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COMPARATIVE STUDY OF MULTI-STORIED RCC BUILDING WITH AND WITHOUT SHEAR WALL

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ABSTRACT

In the seismic design of buildings, reinforced concrete structural wall, or shear wall, acts as a major earthquake resisting member. Structural walls provide an efficient bracing system and offer great potential for lateral load resistance. Shear wall systems are one of the most commonly used lateral-load resisting systems in high-rise buildings. Shear walls have very high in-plane stiffness and strength, which can be used to simultaneously resist large horizontal loads and support gravity loads, making them quite advantageous in many structural engineering applications. The properties of these seismic shear walls dominate the response of the buildings, and therefore, it is important to evaluate the seismic response of the walls appropriately. In this study the main focus is to compare the dynamic responses of frame structure with and without shear wall.

Three models are generated with varying height with and without shear wall. G+5, G+10 and G+15 R-C frame models with and without shear walls are generated with varying structural member dimensions according to height. The models are analysed by Static Method and Response Spectrum Method considering seismic zone V in STAAD. Pro V8i. Parameters like lateral displacement, story drift, base shear and mode shapes are determined for all the models (with and without shear walls) by the three methods and are compared and the effectiveness of shear walls is enumerated. Also, comparisons are made based on some studies previously done by the other authors.

KEYWORDS: Base Shear, Response Spectrum Method, Shear Wall, Static Method

INTRODUCTION

The seismic movement of the ground causes the structure to vibrate and causes structural deformity in the building. Different parameters regarding this deformity like frequency of vibration, time period and amplitude are of significant importance and defines the overall response of the structure. This overall response also depends on the distribution of seismic forces within the structure which again depends on the method which is used to calculate this distribution. Different methods of 3-Dimensional dynamic analysis of structures have become more efficient in use along with the development of technology.

Touqanaet et al. [1] explained the equivalent static lateral load method of design for multi-storey masonry structures. Bagheriet et al. [2] compared the damage assessment of irregular building based on static and dynamic analysis. Bagheriet et al. [3] analysed multi-storey irregular building by using of the static and dynamic analysis and compared the result obtained from both the technique. Khan [4] evaluated the effects of response spectrum analysis on height of building. Patil et al. [5] performed seismic analysis of high-rise building by response spectrum method. Harshitha et al. [6] explained seismic analysis of symmetric RC frame using response spectrum method and time history method. Bhagwatet et al. [7]

depicted comparative study of performance of RCC multi-storey building for Koyna and Bhuj earthquakes. Kangda et al. [8] evaluated base shear and storey drift by dynamic analysis. Patil et al. [9] performed time history analysis of multi-storeyed RCC buildings for different seismic intensities. Chandurkaret et al [10] explained seismic Analysis of RCC Building with and without shear wall. Anshuman et al [11] found the solution of shear wall location in multi-storey building. Misam et al. [12] explained structural response of soft story-high rise buildings under different shear wall location.

The main objectives of this research will be comparative study of seismic behavior of multistoried reinforced concrete rigid frame structure of varying height with and without shear wall by using equivalent static method, time history method and response spectrum method.

METHODOLOGY

Dynamic analysis is related to the inertia forces developed by a structure when it is excited by means of dynamic loads applied suddenly (e.g., wind blasts, explosion, and earthquake). A static load is one which varies very slowly with time. A dynamic load is one which changes with time fairly quickly in comparison to the structure's natural frequency. If it changes slowly, the structure's response may be determined with static analysis, but if it varies quickly (relative to the structure's ability to respond), the response must be determined with a dynamic analysis.

Dynamic analysis of structure is a part of structural analysis in which behaviour of flexible structure subjected to dynamic loading is studied. Dynamic load always changes with time. Dynamic load comprises of wind, live load, earthquake load etc. Thus in general we can say almost all the real life problems can be studied dynamically. Types of sesimic analysis used in this study are Equivalent lateral force method (Static linear method) and Response spectrum method.

Equivalent Lateral Force

The idea of equivalent lateral force method is to distribute part of the seismic force (base shear) to every floor, which are able to transfer lateral loads. As a result of this method, the static forces are generated and applied to rigid (or semi-rigid) diaphragms or vertical elements (columns, wall), which can carry calculated forces. Every code proposes specific limitations of using such method. Most common limitations are structure regularity and its height. Mass of the storey includes added masses and dynamic masses from converted loads. Diaphragms assure proportional distribution of seismic loads on vertical elements. Generated force should be applied to the centre of mass of the diaphragm. Diaphragm or panel not positioned at the plane of storey top does not carry seismic force. In case of lack of diaphragms masses of nodes lying at the plane of storey top (floor plane) are taken into account. Then the proportional to mass force distribution has to be performed. The base shear which is the total horizontal force on the structure is calculated on the basis of structure mass and fundamental period of vibration and corresponding mode shape. The base shear is distributed along the height of structures in terms of lateral force according to code formula. This method is conservative for low to medium height buildings with regular conformation.

Response Spectrum Analysis

This method is applicable for those structures where modes other than the fundamental one affect significantly the response of the structure. In this method the response of Multi-Degree-of-Freedom (MDOF) system is expressed as the superposition of modal response, each modal response being determined from the spectral analysis of single -degree-of-freedom (SDOF) system, which is then combined to compute total response. Modal analysis leads to the response history of the structure to a specified ground motion; however, the method is usually used in conjunction with a response spectrum. A response spectrum is simply a plot of the peak or steady-state response (displacement, velocity or acceleration) of a series of oscillators of varying natural frequency that are forced into motion by the same base vibration or shock. The resulting plot can then be used to pick off the response of any linear system, given its natural frequency of oscillation. One such use is in assessing the peak response of buildings to earthquakes. The science of strong ground motion may use some values from the ground response spectrum (calculated from recordings of surface ground motion from seismographs) for correlation with seismic damage. If the input used in calculating a response spectrum is steady-state periodic, then the steady-state result is recorded. Damping must be present, or else the response will be infinite. For transient input (such as seismic ground motion), the peak response is reported. Some level of damping is generally assumed, but a value will be obtained even with no damping. Response spectra can also be used in assessing the response of linear systems with multiple modes of oscillation (multi-degree of freedom systems), although they are only accurate for low levels of damping. Modal analysis is performed to identify the modes, and the response in that mode can be picked from the response spectrum. This peak response is then combined to estimate a total response. A typical combination method is the square root of the sum of the squares (SRSS) if the modal frequencies are not close. The result is typically different from that which would be calculated directly from an input, since phase information is lost in the process of generating the response spectrum. The main limitation of response spectra is that they are only universally applicable for linear systems. Response spectra can be generated for non-linear systems, but are only applicable to systems with the same non-linearity, although attempts have been made to develop non-linear seismic design spectra with wider structural application.

Flowchart of the Work

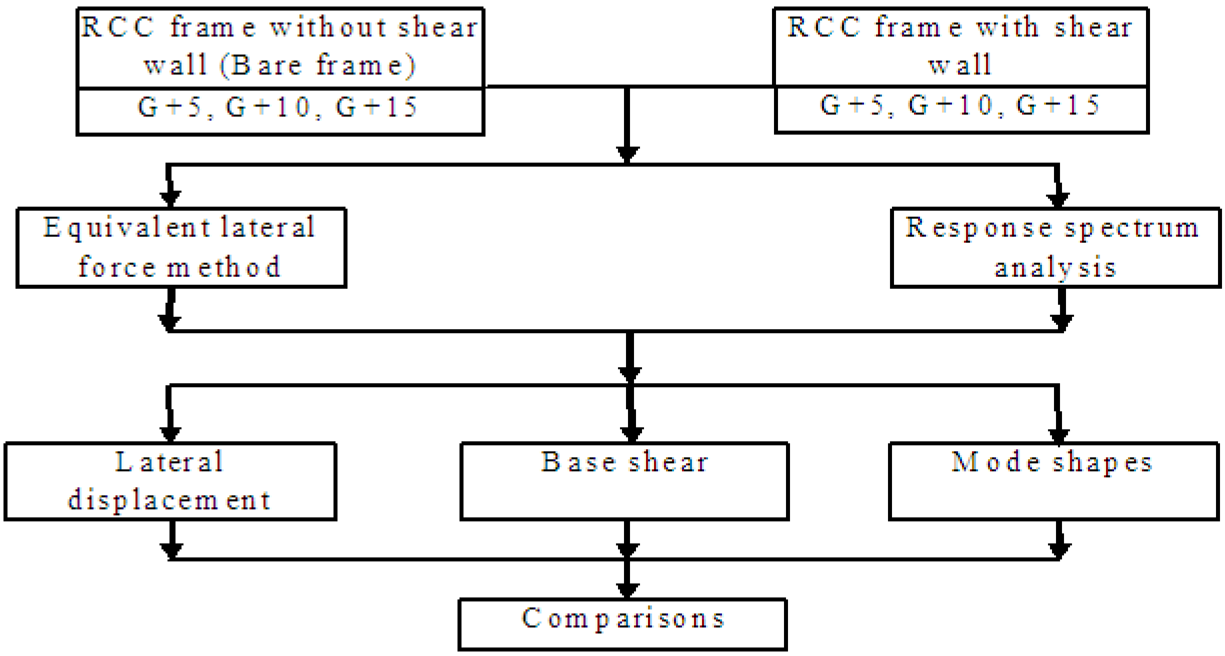
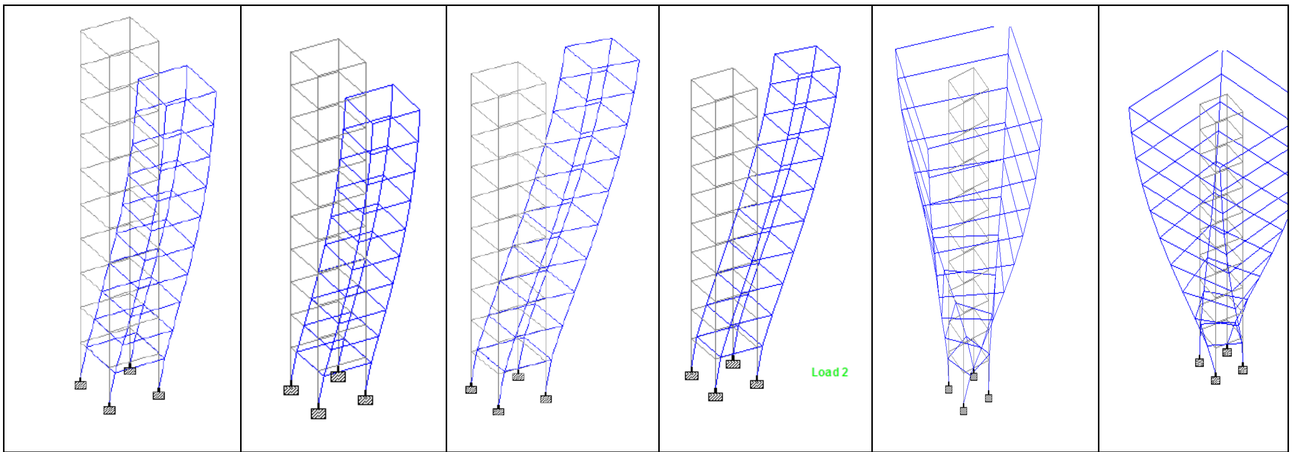


Figure 1: Flowchart of the Work

VALIDATION

To check the accuracy of the software and to establish a close understanding on the papers reviewed, validation of the past works are conducted. In this study, the results obtained from STAAD are compared with the paper of Harshitha et al. (2014). Few of comparisons are shown below.

Comparison of Mode Shape



Harshitha et al. Mode shape 1	In this study Mode shape 1	Harshitha et al. Mode shape 2	In this study Mode shape 2	Harshitha et al. Mode shape 3	In this study Mode shape 3

Figure 2: Comparison of Mode Shape

Comparison of Natural Frequency of the Building by Response Spectrum Method

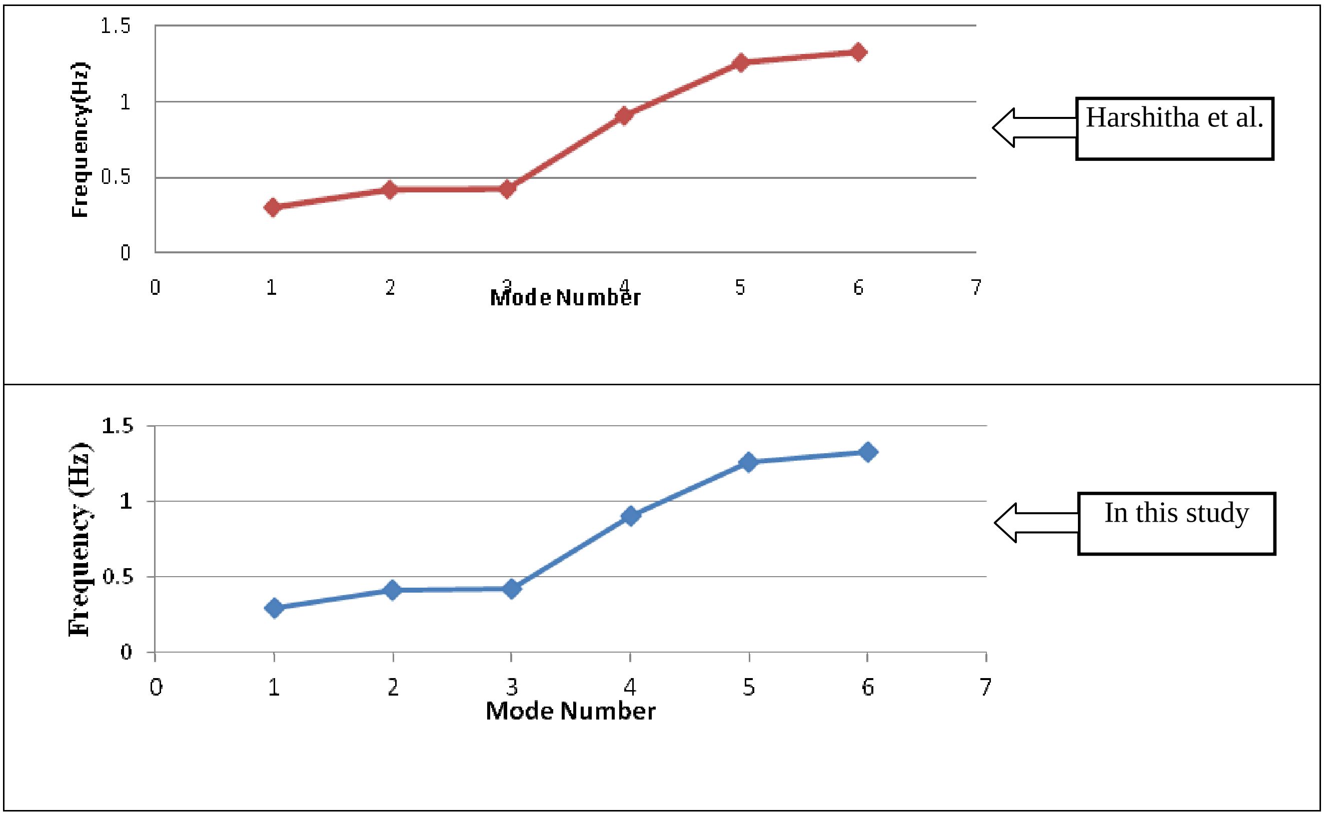


Figure 3: Comparison of Natural Frequency of the Building by Response Spectrum Method

Comparison of Base Shear in Response Spectrum Method

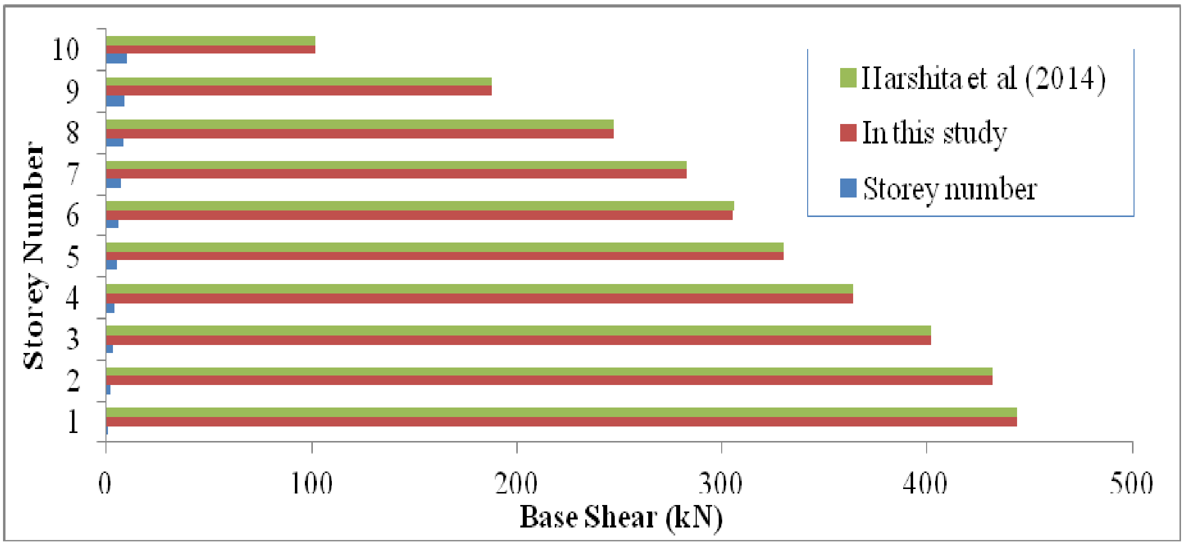


Figure 4: Comparison of Base Shear in Response Spectrum Method

MODELLING

The model is a regular bay frame model with 5 bays of 4m length on X-axis and 5 bays of 4m length on Z-axis. The ground-floor is 4.2m high, and the remaining 5 floors are 3m high each. The beam dimensions are uniform through-out but the column dimensions are varying with height. The outer walls and inner walls are also of varying thickness. A 1.2m high parapet wall is provided on the roof. The depth of the slab is kept uniform through-out. The dimensional properties of structures are shown in Table 1.

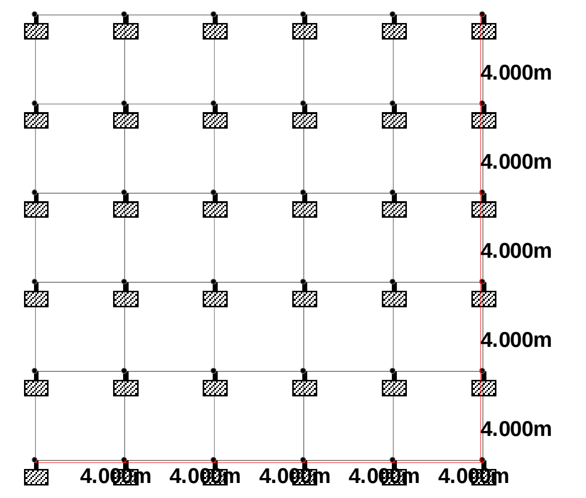


Figure 5: Plan Of G+5', G+10' & G+15 Model Without Shear Wall

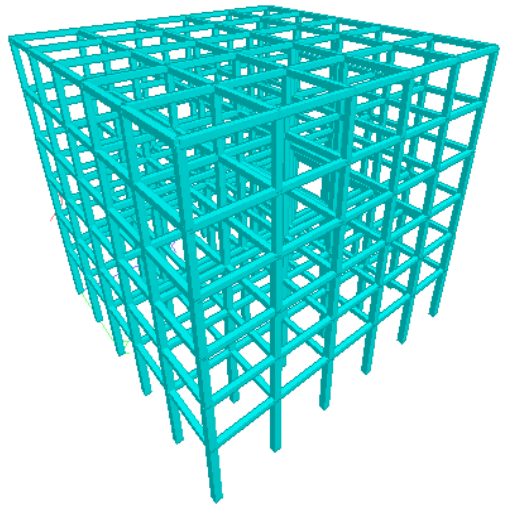


Figure 6: 3D: Rendered View of G+5' Model Without Shear Wall

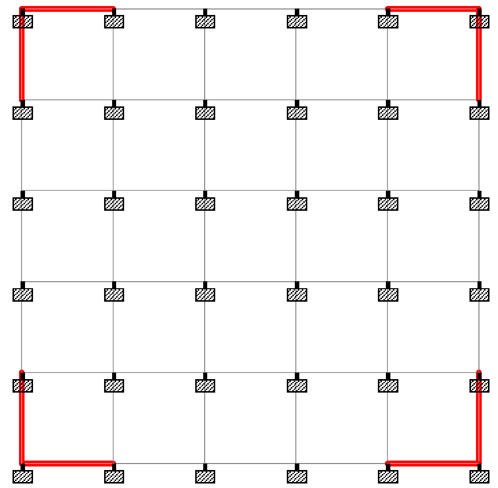


Figure 7: Plan of G+5', G+10' & G+15 Model With Shear Wall

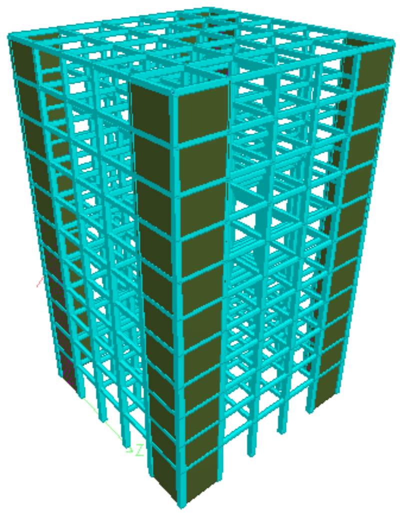


Figure 8: 3D: Rendered View of G+10' Model With Shear Wall

Table 1: Dimensional Property of Structures

G+15' model			G+10' model			G+5' model		
Member	**Dimension**	**Remarks**	**Member**	**Dimension**	**Remarks**	**Member**	**Dimension**	**Remarks**
Beam	0.30m X 0.45m	Uniform throughout	Beam	0.30m X 0.45m	Uniform throughout	Beam	0.3m X 0.45m	Uniform throughout
Column 1	0.55m X 0.55m	Ground to 2^{nd} Floor	Column 1	0.50m X 0.50m	Ground & 1^{ST} Floor	Column 1	0.4m X 0.4m	Ground & 1^{ST} Floor
Column 2	0.50m X 0.50m	3^{rd} to 5^{th} Floor	Column 2	0.475m X 0.475m	2^{ND} & 3^{RD} Floor	Column 2	0.35m X .035m	2^{ND} & 3^{RD} Floor
Column 3	0.45m X 0.45m	6^{th} to 8^{th} Floor	Column 3	0.45m X 0.45m	4^{TH} & 5^{TH} Floor	Column 3	0.3m X 0.3m	4^{TH} & 5^{TH} Floor
Column 4	0.40m X 0.40m	9^{th} to 11^{th} Floor	Column 4	0.40m X 0.40m	6^{TH} & 7^{TH} Floor			
Column 5	0.35m X 0.35m	12^{th} to 15^{th} Floor	Column 5	0.35m X 0.35m	8^{TH} & 9^{TH} Floor			
			Column 6	0.30m X 0.30m	10^{TH} Floor			
Slab	0.15m thick	Uniform throughout	Slab	0.15m thick	Uniform throughout	Slab	0.15m thick	Uniform throughout
Outer wall	0.25m thick	Uniform throughout	Outer wall	0.25m thick	Uniform throughout	Outer wall	0.25m thick	Uniform throughout
Inner wall	0.125m thick	Uniform throughout	Inner wall	0.125m thick	Uniform throughout	Inner wall	0.125m thick	Uniform throughout
Parapet wall	0.15m thick / 1.2m high	Roof	Parapet wall	0.15m thick / 1.2m high	Roof	Parapet wall	0.15m thick / 1.2m high	Roof
Total height of the model = 49.2m			Total height of the model = 34.2m			Total height of the model = 19.2m		
Total length along X-axis = 20m			Total length along X-axis = 20m			Total length along X-axis = 20m		
Total length along Z-axis = 20m			Total length along Z-axis = 20m			Total length along Z-axis = 20m		

RESULTS

Displacement

The displacements are compared for the different types of models by different methods.

Static Linear Method

The displacements for the different types of model are as shown in the graph below,

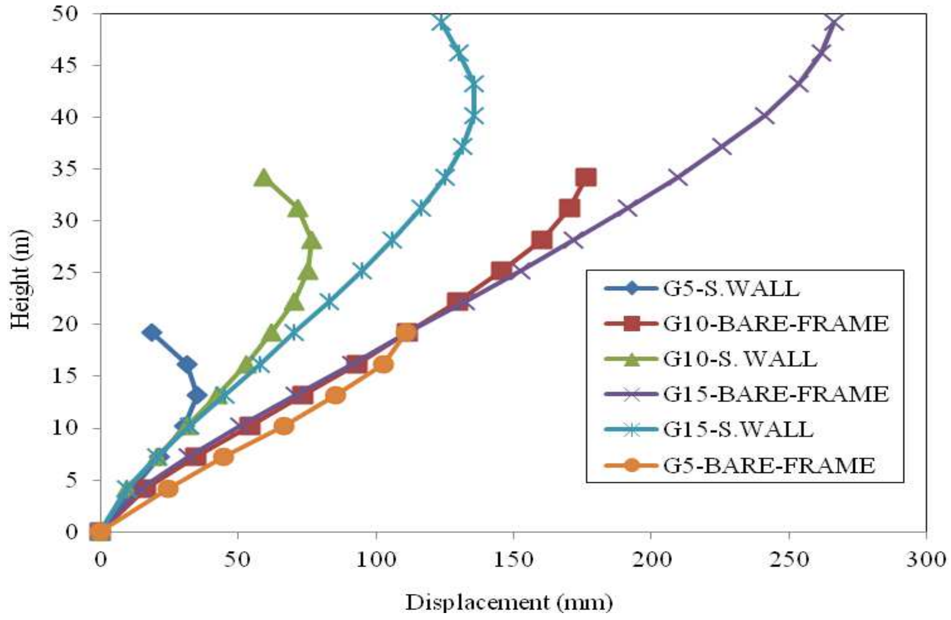


Figure 9: Displacement vs. Height Curve by Static Linear Method

Response Spectrum Method

The displacements for the different types of model are as shown in the graph below,

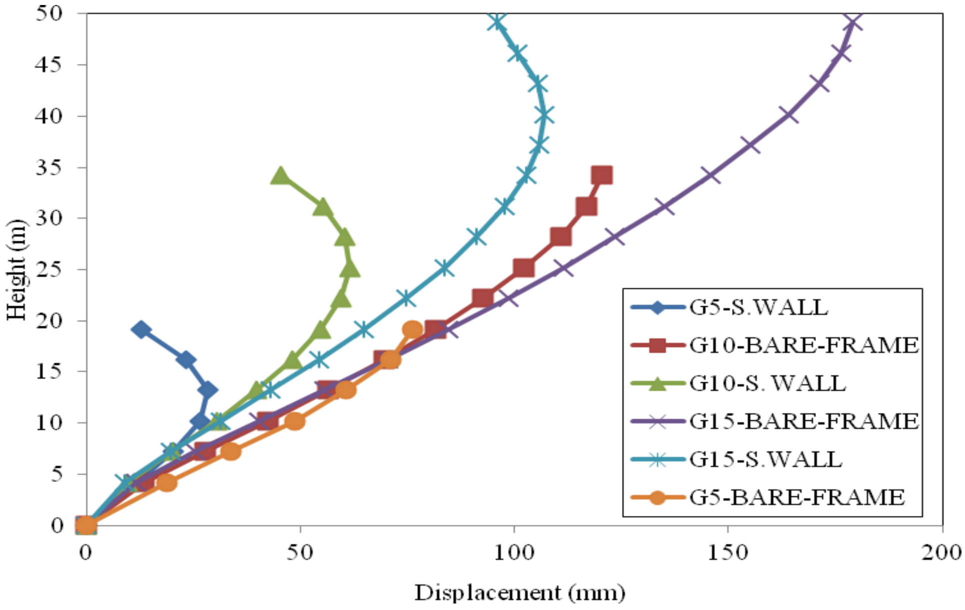


Figure 10: Displacement vs. Height Curve by Response Spectrum Method

BASE SHEAR

Table 2: Comparison of Base Shear

Structure Type		Static Method	Response Spectrum Method (Absolute Shear)
Shear Wall	**Height**	**Base Shear (kN)**	**Base Shear (kN)**
Without Shear Wall	G+5	2390.72	5049.42
	G+10	2541.63	5960.45
	G+15	2725.22	6201.6
With Shear Wall	G+5	2390.72	4992.75
	G+10	2541.63	5607.79
	G+15	2725.22	6012.07

CONCLUSIONS

The following conclusion can be drawn from the study.

- It can be observed that the design seismic coefficient parameters such as fundamental natural period and spectral acceleration coefficient calculated by IS 1893:2002 match accurately by STAAD software. The design horizontal seismic coefficient obtained by STAAD also matches with code. The most important parameter for earthquake design i.e. base shear obtained from all models matches perfectly with the code. The weight of building is also calculated manually and matched with that obtained by software.
- Bare-frame model showed higher displacement, than shear walled-frame model. A significant amount of increase in the lateral stiffness has been also observed in all models of shear wall frame as compared to bare frame.
- The variation in displacement between the bare frame and shear walled frame model increase with the increase of height, the variation in displacement of the two frames for G+5 floors was comparatively less than that of G+15 floors.
- The displacement values will depend upon frequency of earthquake and natural frequency of the structure and building with short time period tends to suffer higher accelerations but smaller displacement.

REFERENCES

1. Touqan A., (2008), “A scrutiny of the equivalent static lateral load method of design for multistory masonry structures”, American institute of Physics, AIP conference proceedings, 1020, pp 1151-1158.
2. Bagheri B. et al., (2013), “Comparative damage assessment of irregular building based on static and dynamic analysis”, International Journal of Civil and Structural Engineering, ISSN 0976 – 4399, Volume 3, No 3.
3. Bagheri B. et al., (2012), “Comparative Study of the Static and Dynamic Analysis of Multi-Storey Irregular Building International Scholarly and Scientific Research & Innovation, World Academy of Science, Engineering and Technology Vol:6.
4. Khan Q. et al., (2010), “Evaluation of effects of response spectrum analysis on height of building”, International Conference on Sustainable Built Environment (ICSBE-2010) Kandy, pp 13-14.

5. Patil S. et al., (2013), “Seismic Analysis of High-Rise Building by Response Spectrum Method”, International Journal Of Computational Engineering Research, ISSN 2250-3005, Vol. 3 Issue 3.

6. Harshitha et al., (2014), “Seismic Analysis of Symmetric RC Frame using Response Spectrum Method and Time History Method”, International Journal of Scientific Research and Education, ISSN 2321-7545, Vol.2 Issue 3.

7. Bhagwat et al., (2014), “Comparative study of performance of RCC multistory building for Koyna and Bhuj earthquakes”, International Journal of Advanced Technology in Engineering and Science Vol. No.02, Issue No. 07.

8. Kangda M. et al., (2015), “Study of base shear and storey drift by dynamic analysis”, International Journal of Engineering and Innovative Technology, ISSN: 2277-3754, Volume 4, Issue 8.

9. Patil A. et al., (2013), “Time History Analysis of Multistoried RCC Buildings for Different Seismic Intensities”, International Journal of structural and civil engineering research, ISSN 2319 – 6009, Vol. 2, No. 3.

10. Chandurkar P et al., (2013), “Seismic Analysis of RCC Building with and Without Shear Wall” International Journal of Modern Engineering Research, ISSN: 2249-6645, Vol. 3, Issue. 3, May - June 2013, pp-1805-1810.

11. Anshumn. S. et al., (2011), “Solution of shear wall location in Multi-storey building.” International Journal of Civil Engineering Vol. 9, No.2 Pages 493-506.

12. Misam A. et al., (2012) “Structural Response of Soft Story-High Rise Buildings under Different Shear Wall Location”, International Journal of Civil Engineering and Technology (IJCIET), ISSN 0976 – 6308, Vol.3 Issue 2.