The permissible limit for storey displacement is H/500. H is 83.4m for the present model. The limit is 0.167m or 167mm.

Case 1: models without shear wall



The models analyzed as per the codal provisions in IS 1893-2016 have higher values of storey displacement than the models analyzed as per IS 1893-2002 and also exceed permissible limits, this is due to the higher factor of safety considered in IS 1893-2016.

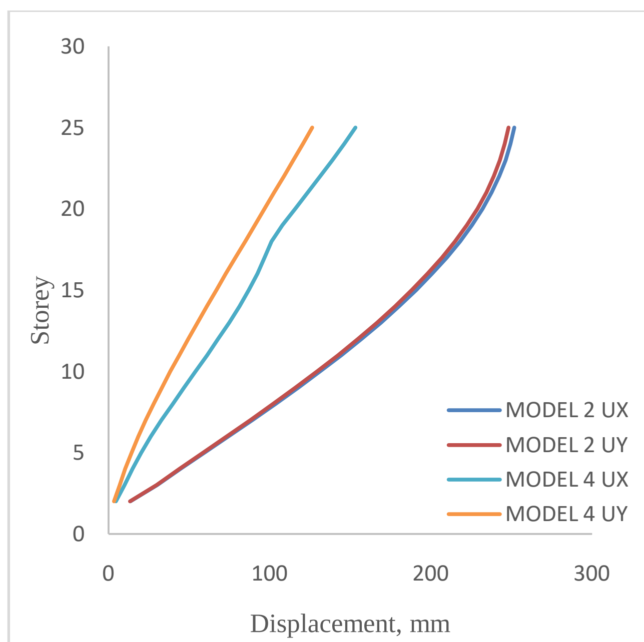
Case 2: models without shear wall



The models analyzed as per the codal provisions in IS 1893-2016 have higher values of storey displacement than the models analyzed as per IS 1893-2002 but both the values are within the limits, this is due to the higher factor of safety considered in IS 1893-2016.

Case 3: models with and without shear wall analyzed as per IS1893-2016

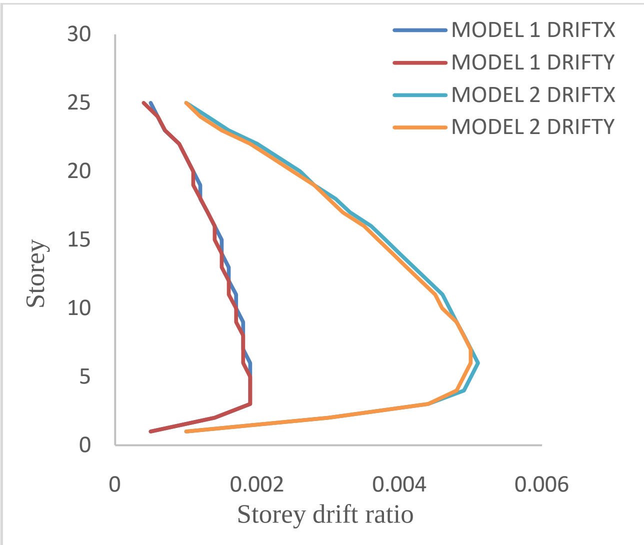
The inclusion of shear wall to the structure decreases displacement. On an average the decrease in displacement for models with shear wall compared to models without shear wall is 36%. The storey displacement of the structure can be decreased and brought within the limits by adding shear wall to the structure.



5.1.2 Storey Drift Ratio

The allowable value for storey drift ratio is 0.004.

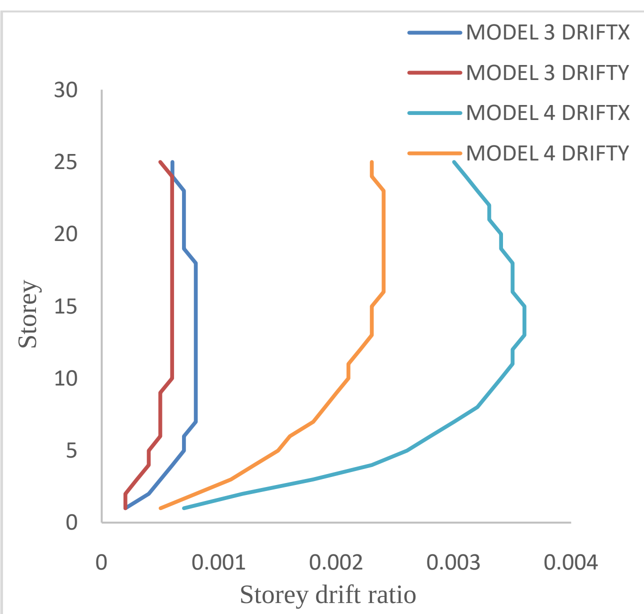
Case1: models without shear wall



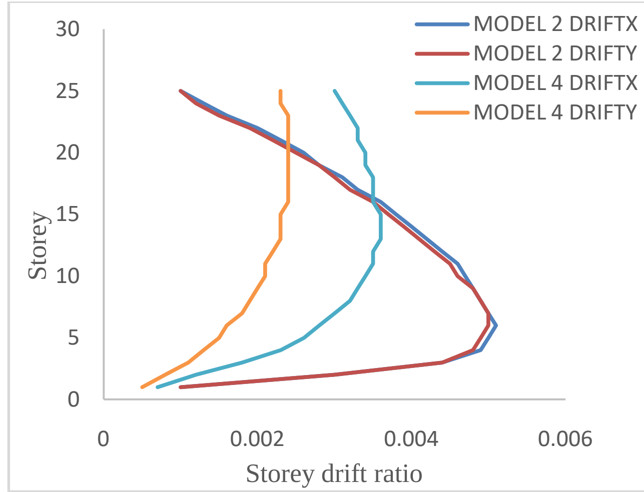
The models analyzed as per the codal provisions in IS 1893-2016 have higher values of storey drift ratio than the models analyzed as per IS 1893-2002 and exceed the permissible limit, this is due to the higher factor of safety considered in IS 1893-2016.

Case 2: models without shear wall

The models analyzed as per the codal provisions in IS 1893-2016 have higher values of storey drift ratio than the models analyzed as per IS 1893-2002, but are within the permissible limits, this is due to the higher factor of safety considered in IS 1893-2016.



Case 3: models with and without shear wall analyzed as per IS1893-2016



The storey drift ratio for models without shear wall is higher than the models with shear wall and also exceed the permissible value. Hence, it can be concluded that the inclusion of shear wall to the models decreases storey drift ratio of the structure.

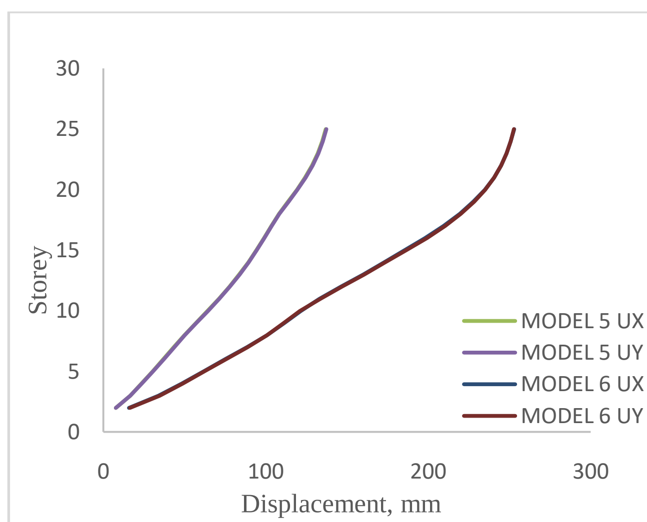
5.2 Time History Method

Model M5, M6, M7 and M8 are analyzed using response spectrum method. M5 and M6 are models without shear wall and M7 and M8 are models with shear wall. Models M5 and M7 are analyzed as per IS 1893-2002(1) and M6 and M8 are analyzed as per IS 1893-2016(1).

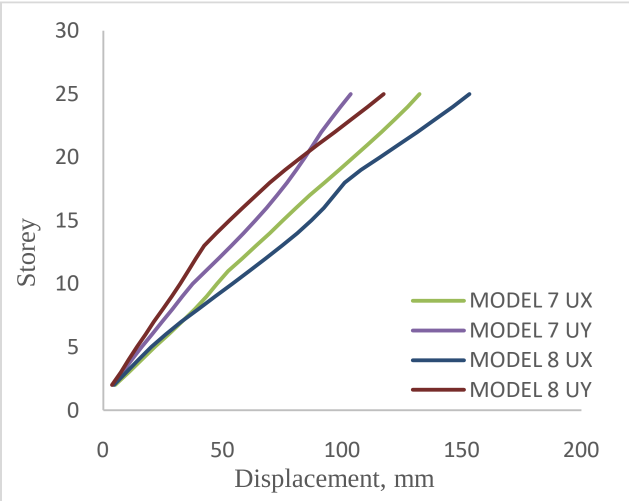
The storey displacement and storey drift ratio are compared in three cases, case1 models without shear wall, case2 models with shear wall and case3 models with and without shear wall for models analyzed as per IS 1893-2016.

5.2.1 Storey Displacement

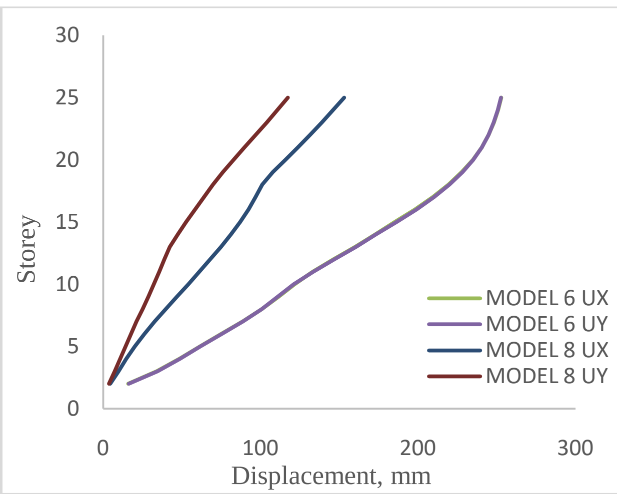
Case1: models without shear wall



Case 2: models without shear wall

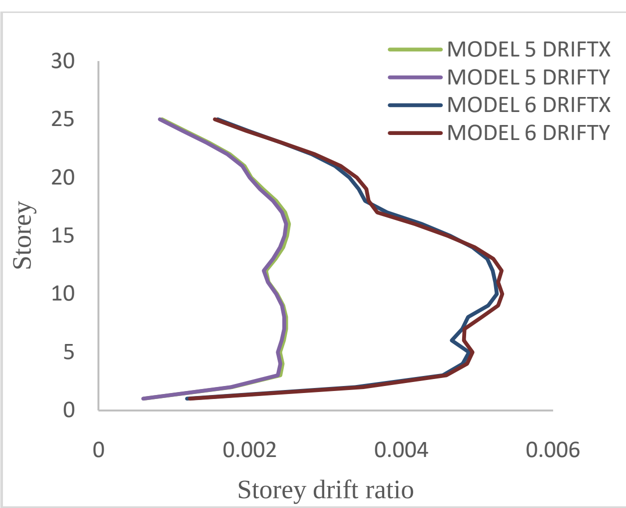


Case 3: models with and without shear wall analyzed as per IS1893-2016

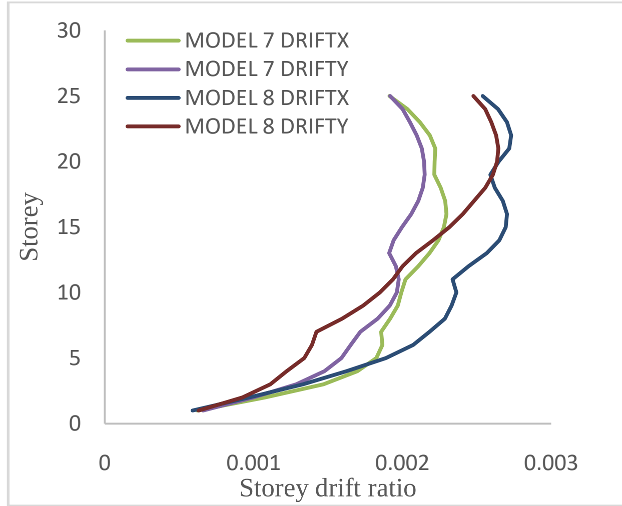


5.2.2 Storey Drift Ratio

Case1: models without shear wall



Case 2: models without shear wall



Case 3: models with and without shear wall analyzed as per IS1893-2016

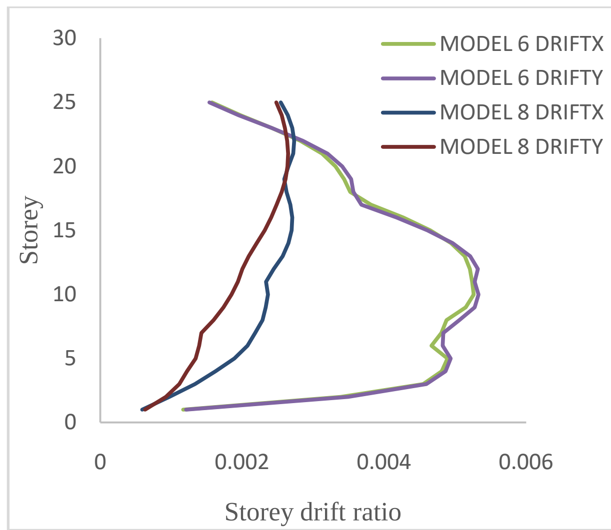


Table-1: Maximum storey displacement

MODEL	MAX. STOREY DISPLACEMENT, mm
1	91.85
2	251.82
3	50.87
4	153.16
5	137.24
6	252.99
7	132.26
8	155.21

Table-2: Maximum storey drift ratio

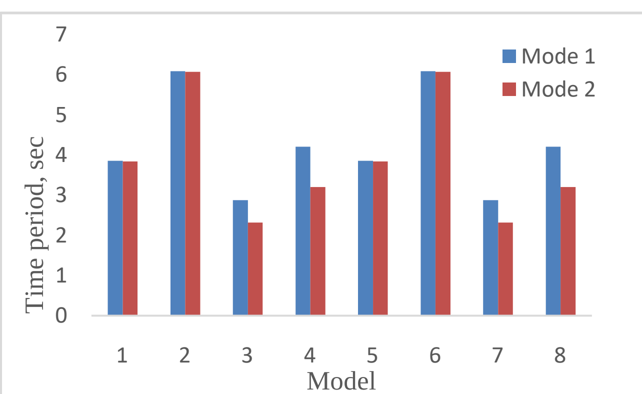
MODEL	MAX. STOREY DRIFT RATIO
1	0.0019
2	0.0051
3	0.0008
4	0.0036
5	0.0025
6	0.0053
7	0.0023
8	0.0027

5.3 Time Period

The time period values obtained from analysis as per IS 1893-2016 give higher values than the models analyzed as per IS 1893-2002. The values of time period decrease with the inclusion of shear wall to the structure. The inclusion of shear wall increases stiffness and decreases flexibility due to which the time period decreases. The difference in the natural time period is less than 10% for models without shear wall, but as per the code IS1893-2016 and IS 16700-2017 it should be higher than 10% to avoid irregular modes of oscillation in 2-principal plan direction (vertical irregularity), by providing shear walls to the structure this can be controlled. It can be seen that the models with shear wall have the difference greater than 10%.

Table-3: Time period

MODEL	TIME PERIOD, sec		DIFFERENCE %
	MODE 1	MODE 2	
1	3.855	3.838	0.44
2	6.084	6.071	0.21
3	2.875	2.318	19.37
4	4.207	3.202	23.89
5	3.855	3.838	0.44
6	6.084	6.071	0.21
7	2.875	2.318	19.37
8	4.207	3.202	23.89



5.4 Modal Mass Participation Ratio

The modal mass participation ratio for the models are obtained. The modes are decided in such a way that the sum of the modal mass participation ratio of all the modes should be greater than 90%. In these models it is attained at 12th mode. As per the code IS 1893-2016 and IS 16700-2017 the sum of first three modes should be greater than 65% and the sum of all the modes should be greater than 90%. All the models satisfy this for 12 modes. If the conditions are not satisfied then the modes should be increased until the conditions are satisfied. The modal mass participation for all the models are tabulated in table below.

Table-4: Modal mass participation ratio

MODEL	MODAL MASS PARTICIPATION RATIO			
	MODE 3		MODE12	
	Sum u_x	Sum u_y	Sum u_x	Sum u_y
1	81.83%	81.83%	95.94%	95.94%
2	80.78%	80.78%	97.39%	97.52%
3	74.18%	71.20%	96.94%	96.23%
4	71.79%	69.28%	97.57%	97.13%
5	81.83%	81.83%	95.94%	95.94%
6	80.78%	80.78%	97.39%	97.52%
7	74.18%	71.20%	96.94%	96.23%
8	71.79%	69.28%	97.57%	97.13%

5.5 Base Shear

The base shear of the structure is the total design lateral force acting at the base of the structure. The base shear of all 8 models is tabulated in the table below. The models with shear wall are marked with red. The models analyzed as per IS 1893-2016 have higher values of base shear than models analyzed as per IS 1893-2002. When the models with and without shear wall analyzed as per IS 1893-2016 are compared, the models with shear wall have higher values of base shear compared to models without shear wall.The base shear for vertical earthquake is computed to the models as per IS 1893-2016. According to this the 2/3rd of the lateral load acting on structure due to earthquake is considered as vertical load due to earthquake and analyzed. The base shear obtained due to vertical earthquake are too less than the gravity loads and hence are ignored in design.

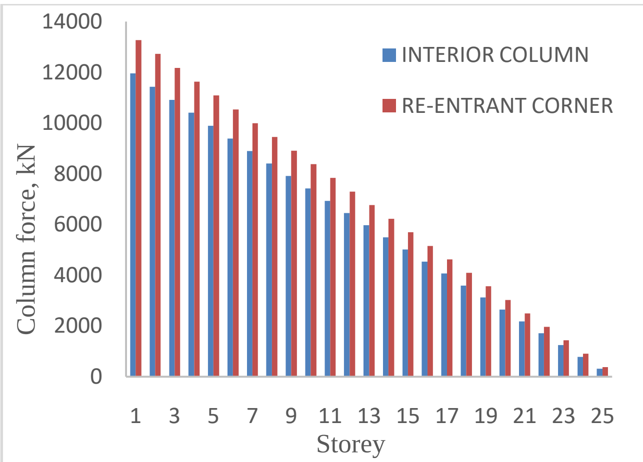
Table-5: Base shear

MODEL	BASE SHEAR (kN)		
	X-Dr	Y-Dr	Z-Dr
1	28171.2	28171.2	
2	33805.5	33805.4	170609
3	27807	27806.9	
4	71275.5	71275.3	254929

5	32087.3	32288	
6	37142.5	34245.6	379775
7	76559.9	86363.3	
8	71275.7	94972.8	337412

5.6 Column Forces

The column forces for an interior column and column at re-entrant corner are compared and plotted in figure below. An average for L shape model is taken and compared. The column force at the re-entrant corner is higher than the interior column.



VI. CONCLUSIONS

i. The models analyzed as per the codal provisions in IS 1893-2016 have higher values of storey displacement than the models analyzed as per IS 1893-2002, this is due to the higher factor of safety considered in IS 1893-2016.

ii. The inclusion of shear wall to the structure decreases displacement. On an average the decrease in displacement for models with shear wall compared to models without shear wall is 36%.

iii. The models without shear wall analyzed as per the codal provisions in IS 1893-2016 have higher values of storey drift ratio than the models analyzed as per IS 1893-2002 and exceed the permissible limit, this is due to the higher factor of safety considered in IS 1893-2016.

iv. The models with shear wall analyzed as per the codal provisions in IS 1893-2016 have higher values of storey drift ratio than the models analyzed as per IS 1893-2002, but are within the permissible limits, this is due to the higher factor of safety considered in IS 1893-2016.

v. The storey drift ratio for models without shear wall is higher than the models with shear wall and also exceed the permissible value. Hence, it can be concluded that the inclusion of shear wall to the models decreases storey drift ratio of the structure.

vi. The time period values obtained from analysis as per IS 1893-2016 give higher values than the models analyzed as per IS 1893-2002 hence, the values of time period decrease with the inclusion of shear wall to the structure. The inclusion of shear wall increases stiffness and decreases flexibility due to which the time period decreases. The difference in the natural time period is less than 10% for models without shear wall, but as per the code IS1893-2016 and IS 16700-2017 it should be higher than 10% to avoid irregular modes of oscillation in 2-principal plan direction (vertical irregularity), by providing shear walls to the structure this can be controlled. It can be seen that the models with shear wall have the difference greater than 10%.

vii. The modal mass participation ratio of the models is according to the provisions in IS 1893-2016 and IS 16700-2017 when the modes are 12 for the analysis.

viii. The storey stiffness of the models increases with the inclusion of shear wall. The models analyzed as per IS 1893-2002 have higher values of storey stiffness than the models analyzed as per IS 1893-2016.

ix. The models analyzed as per IS 1893-2016 have higher values of base shear than models analyzed as per IS 1893-2002. When the models with and without shear wall analyzed as per IS 1893-2016 are compared, the models with shear wall have higher values of base shear compared to models without shear wall.

x. The base shear for vertical earthquake is computed to the models as per IS 1893-2016. According to this the 2/3rd of the lateral load acting on structure due to earthquake is considered as vertical load due to earthquake and analyzed. The base shear obtained due to vertical earthquake are too less than the gravity loads and hence are ignored in design.

xi. For models analyzed as per the codal provisions in IS 1893-2002, the time history method gives higher values of storey displacement and storey drift ratio when compared with response spectrum method models. But for models analyzed as per the IS 1893-2016 there is no much variation in the storey displacement and storey drift values.

xii. Time period, modal mass participation ratio and storey stiffness for the models analyzed by both the methods (response spectrum method and time history method) gave the same values

xiii. The column force at the re-entrant corner is higher than the interior column.

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