Earthquake Analysis of Shear Wall of Multi-Storey Buildings

Vipin Kumar
mirokvipin@gmail.com
M.Tech Scholar, Department of CE, BRCM CET, Bahal, Bhiwani, Haryana
Rishabh Sharma
rishabhsaanwra@gmail.com
Assistant Professor, Department of CE, BRCM CET, Bahal, Bhiwani, Haryana

ABSTRACT

Building multi-story structures is becoming increasingly important due to space constraints and the increasing number of migrants from rural to urban areas. Given the historical seismic experiences, it is critical to consider earthquake effects when designing multi-story constructions. Residents' safety in such constructions is in doubt. Previous research concluded that higher values of stiffness to the columns demand larger sized columns, which are not available due to land constraints. As a result, shear walls are discovered to be an excellent method of imparting rigidity to the structure. Shear walls act similarly to wide columns that withstand the imposed loads. These walls act as structural barriers against earthquake forces. The current study is an attempt to measure the efficacy of shear walls in constructions. In this study, seven models are assessed to have appropriate shear wall configurations. With the help of the platform ETABS 16.2.1, these models are examined for Equivalent Static Analysis and Response Spectrum Analysis. Both analyses are performed in accordance with IS: 1893 - 2002 (Part 1) in the form of various load combinations. Various characteristics such as base shear and fundamental natural time period of vibrations are analysed using both techniques of analysis, and the ideal shear wall configuration is recommended.

Keywords**:** *Shear Wall, Base Shear, Fundamental Time Period of Vibrations, Stiffness.*

INTRODUCTION

Many structures, particularly Reinforced Concrete constructions, have been damaged or collapsed in previous earthquakes. Buildings that collapsed after earthquakes are investigated in terms of their performances. The use of poor quality concrete, an insufficient bond between the end supports, an insufficient length of slices offered, the behavior of short columns, and the partial or erroneous design consideration are discovered to be important problems in the constructions. The basic function of shear wall is to increase the rigidity for lateral load resistance along with providing adequate stiffness and strength to the structure. Reinforced concrete shear wall provides a significant amount of strength and stiffness to the building in the direction of their orientation which considerably reduces lateral sway of the building. However, if a building is designed in highly seismic prone areas without the use of shear wall, the beam and column sizes would be large along with this, it would be difficult to place and vibrate concrete which will lead to larger displacement inducing heavy forces on the structure therefore shear wall becomes an essential part in designing of tall buildings from both economy and stability point of view. With limiting space and fast pace construction of tall buildings, shear wall is gaining popularity day by day especially in construction of apartments and offices. Based on these structural deficiencies, severalcodes have been revised so far. The required ductility of the structure, their lateral stiffness and the strength are comparatively less than those which are designed by the modern codes of building designs. Meanwhile in the present time, the global strengthening techniques are frequently considered as the strength imparting strategies. The modification of the structure's global behavior when subjected to external loads must be considered in these procedures. This strategy increases the value of the structure's lateral load capacity as well as its strength. This method entails installing shear walls on all four sides of the structure. This type of external strengthening has been proven to be more advantageous in terms of cost and ease of construction.

LITERATURE REVIEW

Yu Zhang 2017, focused on optimization for design of tall buildings with shear wall. The paper accelerates the use of optimization using ground structure program formulation and developing algorithms leading to cost saving and economic design of shear wall.

Fazal U Rahman Mehrabi 2017, focussed on building frame without bracing, shear wall and with bracing, shear wall is being designed as per IS 456:2000 & IS1893: 2002.The study was done to check the performance of a building when designed as per Indian standards and also to determine the effect of providing shear wall and bracing to building frame.

G.S. Hiremath 2016, worked on effect of addition of shear wall at different location and configurationalong with varying thickness of shear wall using ETABS v 9.7.1

Ali Kocak, Basak Zengin 2015, discusses the behaviour of frame -wall irregularity on the established reinforced concrete structures that were subjected to the 1999 Kocaeli Earthquake in Turkey.

Gangisetty 2015, presented optimisation techniques which are used to solve problems related to structural engineering involving both size and topological optimization by considering stability, safety, response to different types of loading.

RESEARCH OBJECTIVES

The major goal of the shear wall provision is to strengthen the current structure and to investigate the many methods in which structures can be made more stable against the impacts of heavy seismic loading. Furthermore, the following topics may be covered:

- ETABS will design the most appropriate shear wall.
- To compare and analyses the base and fundamental natural time periods for frames with and without shear walls.
- Using a shear wall to reduce column and beam size.
- Determine the best placement for shear walls based on elastic and inelastic analyses.

FRAMEWORK

In this present study, the modelling of the structure has been classified into two sections viz., the structural frame withoutany shear wall and the structural frame with shear walls having different dimensions, positions and shapes. The table1 and table 2 represent the geometric parameters and the material used for the designing of the structural frame which does not constitute any shear wall. This frame models havebeen named as M-0, M-1, M-2, M-3, M-4, M-5, M-6.

Building plan	48m x 42m
No. of Storey	9
Storey ht.	3.2m
Thickness of slab	125 mm
Thickness of wall	230 mm
Column Size	400 mm x 400 mm (In model M-0and model M-1)
Beam Size	350 mm x 550 mm (In model M-0and model M-1)
Concrete grade	M25
Steel Grade	Fe 500
Live Load on floor	2.5 kN/m2
Floor finish	1 kN/m2

Uniformly distributed load onbeams	17.5 kN/m2
Response Reduction factor	5
Importance Factor	1
Seismic Zone	IV
Zone factor	0.24
Soil type	Medium
Joint Restraint	Fixed

Table-1: Geometric Parameters and Material Used forDesign of Frame M-0

Thickness of Shear Wall	230mm
Wall Grade Concrete	M 30
Size of Beam	300mm x 300mm (In model M-2 to model M-6)
Size of Column	350mm x 350mm (In model M-2 to model M-6)

Table 2: Geometric Parameters of Shear Walls and Size of beams & Columns

RESULTS & DISCUSSIONS

Equivalent Linear Static Analysis

The comparable static analysis always assumes that the structure is a discrete structure with concentrated loads at the floor levels in the form of self-weight of walls, columns, and so on. These loads should be distributed equitably to floors below and above the storey. Furthermore, an adequate amount of induced stress is assessed at floor levels. Various load patterns and load scenarios, as illustrated in tables 3 and 4, are investigated during this analysis.

Live	Live	0	
EQ X	Seismic	0	IS: 1893 - 2002
EQ Y	Seismic	0	IS: 1893 - 2002

Table 3: Load Pattern considered During Equivalent Static Analysis

Name	Type
Dead	Linear Static
Live	Linear Static
EQ X	Linear Static
EQ Y	Linear Static

Table 4: Load Cases considered During Equivalent Static Analysis

Base Shear

The structure's base shear along the X and Y axes is virtually identical. Although the largest value of base shear reported for model M-5 is in the order of 9000 kN. The minimum base was seen in the model M-0 (Bare Frame Model), which was 2850 kN along the X-direction and 2760 kN along the Y-direction. The models M-2 and M-5 have nearly identical base shear values, and this value is exactly the same along both directions. Figure 1 depicts the values of base shear along the storey height for all frame models.

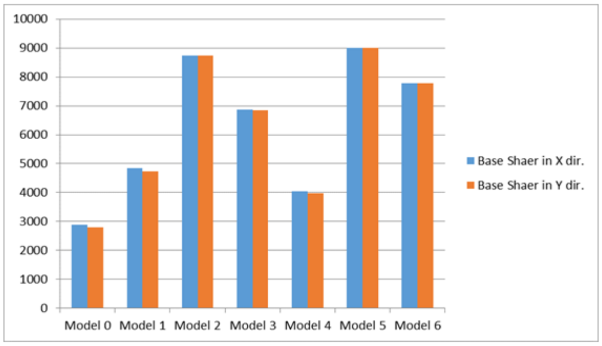

Figure. 1: Base Shear Values of the various Models[Equivalent Linear Static Analysis]

Natural Time Period

The approximate fundamental natural time period of vibrations for the various models is determined using IS: 1893 – 2002. This value is found to be maximum for the bare frame model M-0 and it is interesting to note that this valueis slightly more along Y-direction as compared to X- direction. The models M-2 and M-5 have the minimumvalues of approximate fundamental natural time period of vibrations. It can also be said that these models have maximum value of fundamental natural frequency as it is inversely proportional to the fundamental natural time period of vibrations. Fig. 2 shows the values of fundamental natural time period of vibrations along the storey height forall the frame models.

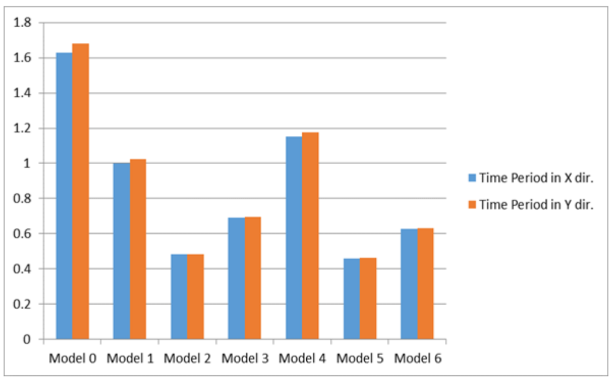

Figure. 2: Natural Time Period of Vibration of the various Models [Equivalent Linear Static Analysis]

Response Spectrum Analysis Method

This method is an approximate linear method which is basedon the modal analysis and on the definition of response spectrum. It should be noted that this procedure results in the maximum response of the structure. The maximum response may be established for each and every mode of loading by the means of some sufficient response spectrum. During this analysis, the various load patterns and load cases are considered which have been shown in table 5 and table6.

Name	Type	Self Weight Multiplier	Auto Load
Dead	Dead	1	
Live	Live	0	
EQ X	Seismic	0	IS: 1893 - 2002
EQ Y	Seismic	0	IS: 1893 - 2002

Table 5: Load Pattern considered During ResponseSpectrum Analysis

Name	Type
Dead	Linear Static
Live	Linear Static
EQ X	Linear Static
EQ Y	Linear Static
RS-X	Response Spectrum
RS-Y	Response Spectrum

Table 6: Load Cases considered During ResponseSpectrum Analysis

Base Shear

The base shear of the structure along X-direction and Y-direction are nearly found to be same. Although the maximum value of base shear is observed for model M-5 andM-6 which is in the order of 3800 kN. It may be due to the effective, symmetrical and uniform distribution of shear walls. The Minimum base has been observed in the model M- 0 (Bare Frame Model) i.e., 1750 kN along X-direction and 1700 kN along Y-direction. The model M-2 and M-3 have almost same values of base shear and this value is exactly same along both the direction. Fig. 3 shows the values of base shear along the storey height for all the frame models.

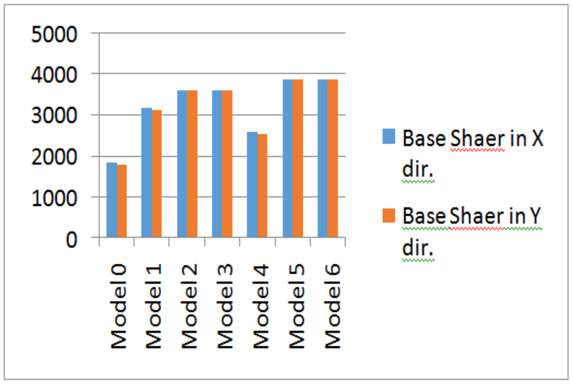

Figure. 3: Base Shear Variation in the Various Models along X-direction and Y-direction [Response Spectrum Analysis]

Natural Time Period

IS:1893 - 2002 is used to establish the approximate fundamental natural time period of vibrations for the various models. This number was discovered to have the highest value for the bare frame model M-0, and it is worth noting that it is somewhat higher along the Y-direction than the X-direction. The minimal values of the estimated fundamental natural time period of vibrations are found in the models M-2 and M-5. These models have the highest fundamental natural frequency value because it is inversely related to the fundamental natural time period of vibrations. The values of the fundamental natural time period of vibrations throughout the storey height are shown in Fig. 4 for all frame models.

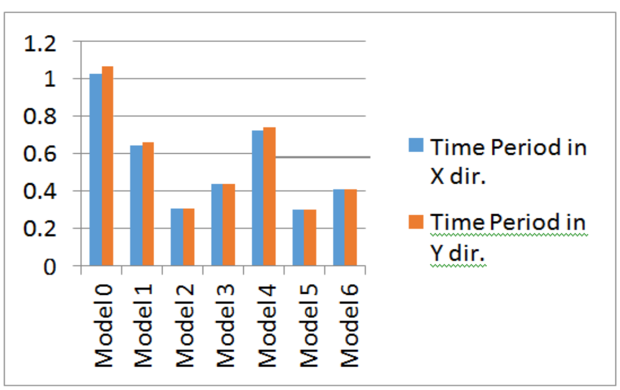

Figure. 4: Natural Time Period Variation in the Various Models along X-direction and Y-direction [Response Spectrum Analysis]

CONCLUSIONS

The following are the salient conclusion drawn from the present study:

1. It was discovered in both the equivalent static analysis and the response spectrum analysis methods that the model with box shaped shear walls at the centroid of the building, M-5, has the smallest value of maximum lateral displacement in both the X and Y directions.
2. In both techniques of investigation, the model M-5 had the most effective distribution of base shear. It is because of the effective uniform distribution of the shear wall, which is provided concentrically in the form of a square box.
3. Based on both techniques of study, it was determined that models M-2 and M-5 have the smallest values of approximate fundamental natural time period of vibrations. These models also have the highest fundamental natural frequency value since it is inversely related to the fundamental natural time period.

REFERENCES

[1] Rai S. K., Prasad J. and Ahuja A. K. (2006), "Reducing Drifts and Damages in Tall Buildings by Shear Wall Panels", National Conference on High-Rise Buildings; Materials and Practices, New Delhi, India, pp. 397-409.

[2] Ashraf M., Siddiqi Z. A. and Javed M. A. (2008), "Configuration of Multi-Storey Building Subjected to Lateral Forces", Asian Journal of Civil Engineering (Building and Housing), ISSN 1563 — 0854, Vol. 9, No 5, pp 525-537.

[3] Kaltakci M.Y., Arslan M.H. and Yavuz G., (2010), "Effect of Internal and External Shear Wall Location onStrengthening Weak RC Frames", Sharif University of Technology, Vol. 17, No. 4, pp. 312- 323.

[4] Anushman S., Dipendu Bhunia and Bhavin Ramjiyani (2011), "Solution of Shear Wall Location in Multi-Storey Building", International Journal of Civil and Structural

Engineering (IJCSE), ISSN 0976 — 4399,Vol. 2, No 2, pp. 493-506.

[5] Kaplan H., Yilmaz S., Cetinkaya N. and Atimtay E. (2011),"Seismic Strengthening of RC Structures with Exterior Shear Walls", Indian Academy of Sciences, Vol.36, Part 1, pp. 17—34.

[6] Yu Zhang, Caitlin Mueller" Shear wall layout optimization for conceptual design of tall buildings "Engineering Structures vol 140, pp 225-240, March 2017.

[7] Fazal U Rahman Mehrabi, Dr.D. Ravi Prasad"Effects of Providing Shear wall and Bracing to Seismic Performance of Concrete Building" ISSN:2395-0056, vol 4, pp 890-896, Feb 2017.

[8] G.S Hiremath, Md Saddam Hussain" Effect of Change in Shear Wall Location with Uniform and Varying Thickness in High Rise Building" ISSN:2347-4718, Vol3, pp2678-2682, June 2016.

[9] Ali Kocak, Basak Zengin, Fethi Kadiog˘lu" Performance assessment of irregular RC buildings with shear walls after Earthquake" Elsevier, Engineering Failure Analysis vol55,pp 157-168,June 2015.

[10] Gangisetty Sri Harsha , Dr. H. Sudarsana Rao" Shear allL Analysis & Design Optimization In High Rise Buildings" ISSN:2277-9655(I2OR), pp 333-341,August 2015.

[11] Kumbhare P. S. and Saoji A. C. (2012), "Effectiveness of Changing Reinforced Concrete Shear Wall Location on Multi-storeyed Building", International Journal of Engineering Research, ISSN: 2248-9622, Vol. 2, Issue 5, pp.1072-1076.

[12] Chandurkar P. P. and Pajgade P. S. (2013), "Seismic Analysis of RCC Building with and without Shear Wall", International Journal of Modem Engineering Research (IJMER), ISSN: 2249-6645, Vol. 3, Issue. 3, pp. 1805-1810.

[13] Kulkami J. G., Kore P. N. and Tanawade S. B. (2013), "Seismic Response of Reinforced Concrete Braced Frames", International Journal of Engineering Researchand Applications (IJERA), ISSN: 2248-9622, Vol. 3, Issue 4, pp.1047-1053.

[14] Sardar S. J. and Karadi U. N. (2013), "Effect of Change in Shear Wall Location in Shear Wall Location on Storey Drift of Multistorey Building Subjected to Lateral Loads", International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET), ISSN: 2319- 8753, Vol 2, Issue 9, pp. 4241-4249.

[15] IS: 875 (Part 1) — 1987, "Code of Practice for Design Loads (Other Than Earthquake) for Buildings and Structures — Dead Loads", Bureau of Indian Standards,New Delhi.

[16] IS: 875 (Part 2) — f987, 'Code of Practice for Design Loads (Oder Than Earthquake) for Buildings and Structures — Imposed Loads", Bureau of Indian Standards, New Delhi.

[17] IS: 13920- 1993, "Indian Standard Code of Practice for Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces", Bureau of Indian Standards, New Delhi.

[18] IS: 456- 2000, "Plain and Rpeforced Concrete-Code of Practice", Bureau of Indian Standard, New Delhi, India.

[19] IS: 1893 (Part 1)- 2002, "Criteria for Earthquake Resistant Design of Structures- General Provisions and Buildings, Fifth Revision", Bureau of Indian Standards, New Delhi.

[20] Ductile Detailing Of ReinforcedConcrete Structures Subjected ToSeismic Forces -Code Of Practice IS13920: 1993.

[21] ACI Committee 318 2005 Building code requirements for structural concrete and commentary (ACI 318M-05). American Concrete Institute.

[22] Gupta R., and Bano A. (2019), - Performance Evaluation of Various Shapes of Shear Wall using Response Spectrum Analysis, International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-8, Issue-1.

[23] Khatri Y. R., and Saha P. (2020), -Effect of Shear wall in Seismic Performance of High-Rise Irregular RC Framed Building, International Journal of Science and Research, Vol. 10, Issue 7.