Seismic Analysis of Multi Storey Buildings With and Without Shear-walls

Tejaswini Dalai [1] *and Pravat Kumar Parhi* [2]

Abstract

A structure in its design life period is subjected to a number of earthquakes of various intensities from small to medium and large. The work of a structural engineer is to come up with a design that will be able to resist the impact of earthquake without collapse. Earthquake resisting members like shear-walls are ductile in nature and they exhibit enough resistance to face the seismic forces and reduce the amount of drifts and displacements. In this study, an under 50m category building (twelve storey, G+11, total height 36m) and a 50-100m category building (twenty-eight storey, G+27, total height 84m) are considered with and without shear-wall configuration for seismic analysis. Both static and dynamic analysis are applied to the structures using ETABs software. Difference in results for drifts and displacements are studied in this investigation.

Keywords : **Base shear, response spectrum, seismic analysis, shear wall, storey drift**

I. INTRODUCTION

By observing the behavior of building structures during severe and very severe earthquakes, it has been reported that the most likely factors responsible for proper seismic behavior of the structure are its simplicity, regularity, ductility, and flow of direction of load from the super structure to sub-structure. So, structural requirement to fulfill the safety and serviceability of a seismically designed structure is to have a configuration which is simple and regular. A structure should offer enough ductility to behave elastically while subjected to seismic loads.

On the other hand, horizontal load resisting member like a shear-wall is found to provide ductility to the structures and minimizes the drifts and displacements resulting from seismic loads. Shear-walls are the load bearing walls in a structure which are provided to counteract the horizontal load caused by wind or earthquake. Shear-wall acts like a vertical member which is restrained against ground and is free at the top level. To resist large intensity seismic loads, boundary elements are specially designed at the ends of shear-walls. Overall, the middle portion takes the flexure while the boundary portion absorbs the shear.

In this study, isolated type shear-walls are taken into consideration with shear-wall configuration. Linear analysis is done both by static seismic co-efficient method and dynamic response spectrum method. Both modeling and analysis are done using ETABs: 2018, which is based on finite element method of analysis for minimizing the error and it generates results with great accuracy. All the seismic provisions are adopted as per IS 1893 (Part 1):2016, which is the current revised code(sixth revision) for earthquake resistant design of structures.

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II. LITERATURE REVIEW

The objective of the work is to obtain the deformational parameters of the structure after the seismic analysis is performed with and without shear-wall configuration by both static and dynamic methods. The observations related to analysis of drifts and displacements in multi-storey buildings applying static and dynamic methods of seismic analysis are thoroughly reviewed here.

- **S. K. Duggal [1]** Presented the theoretical information for all the aspects of earthquake resistant structures. He also presented information about the behaviour of shear-wall regarding its load bearing characteristics. He studied the mathematical computation for analysis of multi-storey buildings for both static and dynamic methods through various numerical examples.

- **Pankaj Agarwal and Manish Shrikhande [2]** Studied numerous mathematical examples for static and dynamic seismic analysis. Specially, the response spectrum analysis is analyzed thoroughly using various methods like Sum of Absolute values (SAB), Square Root of Sum of Squares (SRSS), and Complete Quadratic Combinations. Description about various dynamic seismic parameters like modes, modal mass, and Eigen values are given for better understanding

- **Rama Krishna Kolli and Lingeswaran Nagarathinam [3]** investigated shear-walls without boundary elements to find out the crack pattern in walls. They also experimentally investigated the stress and deflection development in walls due to application of axial and horizontal loads. Results are compared between conventionally reinforced and diagonal reinforced shear-walls which indicates that diagonally reinforced shear-walls are more capable of carrying the loads.

- **Vivek Pal et al [4]** analyzed multi-storey buildings with shear-walls by taking a high rise G +15 building for both wind and earthquake loads. The shear-walls are placed symmetrically at opposite sides of the structure and result for displacement was investigated. It was concluded that the shear walls are very much responsible for minimizing the displacements due to earthquake forces. With the symmetrical placement of shear-walls on opposite sides of the structure gives the structure great strength and stiffness to effectively withstand the response during wind and earthquake.

- **M. V. Naresh and K. J. Bramha Chari [5]** Investigated the static and dynamic analysis of multi-storey buildings in different zones of earthquakes. Series of 10 storey frame models were considered with seismic zone II to V and analyzed using ETABs with both static and dynamic method of analysis. Results were compared among the models with various zones for displacements with static vs. dynamic analysis. The comparison shows that displacements are higher in static analysis and it is not sufficient to perform static analysis for high rise buildings.

III. MATHEMATICAL FORMULATION AND ANALYSIS

Methods of Seismic Analysis

In this study linear static and linear dynamic methods of seismic analysis are adopted as per the criteria given in IS 1893:2016. For static analysis, seismic co-efficient method is used and for dynamic analysis, response spectrum method is used.

Design Base Shear for Static Co-efficient Method

The total design lateral force or design seismic base shear (*VB*), along any principal direction is determined by the expression,

$$V_B = A_h W \qquad (1)$$

Where,
A_h = Design seismic co-efficient &
W = Total seismic weight of the structure

Storey Shear Force in Each Mode for Response Spectrum Method

The pick storey shear force (V_{ik}) acting in storey i, in mode k and for peak lateral force(Q_{ik}) is given by.

$$v_{ik} = \sum_{j=i+k}^{n} Q_{ik} \qquad (2)$$

Permitted drift value

The drift value is limited to 0.004 times the storey height of a structures as per IS 1893:2016. In this analysis storey height is 3m for all the models so that storey drifts for all the models are limited to 0.012m.

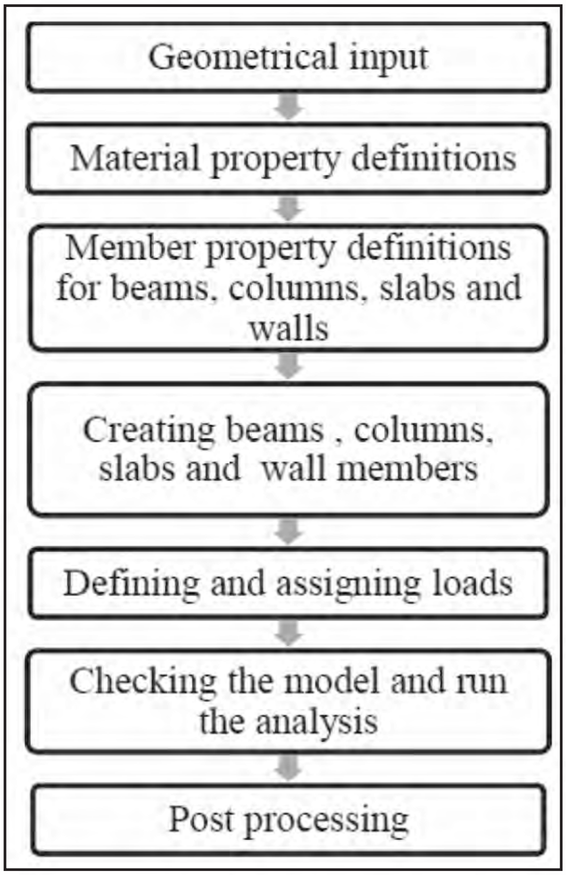

Fig. 1. Steps in Analysis

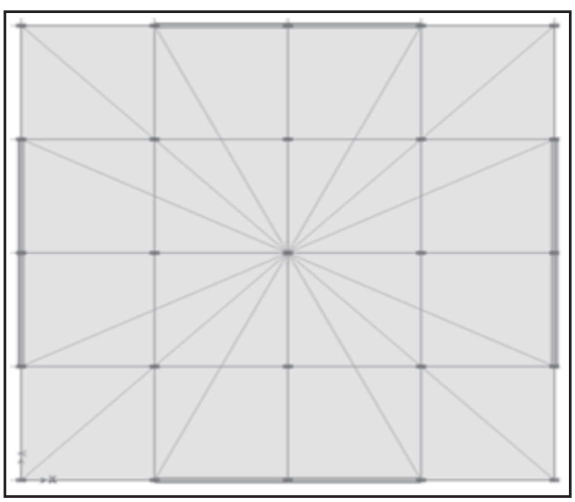

Fig. 2. Plan View of the Model Generated and Analyzed By ETABs

Steps in Analysis by ETABs Flowchart

Fig.2. reveals the plan view of the model generated and analyzed by ETABs. Here Fig. 3 represents the 3D isometric view of the model considered in the present study.

IV. RESULTS AND DISCUSSION

The seismic analysis of a 12 storey(G + 11) and a 28 storey(G + 27) building with two different configurations, that is with and without symmetrically placed shear-walls with both static seismic co-efficient method and dynamic response spectrum method are being analyzed here. The value of storey shear, storey drift, and storey stiffness values are compared for both the cases of analysis. The

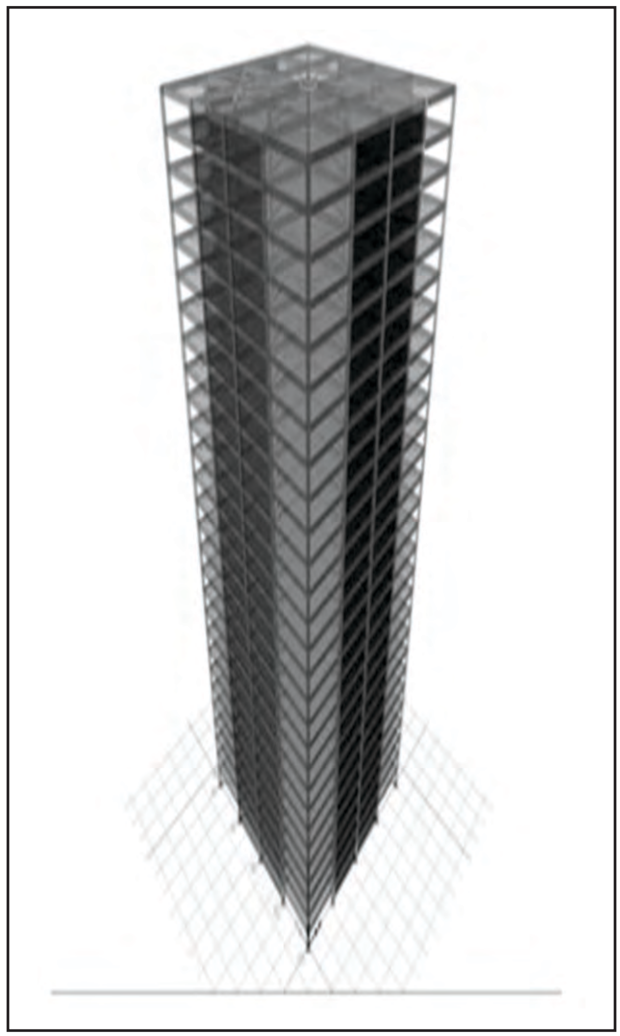

Fig. 3. 3D isomeric View of the Model Generated and Analyzed by ETABs

storey displacement values are also compared for two configurations with and without shear-wall.

(1) Results Obtained for the Twelve Storey Building With and Without Shear-Walls : A 12 storey (G+11) special moment resisting frame building has plan dimensions (32x32) m^2. The storey height is 3m for each storey. Thickness of the floor is 200 mm for each floor. Thickness of the shear-wall is 300mm for each direction of the building. Beams and columns are of cross-section 300 mm * 600 mm. The intensity of live load on each floor is 4 KN/m^2. The soil below the foundation is medium soil. The building is located in seismic zone V. Importance factor is taken as 1 and response reduction factor is taken as 5. Table I shows the base shear values of the 12 storey building for both X and Y directions. Table I shows the static base shear of 12 storey building which is greater than dynamic base shear by about 11%.

(2) Results obtained from 28 storey building with and without shear-wall : A 28 story (G+27) special moment resisting frame building has plan dimensions (32*32) m^2. The storey height is 3 m for each storey. Thickness of the floor is 200mm for each floor. Thickness of the shear-wall is 300mm for each direction of the building. Beams and columns are of cross-section 300 mm*600 mm. The intensity of live load on each floor is 4 KN/m^2. The soil below the foundation is medium soil. The building is located in seismic zone V. Importance factor is taken as 1 and response reduction factor is taken as 5. Table II shows the base shear values of the 28 storey building for both X and Y direction. Table II shows the static base shear of 28 storey building which is greater than dynamic base shear by about 12%.

Fig. 4. shows variation of static displacement in X

TABLE I.

BASE SHEAR VALUES OF 12 STOREY

Base Shear(KN)			
X - Direction		Y - Direction	
Static	Dynamic	Static	Dynamic
2096.13	1849.511	1513.307	1371.590

TABLE II.

BASE SHEAR VALUES OF 28 STOREY BUILDING

Base Shear(KN)			
X – Direction		Y – Direction	
Static	Dynamic	Static	Dynamic
2333.396	2029.428	2333.396	1979.316

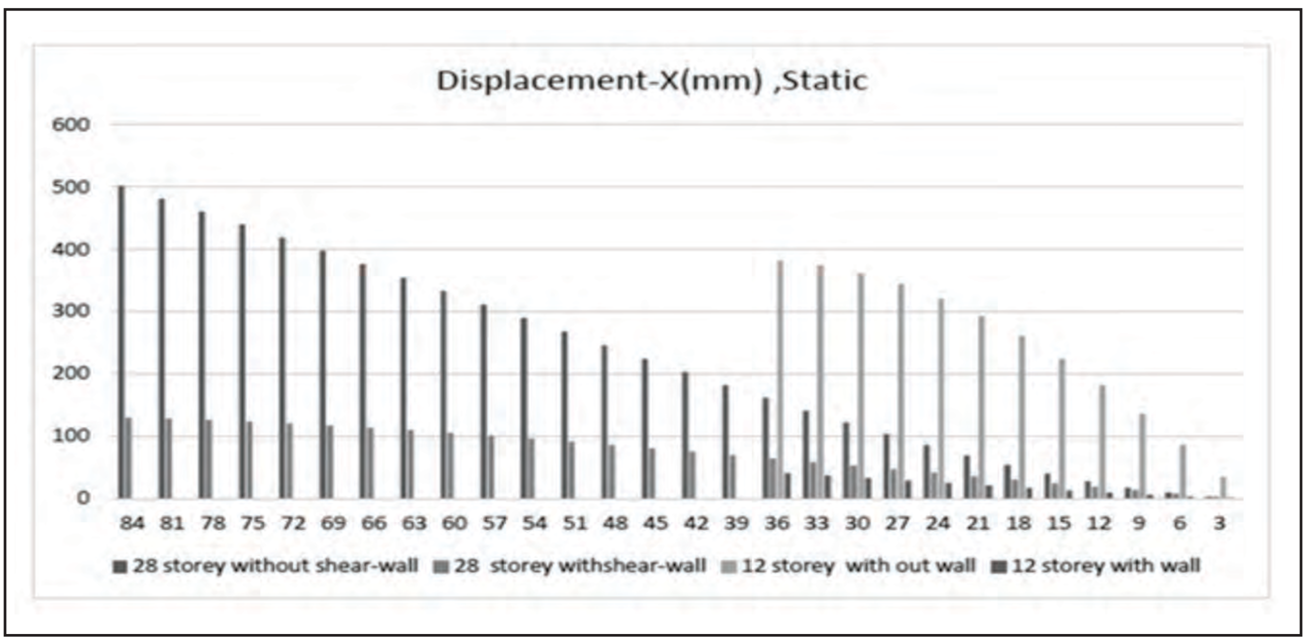

Fig. 4. Storey height – Static Displacement Plot for X- Direction

direction for 12 and 28 storey buildings. Displacements are maximum for 28 and 12 storey buildings without shear-wall and with shear-wall they are lesser about 80 to 90%.

Fig. 5 shows dynamic displacements in X-direction for 12 and 28 storey building. Displacements are maximum for 28 storey buildings without shear-wall and with shear-wall they are decreasing upto 60% to 80%.

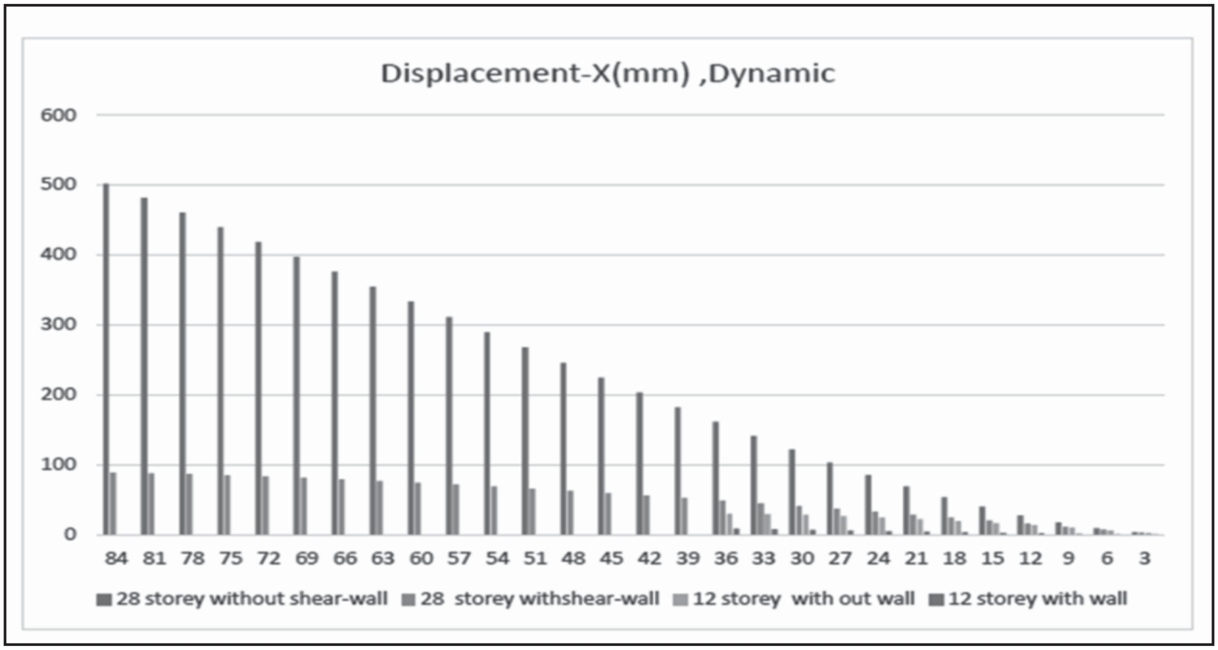

Fig. 5. Storey Height – Dynamic Displacement for X-Direction

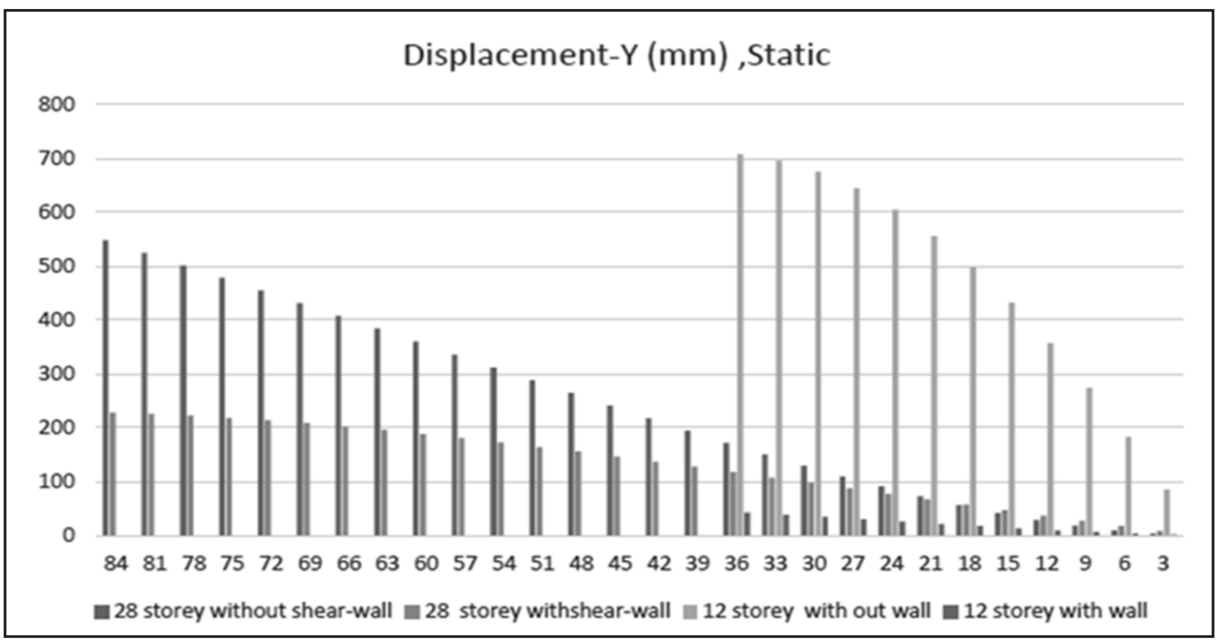

Fig. 6. Storey Height – Static Displacement Plot for Y-Direction

Fig. 6 shows static displacement in Y-direction for 12 and 28 storey building. Displacements are maximum in 12 storey without shear-wall and with shear-wall they decrease upto 80% to 90%.

Fig. 7. shows dynamic displacement in Y direction for 12 and 28 storey buildings. Displacements are maximum in 28 storey without shear-wall and with shear-wall they decrease upto 60% to 80%.

Fig. 8 shows static drift in X direction for 12 and 28 storey buildings. Drifts are maximum in 12 storey

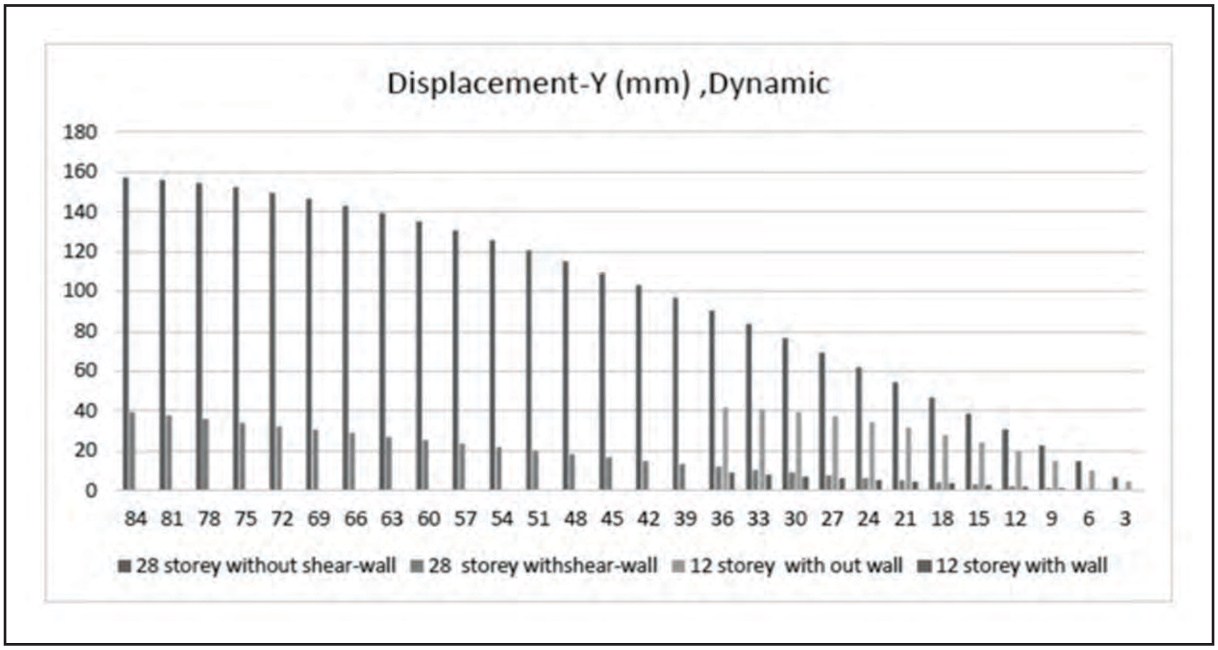

Fig. 7. Storey Height – Dynamic Displacement Plot for Y-Direction

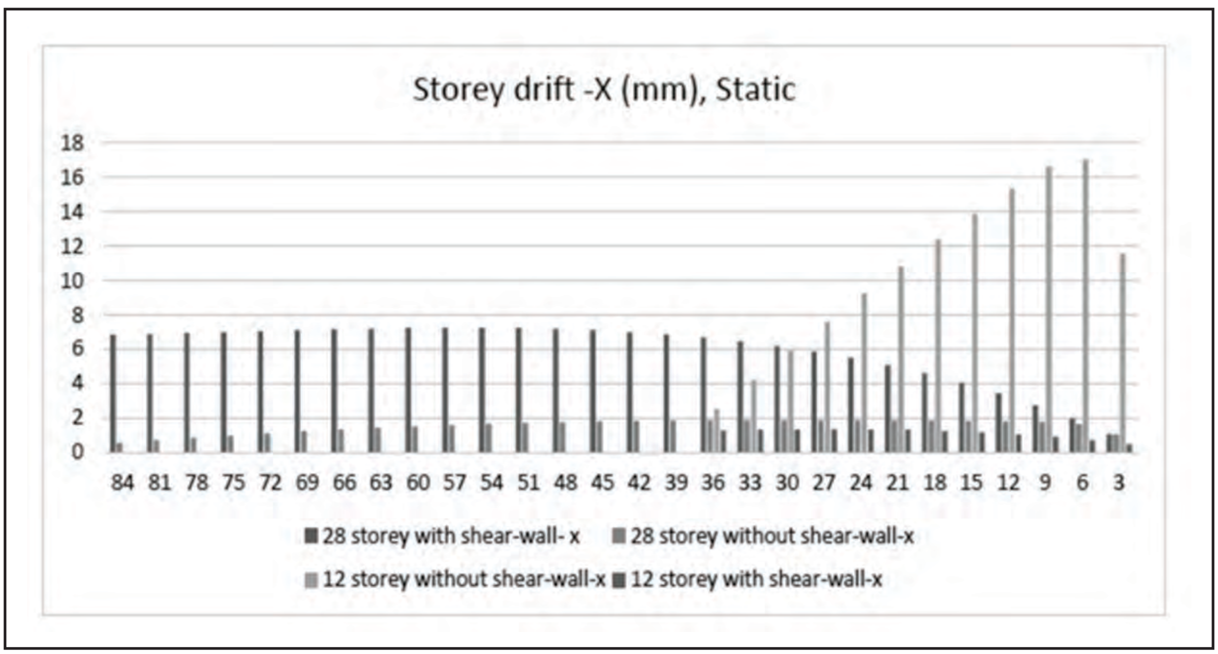

Fig. 8. Storey Height – Static Drift Plot for X-Direction

building without shear-wall and with shear-wall it decreases upto 50%. For 28 storey building drifts are increasing with shear-wall configuration.

Fig. 9. shows dynamic drifts in X direction for 12 and 28 storey building. Drifts are maximum in 28 storey without shear-wall and with shear-wall they are decreasing upto 30%.

Fig. 10 shows static drifts in Y direction for twelve and twenty-eight storey buildings. Drifts are maximum in 12 storey without shear-wall and with shear-wall they are

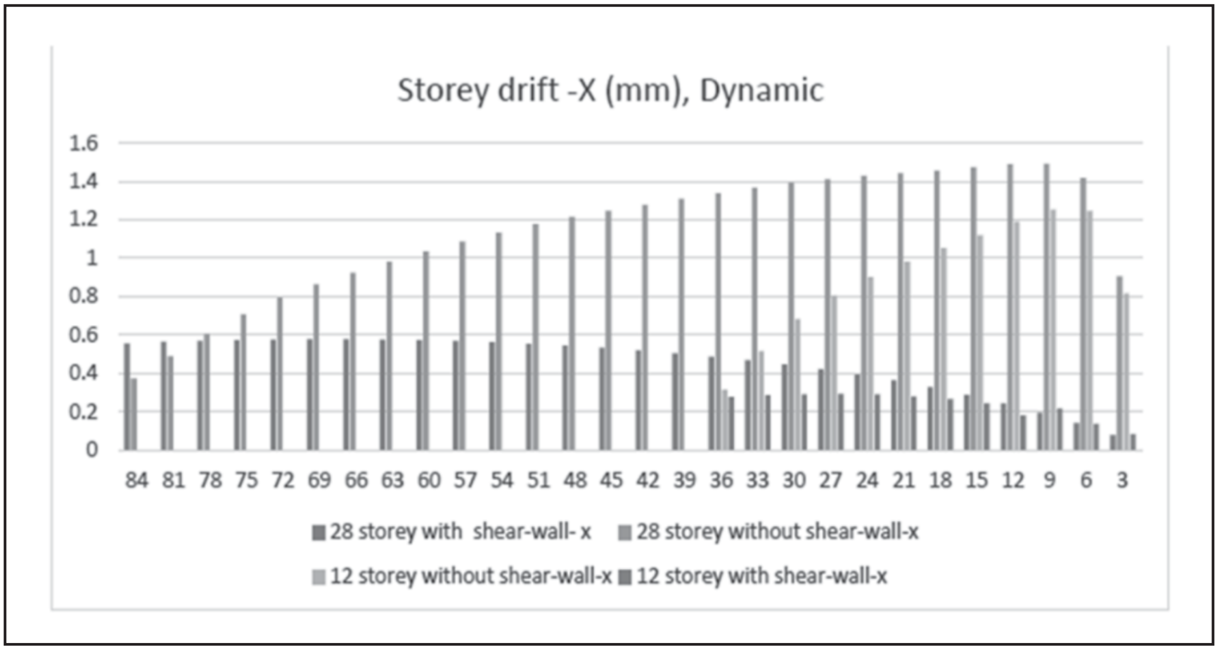

Fig. 9. Storey Height – Dynamic Drift Plot for X-Direction

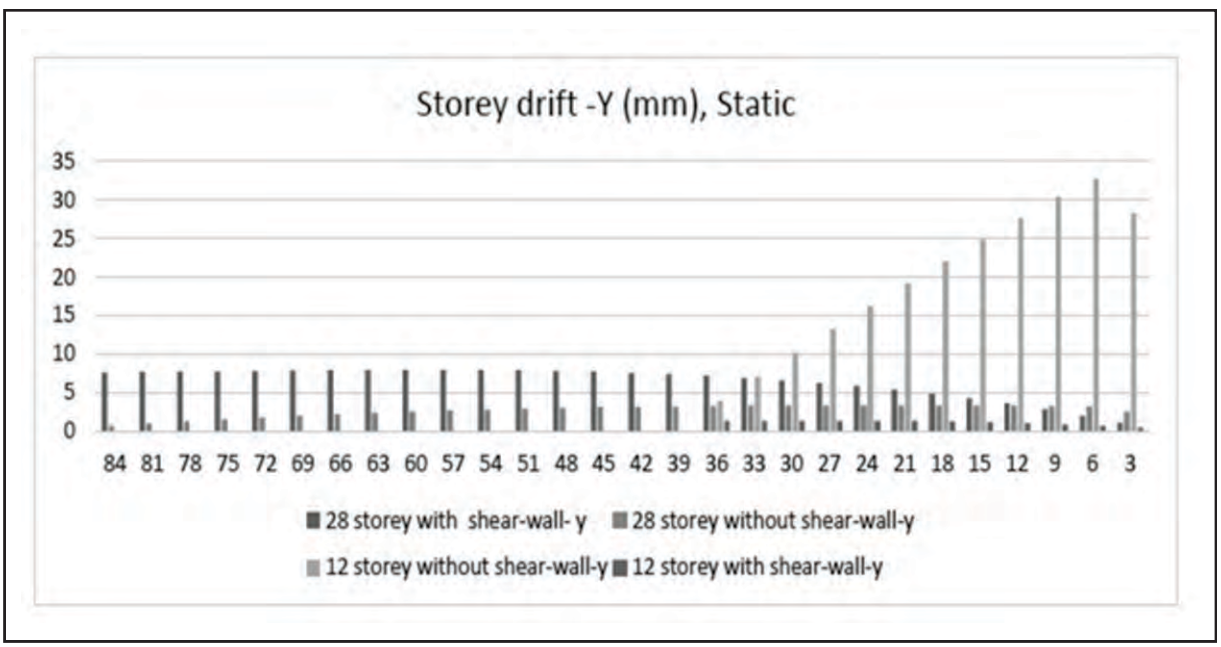

Fig. 10. Storey Height – Static Drift Plot for Y-Direction

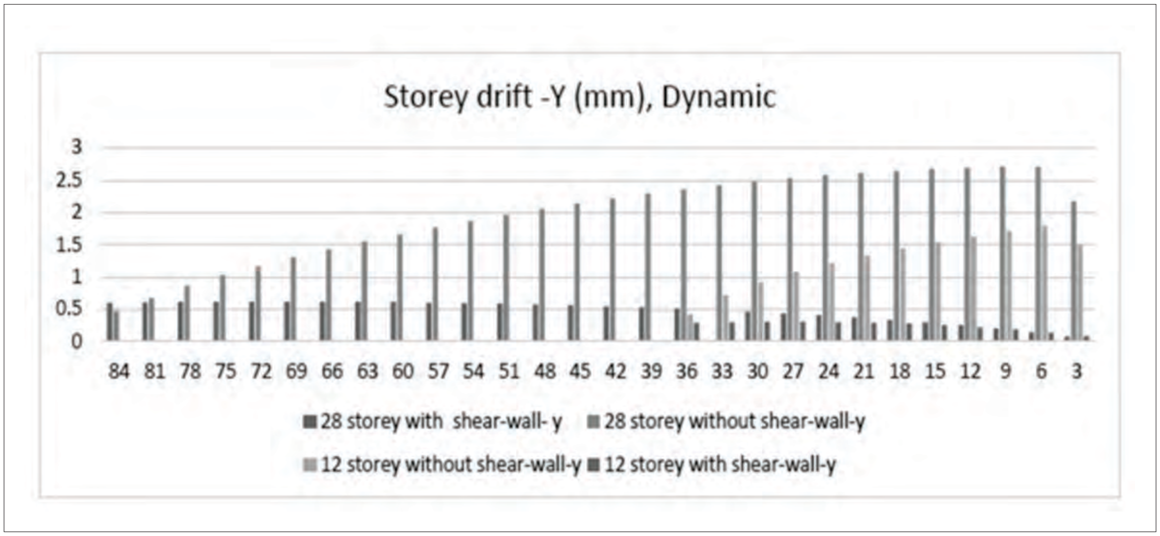

Fig. 11. Storey Height – Dynamic Drift Plot for Y-Direction

decreasing upto 50%. For 28 storey building, drifts are increasing for shear-wall configuration.

Fig.11 shows dynamic drifts in Y direction for twelve and twenty-eight storey buildings. Drifts are maximum in 28 storey without shear-wall and with shear-wall they are decreasing upto 30%.

A. Discussion

From the obtained results, the following observations are made:

- The base shear value is maximum for X direction for both static and dynamic analysis in 12 storey building and the static base shear is 11% higher than the dynamic base shear. Base shear for 28 storey building is same for both the directions in static analysis and in dynamic analysis, it is maximum for X direction. However, static base shear is greater than dynamic base shear by 12%.
- The static and dynamic displacements for 12 storey building is maximum in Y-direction and static displacement is about 90% higher than the dynamic displacement for both the directions without shear wall configuration.
- The static and dynamic displacements for 28 storey building is maximum for Y-direction and static displacement is about 80% higher than the dynamic displacement for X-direction and about 70% higher than dynamic displacement in Y-direction.
- The static and dynamic displacement for 12 storey building with shear-wall configuration is higher in Y direction and the static displacement is about 80% higher than the dynamic displacements for both the directions. There is 80% to 90% decrease in displacement values.
- The static and dynamic displacements for 28 storey building with shear-wall configuration is higher in X-direction and the static displacement is about 70% higher than the dynamic displacement in X-direction and 80% higher in Y-direction. There is 60% to 70% decrease in displacement values.
- The drift with shear-wall configuration for 12 storey is reduced by 50% in static analysis and 10% in dynamic analysis for both the directions. From this it may be concluded that providing symmetrically placed shear-walls in each lateral direction is effective to reduce the drift of the structure.
- The drift with shear-wall configuration for 28 storey building is decreasing 30% in dynamic analysis while increasing in static analysis. From this it may be concluded that providing symmetrically placed shear-wall in each lateral directions is effective to reduce the drift of the structure and for buildings with increasing height it is necessary to perform dynamic analysis.

V. CONCLUSION

In this study, two multi storey buildings of 12 (G+11) and

28 storey (G+27) of same plan area have been analyzed with static seismic co-efficient method as well as dynamic response spectrum method with two different configurations that is with and without shear walls symmetrically placed in each lateral direction using ETABs : 2018 software.

From the overall result obtained for both 12 and 28 storey with and without shear-wall configurations, we may conclude that multi-storey buildings should be analyzed with dynamic approach, because static analysis is not sufficient for high-rise multi-storied structures.

The values of storey shears, storey-displacements, story-drift are comparatively lower in dynamic approach than from the static approach, so that it is not economical to design earthquake resisting structures with static analysis only.

By using shear walls in each direction, the obtained drift values are much smaller than the value obtained by without shear wall configuration, that is about 10% to 50%.

The lateral displacements are also decreasing with shear-wall configuration upto 75%. Although the percentage of decrease reduces with increase in building height, it can be managed by proper design of the shear-walls. So, the seismic resisting members like shear walls may be used to counteract the lateral forces effectively but for buildings more than 50 m height, it is necessary to perform dynamic analysis.

The present study is limited to its geometric parameters, but it can be extended to various different types of geometric configurations. Shear wall in this paper is provided in both the directions symmetrically as outer walls. However, it can be provided in any direction symmetrically or asymmetrically, inner or outer section of the structure. Except for isolated shear-walls, brick infill walls and coupled shear-walls may be adopted for analysis.

AUTHORS' CONTRIBUTION

Tejaswini Dalai and Prof. P. K. Parhi conceived the idea to have the comparative study of the seismic analysis of multistory buildings with and without shear wall. The investigation for static and dynamic analysis of the structure and also the drift and displacement study were carried out jointly by the authors. Tejaswini Dalai prepared the manuscript in consultation and guidance of Prof. P. K. Parhi .

CONFLICT OF INTEREST

The authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest, or non-financial interest in the subject matter, or materials discussed in this manuscript.

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REFERENCES

[1] S. K. Duggal, "Earthquake resistant design of structures, " *Oxford Higher Edu.*, 2007.

[2] P. Agarwal and M. Shrikhande, *Earthquake resistant structures*, Eastern Economy Edition. India: Prentice-Hall of India Pvt. Ltd., 2019.

[3] R. K. Kolli and L. Nagarathinam, "Experimental investigation and analysis on shearwalls," *Int. J. for Recent Technol. and Eng.,* vol. 7, no. -6C2, 2019.

[4] V. Pal, G. Yogesh, P. Chetan, V. Kadlag, and N. Maske, "Seismic analysis of R.C.C. building with shear-walls using STAAD pro," *Int. J. of Advanced Research and Innovative Ideas in Education*, vol. 4, no. 3, pp. 1353–1359,2018. [Online]. Available: http://ijariie.com/AdminUploadPdf/Seismic_Analysis_of_rcc_building_with_shear_walls_using_staad_pro_ijariie8606.pdf

[5] M. V. Naresh and K. J. B. Chari, "Study on static and dynamic analysis of multi-storied building in seismic zones, " *Int. J. of Recent Technol. and Eng.*, vol. 7, no.-6C2, pp. 154–159, 2019. [Online]. Available:https://www.ijrte.org/wp-content/uploads/papers/v7i6c2/F10280476C219.pdf

[6] D. Kumar and R. Gohel, "Structural design of reinforced concrete shear-wall," *Int. Research J. of Eng. and Techno*l., 2020. [Online]. Available:https://www.irjet.net/archives/V7/i5/IRJET-V7I5275.pdf

[7] H. P. Bhagat, K. V. Patil, S. T . Gauri, and C. Thakur, "Design of shearwall at project desire-Brahmand,Thane,India," *Int. Res. J. of Eng. and Technol.*, vol. 5, no. 3, pp. 2945–2947, 2018. [Online]. Available:https://www.irjet.net/archives/V5/i3/IRJET-V5I3676.pdf

[8] Naveen G.M., and Chaya, S. "Study on regular and irregular building structures during an earthquake," *Int. J. of Latest Eng. Res. and Application*,2016.[Online].Available: http://www.ijlera.com/papers/v1-i8/5.201611171.pdf

[9] M. N. Patil and Y. N. Sonawane ,"Seismic analysis of multistorey building," *International Journal of Eng. and Innovative Technol.*, vol. 4, no. 9, pp. 123–130, 2015. [Online]. Available:https://www.researchgate.net/publication/333533507_Seismic_Analysis_of_Multi_Storied_Building_in_Different_Zones

[10] Criteria for earthquake resistant design of structures, IS 1893(Part 1) :2016.

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