Dynamic Analysis of Multi-Storey Building with Provision of RC Shear Wall

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Abstract. The research emphasizing the need for shear walls in improving seismic performance, this study focuses on the dynamic analysis of a G+16 RC-framed structure located in Earthquake Zone V. Shear walls are required to resist lateral stresses, provide structural rigidity, and reduce displacements under seismic loads. The STAAD-Pro program used. Response spectrum analysis was conducted for important parameters including base shear, axial forces, moments, and lateral displacements for several shear wall constructions using STAAD-Pro program. The results show that shear walls greatly lower axial stresses, moments, and displacements while nevertheless increasing general structural stability and seismic resilience. The outcomes highlight the need of maximizing shear wall location to improve the dynamic behavior and earthquake resistance of high-rise buildings, thereby provide insightful information for next structural design in seismic areas.

Keywords: Dynamic Analysis, Lateral Displacement**,** Seismic Analysis, Shear Walls, RC-framed Building, Response Spectrum, Earthquake Resistance.

INTRODUCTION

The research shows how the abrupt release of energy in the Earth's crust may inflict catastrophic damage, particularly to high-rise buildings. In this study, we analyse how earthquakes affect buildings. This is a crucial field of research, as elements like natural vibration frequency and dampening typically magnify the dynamic reaction of structures to ground motion. We are concentrating on shear walls, fundamental structural components in multi-story structures that withstand the combined impacts of shear, moment, and axial loads caused by lateral forces, such as wind and earthquake, as well as gravity loads, to meet these problems. Often combined as lift wells or designated shear walls, reinforced concrete shear walls are essential in contemporary tall building construction as they connect the centre of mass of the structure with its centre of rigidity, therefore providing the required stiffness. This work intends to use Matrix methodology-based software such as STAAD to dynamically analyse an RC-framed building (G+16) in an earthquake-prone Zone V. Using the response spectrum approach, we will examine the construction, especially with regard to various shear wall configurations. Among the goals are figuring out the basic natural frequency of many building designs, measuring displacements at several structural levels in relation to ground displacements, and evaluating base shear values for different kinds of buildings. We aim to maximize the design and location of shear walls by using dynamic analytic techniques like Response Spectrum analytic, therefore improving the seismic resistance and stability of high-rise structures in areas with frequent earthquakes.

LITERATURE REVIEW

Shear walls and braces are very important for making multi-story structures more durable, according to recent seismic analysis studies conducted using instruments such STAAD Pro, ETABS, and SAP 2000 Studies by [1] and [2] assert that bracing and shear walls might greatly reduce storey drift and boost lateral stiffness. More precise seismic performance data are generated by dynamic analysis than by static analysis [3]. [4] and [5] stressed the significance of designing with reinforcement and thinking through dynamic responses. [6] argue that idealised shear wall properties would not be a good mirror of how things really work. Although open-frame buildings are susceptible to notable storey drifts [7], square buildings under less strain than other forms [8]. [9] stressed the importance of carefully building shear walls to lower displacement and drift as [10]. The research on multi-story RC frame construction have proven, particularly under seismic stresses, how efficiently shear walls increase structural integrity. [11] assert that shear wall frames exhibit better lateral stiffness than bare frames when displacement rises building height increases. While their studies mostly focused on stationary loads, [12] revealed that centre shear walls minimise moments and displacement. Although they recognised flaws in their method, [13] underlined the expense of shear walls in boosting seismic performance. [14] enhanced the safety of high-rise structures by employing shear walls and lift core walls, hence overcoming project limits in seismic performance and [15] underscored the benefits of shear walls in lowering seismic sensitivity in multi-story structures, even if their implementation offers issues of economic sustainability. When [16] compared STAAD.Pro with ETABS, STAAD.Pro generally indicated much higher values for critical criteria, thereby affecting design choices. Shear walls, according to [17], minimise base shear and peak storey shear, thereby enhancing performance in unevenly designed buildings. Shear walls boost the stability of high-rise buildings even if their usage may restrict design alternatives, according to [18], by enhancing ductility and minimising drift.

RESEARCH METHODOLOGY

The steps that we take to conduct the comprehensive literature review are as follows:

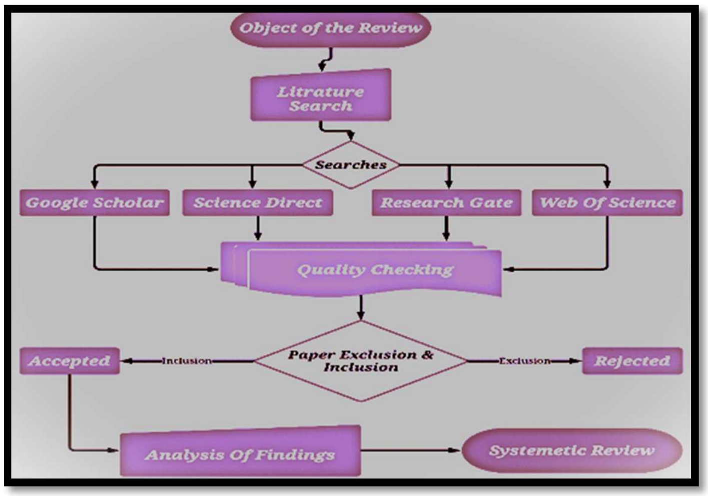

FIGURE 1. Methodology of Research

- **Find the goal of the review:** At this stage as well as the elements influencing the dynamic analysis of multi story building with RC shear wall in zone V and several approaches applied.
- **Literature search:** Based on the criteria and goal, looking for pertinent research articles is a major chore using keywords that match the intended content. The search is conducted by many worldwide depositories like Research Gate, Web of Science, Science Direct, etc., Paper searches are carried out.
- **Quality Assurance:** After a fruitful search for research articles, their quality is assessed depending on their abstracts and contents. Examined was the quality of the research papers; based on the pertinent keywords, a shortlist was developed.
- **Inclusion/Exclusion:** We decide which papers should be included in the short list of publications and which should be excluded depending on the usefulness of the literature for systematic reviews.
- **Observation:** We now examine the outcomes of the literary survey depending on the selected papers for the systematic literature review.
- **Review:** Last but not least, we go over the literature methodically. Fig. 1 shows the process.

PROPOSED SYSTEM

In this research, we want to assess the seismic reaction of our structural models using a Response Spectrum Analysis approach. This method is especially useful for buildings when the general response is much influenced by many modes of vibration. We present the response of the structure as a superposition of modal responses, each generated from the spectral analysis of a Single-Degree-of- Freedom (SDOF) system, by using a Multi-Degree-of- Freedom (MDOF) system. The overall response of the building will be computed by aggregating these modal responses using techniques such as the Square Root of Sum of Squares (SRSS).

Essential for evaluating the seismic performance of structures, the Response Spectrum Analysis enables us to map the peak responses (displacement, velocity, or acceleration) of oscillators with different natural frequencies exposed to the same base motion. We will use this approach in the dynamic study of a G+16 RC-framed structure situated in Earthquake Zone V. Different shear wall designs will be evaluated, modal mass and participation factors will be computed, and peak lateral forces and shear forces at many structural levels will be found by this study. We will also conduct a dynamic study using STAAD software, which more precisely represents the distribution of seismic forces throughout the height of the structure and considers the consequences of higher vibration modes. To find natural frequencies, quantify structure displacements relative to ground motion, and evaluate base shear values, our method will include analysis of both regular and irregular building layouts.

MODELLING AND ANALYSIS

Modelling

Description of The Building-

- The current section tackles the mathematical modelling of structures with different shear wall designs to assess their seismic response making use of STAAD-PRO program. To replicate its behavior under gravity and seismic stress, we have modelled the construction as a 3D space frame with six degrees of freedom at every node. With regard to all loading combinations as per IS 1893:2002, the study comprises response spectrum analysis for many examples. With each story at 4m, the rectangular in plan structure with dimensions of 24m by 16m has a total height of 68m (Figure 1) shows a typical frame plan here). The frame has 4 meters of spacing in both width and length. Material grades for concrete M25 and Fe550 and for shear wall M30 and Fe550 were used in design; the support condition is regarded as entirely fixed.

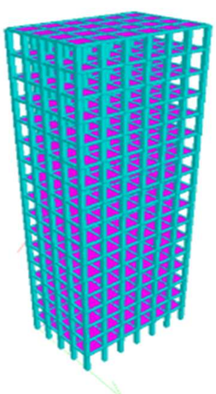

FIGURE 2. 3d View of Bare Frame Building

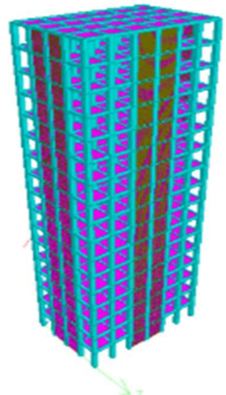

FIGURE 3. 3d View of Building with shear wall 1

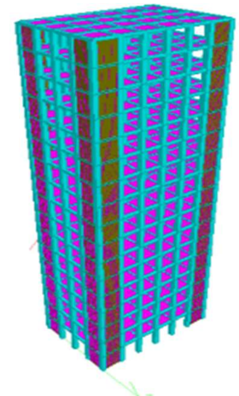

FIGURE 4. 3d View of Building with shear wall 2

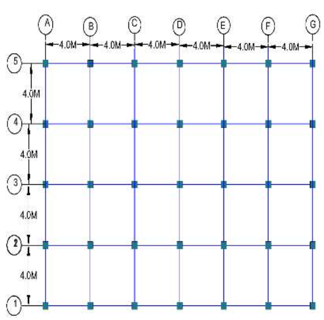

FIGURE 5. Plan of Bare Frame Building

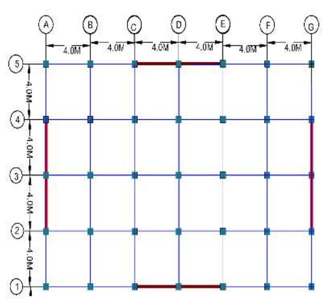

FIGURE 6. Plan of Building with Shear Wall 1

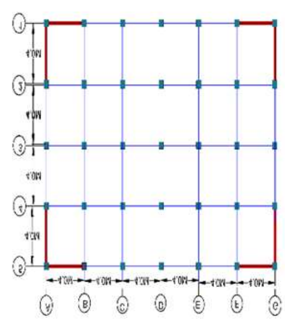

FIGURE 7. Plan of Building with shear wall 2

Building Properties-

- **Site Properties:**
  Details of building::G+16
  Outer wall thickness::230mm
  Inner wall thickness::127mm
  Parapet wall thickness::200mm
  Floor height::4m
  Depth of foundation::2000mm
- **Seismic Properties**
  Seismic zone::V
  Zone factor::0.36
  Importance factor::1.5
  Response Reduction factor R::5
  Soil Type::medium
- **Material Properties**
  Material grades of concrete is M25 & Fe550 and for shear wall M30 & Fe550 were used for the design.
- **Loading on structure**
  Dead load::self-weight of structure
  Weight of 230mm wall, 127mm wall, 200mm wall
  Live load::Floor -4kN/m²
  Beam 4.25 kN/m²
  Wind load::Not considered
  Seismic load::Seismic Zone V
- **Preliminary Sizes of members**
  Column::750mm x 750mm
  Beam::350mm x 450mm
  Slab Thickness::150mm
  Shear wall Thickness::230mm

Load Combination- Load combinations that are to be used for Limit state Design of reinforced concrete structure are listed below.

- 1.5(DL+LL)
- 1.2(DL+LL)
- 1.2(DL+LL±EQX)
- 1.2(DL+LL±EQ-X)
- 1.2(DL+LL±EQZ)
- 1.2(DL+LL±EQ-Z)
- 1.5(DL)
- 1.5(DL±EQX)
- 1.5(DL±EQ-X)
- 1.5(DL±EQZ)
- 1.5(DL±EQ-Z)
- 0.9(DL±1.5EQX)
- 0.9(DL±1.5EQ-X)
- 0.9(DL±1.5EQZ)
- 0.9(DL±1.5EQ-Z)

Analysis

Calculated Base shear in x-dir/z-dir

- The calculated base shear for structures is presented in table-

Table 1. Maximum Base Shear in X – dir (kN)

Type of Model	X-dir
Bare-Frame	6634.75
Frame with Shear Wall I	7329.82
Frame with Shear Wall II	7329.82

Table 2. Maximum Base Shear in Z – dir (kN)

Type of Model	Z-dir
Bare-Frame	6634.75
Frame with Shear Wall I	7329.82
Frame with Shear Wall II	7329.82

Maximum Axial Force

- The maximum axial force for structures is presented in table-

Table 3. Maximum Axial Force (kN)

Bare-Frame	10946.672
Frame with Shear Wall I	6699.625
Frame with Shear Wall II	11272.5

Maximum Shear Force in y-dir/z-dir

- The maximum shear force for structures is presented in table-

Table 4. Maximum Shear Force in y-dir (kN)

Type of Model	y-dir
Bare-Frame	464.756
Frame with Shear Wall I	135.282
Frame with Shear Wall II	309.314

Table 5. Maximum Shear Force in z-dir (kN)

Type of Model	z-dir
Bare-Frame	382.379
Frame with Shear Wall I	126.074
Frame with Shear Wall II	241.710

Maximum Moment in y-dir/z-dir

- The maximum moment for structures is presented in table-

Table 6. Maximum Moment in y-dir (kN)

Type of Model	y-dir
Bare-Frame	1180.008
Frame with Shear Wall I	219.47
Frame with Shear Wall II	586.445

Table 7. Maximum Moment in z-dir (kN)

Type of Model	z-dir
Bare-Frame	1534.696
Frame with Shear Wall I	306.879
Frame with Shear Wall II	558.653

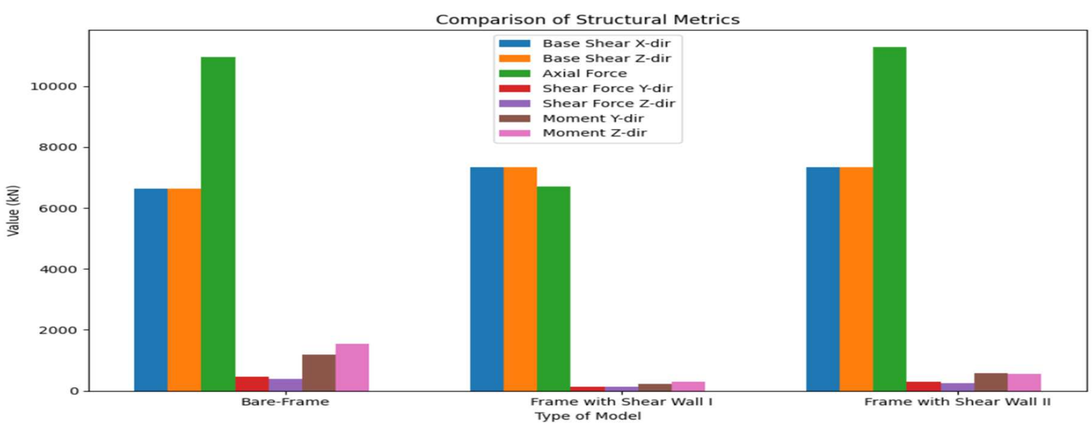

FIGURE 8. Graph Comparison of Structural Metrics

Maximum Lateral Displacement in x-dir/z-dir

- The calculated maximum lateral displacement for structures is presented in table-

Table 8. Maximum Lateral Displacement in X– dir (kN)

Type of Model	X-dir
Bare-Frame	21.68
Frame with Shear Wall I	11.59
Frame with Shear Wall II	14.80

Table 9. Maximum Lateral Displacement in Z – dir (kN)

Type of Model	Z-dir
Bare-Frame	24.03
Frame with Shear Wall I	12.88
Frame with Shear Wall II	15.93

Mode vs Frequency and Time period

➢ The mode vs frequency and time period for structures are presented in table-

Table 10. Mode, Frequency and Time Period for Bare Frame

Mode	Frequency Hz	Period Seconds	Participation X %	Participation Y%	Participation Z %	Type
1	0.463	2.162	78.82	0	0	Elastic
2	0.863	1.158	0	0	0	Elastic
3	1.429	0.700	10.23	0	0	Elastic
4	2.529	0.395	3.66	0	0	Elastic
5	2.645	0.378	0	0	0	Elastic
6	3.739	0.267	2.03	0	0	Elastic

Table 11. Mode, Frequency and Time Period with SW1

Mode	Frequency Hz	Period Seconds	Participation X %	Participation Y%	Participation Z %	Type
1	0.553	1.809	71.23	0	0	Elastic
2	1.363	0.733	0	0	0	Elastic
3	2.091	0.478	15.74	0	0	Elastic
4	4.443	0.225	5.98	0	0	Elastic
5	5.297	0.189	0	0	0	Elastic
6	7.040	0.142	2.79	0	0	Elastic

Table 12. Mode, Frequency and Time Period with SW2

Mode	Frequency Hz	Period Seconds	Participation X %	Participation Y%	Participation Z %	Type
1	0.487	2.053	71.41	0	0	Elastic
2	1.202	0.832	0	0	0	Elastic
3	1.823	0.548	15.05	0	0	Elastic
4	3.873	0.258	5.86	0	0	Elastic
5	4.908	0.204	0	0	0	Elastic
6	6.201	0.161	2.86	0	0	Elastic

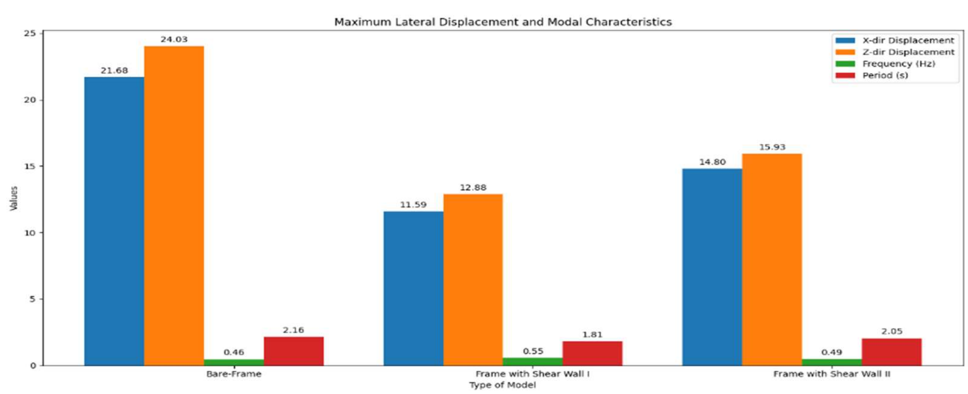

FIGURE 8. Graph of MLD & Model Characteristics

RESULT

- **Base Shear:**
  - The addition of shear walls resulted in a 10.48% increase in base shear values, but does not alter the maximum base shear readings.
- **The Axial Force is:**
  - The Frame with Shear Wall I achieves a 38.47% decrease in axial force compared to the Bare-Frame, while the Frame with Shear Wall II shows a 3% gain.
- **The Shear Force is:**
  - Improvements of up to 70.97% in the Y-direction and 67.01% in the Z-direction are achieved by the Frame with Shear Wall I, which represents the most significant reductions in shear forces.
- **Moment:**
  - A reduction of up to 81.37% in the Y-direction and 80.03% in the Z-direction is achieved by the Frame with Shear Wall I, which also achieves the highest reductions in moments.
- **Lateral Displacement:**
  - With a decrease of up to 46.6% in both the X-direction and the Z-direction, the Frame with Shear Wall I demonstrates the most substantial reduction in lateral displacements.
- **Analysis of Modal:**
  - Natural Frequency and Period: Frame with Shear Wall I: The frequency rises to 0.553 Hz in the X-direction and 1.809 Hz in the Z-direction, while the periods reduce to 1.809 seconds (X-direction) and 0.225 seconds (Z-direction).
  - The frequency increases to 0.487 Hz in the X-direction and 2.053 Hz in the Z-direction in the frame with Shear Wall II. The periods decrease to 2.053 seconds in the X-direction and 0.258 seconds in the Z-direction as the frequency increases.face

Table 13. Result Table

Metric	Bare-Frame	Frame with Shear Wall I	Frame with Shear Wall II
Base Shear (X-dir & Z-dir)	6634.75 kN	7329.82 kN	7329.82 kN
Percentage Increase	-	10.48%	10.48%
Maximum Axial Force	10946.672 kN	6699.625 kN	11272.5 kN
Reduction in Axial Force	-	38.47%	3.00%
Maximum Shear Force (y-dir)	464.756 kN	135.282 kN	309.314 kN
Reduction in y-dir Shear	-	70.97%	33.47%
Maximum Shear Force (z-dir)	382.379 kN	126.074 kN	241.710 kN
Reduction in z-dir Shear	-	67.01%	36.80%
Maximum Moment (y-dir)	1180.008 kN	219.47 kN	586.445 kN
Reduction in y-dir Moment	-	81.37%	50.27%
Maximum Moment (z-dir)	1534.696 kN	306.879 kN	558.653 kN
Reduction in z-dir Moment	-	80.03%	63.62%
Maximum Lateral Displacement (X-dir)	21.68 mm	11.59 mm	14.80 mm
Reduction in X-dir Displacement	-	46.60%	31.90%
Maximum Lateral Displacement (Z-dir)	24.03 mm	12.88 mm	15.93 mm
Reduction in Z-dir Displacement	-	46.60%	33.60%
Modal Analysis (Frequency)	Varies	Increases	Increases
Modal Analysis (Period)	Varies	Decreases	Decreases

CONCLUSION

Response Spectrum Analysis was used to evaluate, in Earthquake Zone V, the seismic performance of a G+16 RC-framed building. Using STAAD-PRO program, the study computed important values and investigated many shear wall configurations. Shear walls found to greatly lower axial forces, shear forces, moments, and lateral displacements. Frame with Shear Wall I showed the most significant increases with cuts of up to 81.37% in moment and 46.6% in lateral displacements. Modal study also revealed lower periods and higher natural frequencies for structures with shear walls, therefore implying better dynamic performance. By increasing the seismic resilience of the building, shear walls maximized its performance under earthquake conditions.

FUTURE SCOPE

- Investigate the seismic performance of irregularly shaped buildings or non-standard configurations.
- Analyze the effects of shear walls placed at different locations for enhanced seismic resistance.

- Validate and compare alternative structural analysis software, such as SAP2000 or ETABS.
- Conduct dynamic analysis using the time history method to evaluate the building's response to seismic events. by comparing outcomes of time history and response spectrum analysis to understand advantages and limitations.
- Extend the study to include various soil types and conditions to evaluate ground characteristics' impact on seismic response.

REFERENCES

[1] S. S. Patil, M. S. A. Ghadge, C. G. Konapure, and C. A. Ghadge, 'Seismic Analysis of High-Rise Building by Response Spectrum Method'. [Online]. Available: www.ijceronline.com

[2] P.P Chandurkar and Dr. P. S. Pajgade, "Seismic Analysis of RCC Building with and Without Shear Wall." International Journal of Modern Engineering Research (IJMER), www.ijmer.com, Vol. 3, Issue. 3, May - June 2013, pp-1805-1810, ISSN: 2249-6645.

[3] M. Sharma, S. Maru, and (H O D Professor, '"Dynamic Analysis of Multistoried Regular Building"', 2014. [Online]. Available: www.iosrjournals.orgwww.iosrjournals.org

[4] T. Saikrishna, V. Srinivasarao, and M. Tech, 'EARTHQUAKE ANALYSIS AND DESIGN OF MULTI-STORIED BUILDING FOR DIFFERENT ZONES IN INDIA', 2016. [Online]. Available: www.ijtre.com

[5] A. R. Kohli, G. Gore, and B. E. Undergraduate, 'Analysis and Design of an Earthquake Resistant Structure using STADD. Pro', *International Research Journal of Engineering and Technology*, 2017, [Online]. Available: www.irjet.net

[6] J. Tarigan, J. Manggala, and T. Sitorus, 'The effect of shear wall location in resisting earthquake', in *IOP Conference Series: Materials Science and Engineering*, Institute of Physics Publishing, Mar. 2018. doi: 10.1088/1757-899X/309/1/012077.

[7] R. Gowhar and N. Mehta, 'EARTHQUAKE RESISTANT DESIGN OF MULTISTOREY BUILDING', *International Research Journal of Engineering and Technology*, 2008, [Online]. Available: www.irjet.net

[8] M. Gaurav, N. Chauhan, and D. P. Joshi, 'INTERNATIONAL RESEARCH JOURNAL OF ENGINEERING AND TECHNOLOGY (IRJET) DYNAMIC ANALYSIS OF MULTI-STOREY R.C.C BUILDINGS HAVING DIFFERENT GEOMETRY', 2020.

[9] B. Anya and T. Ghosh, 'A Study on Effect of Shear Wall in Seismic Analysis of Building', in *IOP Conference Series: Earth and Environmental Science*, IOP Publishing Ltd, Aug. 2021. doi: 10.1088/1755-1315/796/1/012049.

[10] A. Dwivedi and B. S. Tyagi, 'Seismic Analysis of Building with and Without Shear Wall for Building with RCC and Composite Column'. [Online]. Available: www.ijert.org

[11] S. Dewangan and M. Rathore, 'https://seyboldreport.net/ COMPARATIVE ANALYSIS OF G+9 MULTI-STORIED BUILDING FOR DIFFERENT POSITIONS OF SHEAR WALL BY USING STAAD.PRO', 2023. [Online]. Available: https://seyboldreport.net/

[12] A. Garhwal, S. Sharma, U. Pradesh, I. Yogesh, K. Sabita, and M. Singh, 'ANALYSIS OF RCC BUILDING WITH AND WITHOUT SHEAR WALL-A COMPARATIVE STUDY', 2016. [Online]. Available: http://www.ijeast.com

[13] N. K. Meshram and G. M. Munde, 'Seismic Analysis of Shear Wall at Different Location on Multi-storey RCC Building'. [Online]. Available: www.ijiird.com

[14] P. Sandhya Rani, 'DYNAMIC RESPONSE OF HIGH RISE BUILDINGS UNDER THE CONFIGURATION OF SHEAR WALL BY USING STAAD PRO'.

[15] M. Chouhan and R. Kumar Makode, 'Dynamic Analysis of Multi-Storeyed Frame-Shear Wall Building Considering SSI', 2016. [Online]. Available: www.ijera.com

[16] M. S. Kumar and P. Sai Pravallika, 'A COMPARATIVE STUDY ON EFFECT OF VERTICAL AND LATERAL LOADS UNDER DYNAMIC ANALYSIS FOR SHEAR WALLS OF AN R.C.C. STRUCTURE USING STAAD AND ETABS SOFTWARE', *International Research Journal of Engineering and Technology*, 2020, [Online]. Available: www.irjet.net

[17] A. Saha, 'Seismic Study on Tall Structures with RC Shear Walls: Static and Dynamic Analysis', *Int J Res Appl Sci Eng Technol*, vol. 8, no. 11, pp. 965–972, Nov. 2020, doi: 10.22214/ijraset.2020.32321.

[18] M. P. Soni, M. Purushottam Lal Tamrakar, V. Kumhar, and P. G. Student, 'Structural Analysis of Multistory Building of Differentshear Walls Location and Heights', *International Journal of Engineering Trends and Technology*, vol. 32, 2016, [Online]. Available: http://www.ijettjournal.org

[19] IS 1893-2002, Indian Standard Criteria for Earthquake Resistant Design of Structures (5 th Revision)

[20] IS 4326-1993, Indian Standard Code of Practice for Earthquake Resistant Design and Construction of Buildings (2nd Revision)

[21] IS 13827-1993, Indian Standard Guidelines for Improving Earthquake Resistance of Low Strength Masonry Buildings

[22] IS 13920-1993, Indian Standard Code of Practice for Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces
[23] IS 13935-1993, Indian Standard Guidelines for Repair and Seismic Strengthening of Building
[24] IS 456-2000, Plain and Reinforced concrete-code of practice