# Evaluation of Stiffness Modifier Variations with Height in the Analysis of Multi-Story R.C.C. Structures

Sanket. S. Sawant[1], S.A. Rasal[2] and Radhika Jadhav[3]

[1]*Post Graduate Student, Dept. of Civil Engineering, Datta Meghe College of Engineering, Airoli, Navi Mumbai 400708, Maharashtra, India*

[2] *Assistant Professor, Dept. of Civil Engineering, Datta Meghe College of Engineering, Airoli, Navi Mumbai 400708, Maharashtra, India*

[3] *Assistant Professor, Dept. of Civil Engineering, Datta Meghe College of Engineering, Airoli, Navi Mumbai 400708, Maharashtra, India*

***Abstract*—The stiffness of structural elements plays a crucial role in determining the overall performance and serviceability of reinforced concrete (R.C.C.) structures. Stiffness modifiers, which are used to account for variations in material properties, construction practices, and load distribution, significantly impact the structural response under different loading conditions. This paper investigates the effect of stiffness modifiers on the behaviour of R.C.C. structures, focusing on their influence on serviceability limits, such as deflection and vibration control. A comprehensive review of various stiffness modifier values proposed by researchers and design codes is presented, highlighting their implications for structural analysis and design. The study demonstrates how the appropriate selection of stiffness modifiers can enhance the accuracy of structural predictions, ensuring that R.C.C. structures meet both strength and serviceability requirements. Additionally, the paper discusses the challenges and considerations in applying these modifiers in real-world design scenarios, aiming to improve the efficiency and reliability of structural designs.**

***Index Terms*—Stiffness modifiers, Serviceability limits, Deflection control, Vibration control, Structural reliability**

## I. INTRODUCTION

The stiffness of structural elements is a fundamental property that directly influences the behaviour and performance of reinforced concrete (R.C.C.) structures. It represents an element's ability to resist deformation under external loads, thereby ensuring the structural integrity and serviceability of the entire system. In structural design, stiffness modifiers are often introduced to adjust the theoretical stiffness values, accounting for factors such as material variability, construction tolerances, and load distribution patterns. These modifiers are essential in refining the analysis of deflections, vibrations, and overall serviceability, which are critical aspects in the design of structures, particularly under non-ultimate load conditions. The incorporation of stiffness modifiers has become increasingly important as it helps in more accurately predicting the behaviour of R.C.C. elements during service life, particularly for structures subjected to dynamic and fluctuating loads. The definition of stiffness modifiers in ETABS refers to the factors that are used to adjust the stiffness properties of a structural element, particularly in concrete members. These modifiers are used to either increase or decrease the values of properties like the cross-sectional area, moment of inertia, or torsional constant. This is done to simulate the behavior of concrete when it cracks under load, as concrete loses some of its stiffness when it cracks. Essentially, stiffness modifiers help more accurately represent the realistic performance of a concrete element under stress, especially in the cracked state, by adjusting the calculated stiffness values.

## II. REVIEW OF LITERATURE

Ahmed *et al*. (2008) conducted a study on the effects of concrete cracking on the lateral response of building structures. They examined how cracking impacts the stiffness of reinforced concrete (R.C.C.) elements, which in turn influences the building's ability to resist lateral loads, such as those caused by seismic forces. This research highlights the critical need to account for concrete cracking in lateral response analysis to ensure the safety and performance of structures under lateral forces. Adjustment factors and conditions were reviewed to accurately represent the behaviour of cracked concrete under seismic loading, with a focus on compliance with standards like the Indian seismic code.

The behaviour of flat slab structures subjected to lateral forces, such as those experienced during seismic events is studied by Sang-Whan Han et al. (2009). The study develops equations for the stiffness reduction factor (β) in flat slab structures, representing stiffness loss due to cracking from increasing lateral moments. Using the Effective Beam Width Model (EBWM), which treats the slab as an equivalent beam, β is defined as the ratio of reduced stiffness post-cracking to uncracked stiffness. Nonlinear regression of test data from 30 slab-column specimens, considering normalized applied moments (Ma/Mcr), derives these equations. The results provide engineers a practical tool to include stiffness degradation in flat slab design, improving lateral displacement predictions during seismic events. The proposed β equations differ for interior and exterior slab-column connections, accurately reflecting the applied moment–stiffness relationship. Verification against experimental data confirms their reliability in predicting lateral stiffness reductions for slab-column and multi-span flat plate systems.

Further, Bing Li *et al.* (2012) investigates methods to estimate the initial stiffness of reinforced concrete (RC) columns and walls under seismic loads, addressing uncertainties in traditional approaches. The study develops and validates analytical methods and equations for estimating initial stiffness of RC columns and walls through experimental data and parametric studies. It favors a yield-criteria-based method and identifies axial load ratio and aspect ratio as key factors, while concrete strength and reinforcement ratio have minimal effect.

Prashant Sunagar *et al.* (2012) The study evaluates seismic response modification factors (R-factors) for reinforced concrete (RCC) moment-resisting frames (MRFs) using nonlinear static (pushover) and response spectrum analyses. By analysing 3-, 9-, and 20-story RCC MRFs designed per Indian seismic codes, the study investigates lateral load resistance and ductility characteristics. The study reveal that current R-factor definitions oversimplify structural inelastic behaviours, leading to non-uniform seismic performance.

Prof. K.K. Tolani *et al.* (2015) investigates the impact of infill walls on the seismic performance of reinforced concrete (R/C) frame structures. Utilizing static earthquake analysis and response spectrum methods, the authors create lump mass models for both bare frames and equivalent strut models, analysed through SAP 2000 software. The study reveals that incorporating infill walls significantly enhances the stiffness and strength of structures, with base shear increasing by 1.3 times when infill stiffness is considered. The natural time period of the structure is reduced from 0.257 to 0.162 seconds, indicating improved dynamic response.

The study conducted by Kontoni and Farghaly et al (2018) shows the critical role of stiffness in structural elements—columns, beams, and slabs—on the seismic performance of reinforced concrete (RC) high-rise buildings (H.R.B.s). Through a comprehensive time, history analysis using SAP2000, the authors systematically reduce the stiffness of these elements by 10% to 90% across thirteen 3D models of 12-story buildings. The results indicate that column stiffness is paramount, significantly influencing overall structural resistance to seismic loads, while beam and slab stiffness contribute less.

Sourav Das *et al.* studied how member stiffness affects the seismic performance of RC frame buildings. They found traditional methods using gross or empirical stiffness can misestimate structural behavior. Nonlinear dynamic analyses compared gross stiffness, FEMA-356 effective stiffness, and actual effective stiffness based on strength. Results showed gross stiffness leads to conservative performance estimates, while strength-based effective stiffness provides more realistic responses. Estimating actual effective stiffness for columns is complex, so they proposed using artificial neural networks (ANN), which accurately predict effective stiffness. The study highlights the importance of using actual effective stiffness in nonlinear seismic analyses for reliable evaluations.

M. Jesse Leo Pragnan *et al* (2019) investigates a comprehensive seismic analysis of a G+15 reinforced concrete (RCC) building utilizing Response Spectrum and P-Delta methods in accordance with IS 16700:2017. The study emphasizes the critical need for P-Delta analysis in high-rise structures, particularly in seismic zone V, where lateral loads significantly impact structural integrity. Utilizing ETAB software, the authors model the building and evaluate key seismic parameters, including time period, base shear, and storey drift.

The seismic performance of a 15-storey RCC building with different shear wall placements on hard, medium, and soft soils is Studied by Vijayashree N et al. The study involved equivalent static and dynamic analyses under seismic loads in Zone II. Results showed that buildings without shear walls experienced higher lateral displacements than those with core or corner shear walls. Displacement reductions of about 4% were noted across all soil types when shear walls were present. The research also highlighted how shear wall positions affect storey drift, stiffness, and base shear. Notably, corner shear walls were found to improve structural stability more effectively than core shear walls.

Parth v Bhavsar *et al* (2021) investigates the seismic performance of multi-storey buildings, specifically comparing configurations with and without shear walls. Utilizing ETABS-2015, the authors conduct a dynamic analysis based on the Response Spectrum Method, adhering to IS 1893 (Part 1):2016 guidelines. The study focuses on key parameters such as storey displacement, storey drift, base shear, and natural time period, which are critical for assessing structural integrity under seismic loading.

The seismic performance of a G + 15 multi-story residential building, comparing structures with and without shear walls using Response Spectrum Analysis is studied by Abhishek Yadav et al (2022). They emphasize the importance of shear walls in enhancing the stiffness and stability of high-rise buildings against lateral forces from earthquakes. Utilizing ETABS 2016 software, the study analyses various seismic parameters, including storey drift, displacement, and shear forces, under seismic zone 3 conditions.

Sneha S. Darekar *et al.* (2023) investigates the effects of reduced slab stiffness on the seismic performance of reinforced concrete (RCC) structures, particularly high-rise buildings. The study highlights the role of stiffness modifiers to reflect concrete cracking effects. Using ETABS 18, response spectrum analysis of four 32-story RCC building models showed that reduced slab out-of-plane stiffness increases top storey displacement, story drift, and shear wall moments. Models with low stiffness exceeded displacement limits, posing seismic risks.

## III. OBJECTIVES OF THE STUDY

1. To compare structural response parameters such as storey displacement, storey drift across different tall building models to understand their seismic performance variations accurately.
2. To perform response spectrum and equivalent static analyses on tall building models, evaluating how seismic loads influence their dynamic behaviour and ensuring design safety and reliability under earthquake conditions.
3. To create detailed models of G+33, G+30, G+28, and G+25 multistorey buildings using actual architectural plans in ETABS 2022, enabling precise seismic analysis and behaviour prediction.
4. To investigate how stiffness varies with height in multi-story reinforced concrete buildings and understand the implications of this variation on their seismic resistance and overall stability.
5. To provide informed recommendations aimed at updating and improving current design practice guidelines, enhancing the seismic design and safety of tall multi-story buildings based on research findings

## IV. METHOD OF ANALYSIS

*Details of Structure and Analysis*

The analysis of G+33, G+30, G+28, G+25 RC Structure is carried out. Seismic analysis according to IS 1893 (Part-1):2016. Analysis is carried out for structure in zone II, III IV and V. Effects of Earthquake loads applied on the structures are studied in two methods, namely

a. Equivalent static method

b. Dynamic analysis method

1. Select the site conditions and seismic zone.
2. Define the building geometry and model the structural system in ETABS 2022 for a consistent plan.
3. Apply loads and load combinations following standard code requirements.
4. Analyze each building frame model.
5. Compare results including fundamental time period, storey displacement, storey drift, and base shear.

6. Perform further analysis on each building frame model.
7. Examine the effects of parametric changes on the models. This restates the methodology for studying Response Spectrum , and stiffness modifiers in terms of key seismic response parameters.

Table.1:Description of Models

| Model number | Description of Models |
|---|---|
| Model 1 | G+33 model with stiffness modifier value 1 |
| Model 2 | G+33 model with stiffness modifier value 0.25 |
| Model 3 | G+33 model with stiffness modifier value 0.2 |
| Model 4 | G+30 model with stiffness modifier value 1 |
| Model 5 | G+30 model with stiffness modifier value 0.25 |
| Model 6 | G+30 model with stiffness modifier value 0.2 |
| Model 7 | G+28 model with stiffness modifier value 1 |
| Model 8 | G+28 model with stiffness modifier value 0.25 |
| Model 9 | G+28 model with stiffness modifier value 0.2 |
| Model 10 | G+25 model with stiffness modifier value 1 |
| Model 11 | G+25 model with stiffness modifier value 0.25 |
| Model 12 | G+25 model with stiffness modifier value 0.2 |

## V. STRUCTURAL MODELLING

Analysing the data: Following data are used in the model

1. Size of Building: 32.89 m X 28.10 m.
2. Grade of concrete: M 30, M35, M40, M45
3. Grade of steel: Fe 415
4. Floor to floor height: 2.8 m
5. Slab thickness: 150 mm
6. Wall thickness: 150 mm
7. Shear wall thickness: 300 mm
8. Size of beam: 300mm × 600mm
9. Live load on floor: 2KN/m $^2$
10. Floor finishes: 1.5 KN/m $^2$
11. Roof treatment: 4KN/m $^2$
12. Soil condition: Medium
13. Importance factor: 1
14. Building frame: 5 [SMRF]
15. Load case type: response spectrum method
16. Wind speed: 44 m/s
17. Density of concrete: 25 KN/m $^3$
18. Seismic Zone: 3 [0.16]

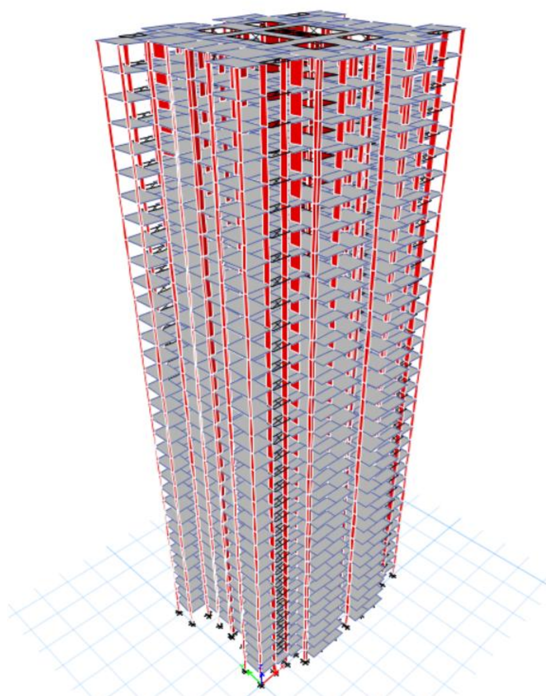

Fig. 1: MATHEMATICAL MODEL

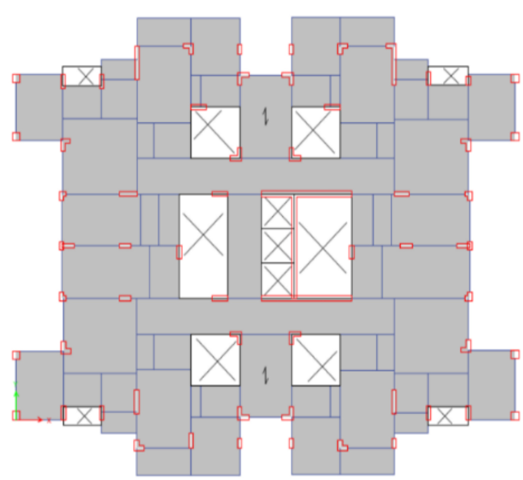

Fig. 2. TYPICAL PLAN OF G+33, G+30, G+28, G+25

## VI. RESULTS AND DISCUSSION

The analysis on the G+33, G+30, G+28, G+25 Buildings results is discussed below. And analysis as done by using the ETABS software. The parameters considered are story displacement, storey drift.

Table 3. Storey Drift (mm) X- Direction From table 2, Model 1, 33 Storey drift is 0.000289 Model 2 & Model 3 top Storey (Storey 33) drift increased by 6.22% & 13.14%, while mid-storey level such as Storey 30 & Storey 28 also increased by 5.72% and 5.75%, then Model 4, at 30 Storey drift is 0.000246, Model 5 & Model 6 drift increased by 6.91% & 8.94, In Model 4 While at mid -Storey level such as storey 28 drift is 0.000272 Model 5 & Model 6 is moderately increases by 6.25% & 8.45%. Model 7 storey 28 drift is 0.000224 Model 8 & Model 9 drift is increase by 5.35% & 8.03%, While at Mid-Storey level such as storey 25drift is 0.000265 Model 8 & Model 9 storey drift is increased by 4.90% & 7.16%. Model 10, storey 25 drift is 0.00217. Model 11 & Model 12 drift is slightly Increases by 3.68% & 5.99%

| Storey | Model -1 | Model -2 | Model -3 | Model -4 | Model -5 | Model- 6 | Model- 7 | Model -8 | Model-9 |
|---|---|---|---|---|---|---|---|---|---|
| | Drift | Drift. (% inc.) | Drift. (% inc.) | Drift | Drift. (% inc.) | Drift. (% inc.) | Drift | Drift. (% inc.) | Drift. (% inc.) |
| Storey 33 | 0.000289 | 0.000307 (6.22%) | 0.000327 (13.14%) | | | | | | |
| Storey 30 | 0.000332 | 0.000351 (5.72%) | 0.000373 (12.34%) | 0.000246 | 0.000263 (6.91%) | 0.000268 (8.94%) | | | |
| Storey 28 | 0.000365 | 0.000386 (5.75%) | 0.00041 (12.32%) | 0.000272 | 0.000289 (6.25%) | 0.000295 (8.45%) | 0.000224 | 0.000236 (5.35%) | 0.000224 (8.03%) |
| Storey 25 | 0.000413 | 0.000436 (5.56%) | 0.000462 (11.86%) | 0.000319 | 0.000338 (5.95%) | 0.000344 (7.83%) | 0.000265 | 0.000278 (4.90%) | 0.00284 (7.16%) |
| Storey 20 | 0.000472 | 0.000497 (5.29%) | 0.000527 (11.65%) | 0.000389 | 0.000408 (5.15%) | 0.000416 (7.21%) | 0.000338 | 0.000351 (3.84%) | 0.000358 (5.91%) |
| Storey 15 | 0.000493 | 0.000518 (5.070%) | 0.00549 (11.35%) | 0.000421 | 0.000443 (5.22%) | 0.000451 (7.12%) | 0.00038 | 0.000394 (3.68%) | 0.000401 (5.52%) |
| Storey 10 | 0.000467 | 0.000489 (4.71%) | 0.000518 (10.92%) | 0.000409 | 0.000429 (4.88%) | 0.000436 (6.60%) | 0.000377 | 0.00039 (3.44%) | 0.000397 (5.30%) |
| Storey 5 | 0.000374 | 0.000389 (4.01%) | 0.000412 (10.16%) | 0.000333 | 0.000347 (4.20%) | 0.000352 (5.70%) | 0.000311 | 0.000319 (2.57%) | 0.000324 (4.18%) |

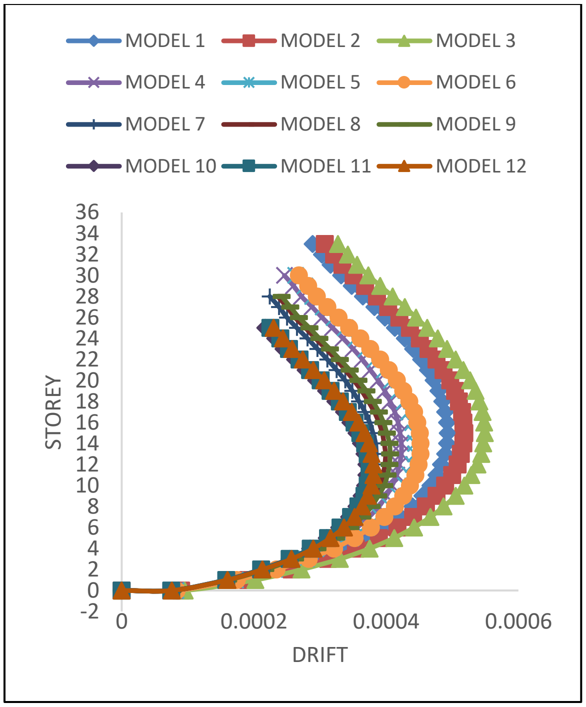


Fig. 3: Story Drift X – Direction

| Storey | Model-10 | Model -11 | Model -12 |
|---|---|---|---|
| | Drift. | Drift.<br>(% inc.) | Drift.<br>(% inc.) |
| Storey 25 | 0.00217 | 0.000225<br>(3.68%) | 0.00023<br>(5.99%) |
| Storey 20 | 0.000294 | 0.000301<br>(2.38%) | 0.000306<br>(4.08%) |
| Storey 15 | 0.000355 | 0.000361<br>(1.69%) | 0.000367<br>(3.38%) |
| Storey 10 | 0.000368 | 0.000372<br>(1.08%) | 0.000378<br>(2.71%) |
| Storey 5 | 0.00031 | 0.000312<br>(0.64%) | 0.000316<br>(1.93%) |
| | | | |

Table 3. Storey Drift (mm) Y- Direction

| Storey | Model -1 | Model -2 | Model -3 | Model -4 | Model -5 | Model- 6 | Model- 7 | Model -8 | Model-9 |
|---|---|---|---|---|---|---|---|---|---|
| | Drift (mm) | Drift (mm) | Drift (mm) | Drift (mm) | Drift (mm) | Drift (mm) | Drift (mm) | Drift (mm) | Drift (mm) |
| Storey 33 | 0.000369 | 0.000455<br>(23.30%) | 0.000471<br>(27.64%) | | | | | | |
| Storey 30 | 0.000407 | 0.000486<br>(19.41%) | 0.000503<br>(23.58%) | 0.000312 | 0.000384<br>(23.07%) | 0.000398<br>(27.56%) | | | |
| Storey 28 | 0.000437 | 0.000514<br>(17.62%) | 0.00053<br>(21.28%) | 0.000335 | 0.000404<br>(20.59%) | 0.000418<br>(24.77%) | 0.000278 | 0.000341<br>(22.66%) | 0.000353<br>(26.97%) |
| Storey 25 | 0.000478 | 0.000556<br>(16.31%) | 0.000572<br>(19.66%) | 0.000376 | 0.000441<br>(17.28%) | 0.000454<br>(20.74%) | 0.000314 | 0.00037<br>(17.83%) | 0.000381<br>(21.33%) |
| Storey 20 | 0.000527 | 0.000602<br>(14.23%) | 0.000618<br>(17.26%) | 0.000433 | 0.000497<br>(14.78%) | 0.00051<br>(17.78%) | 0.000374 | 0.000429<br>(14.70%) | 0.000441<br>(17.91) |
| Storey 15 | 0.000535 | 0.000603<br>(12.71%) | 0.000617<br>(15.32%) | 0.000455 | 0.000513<br>(12.74%) | 0.000525<br>(15.38%) | 0.000404 | 0.000455<br>(12.62%) | 0.000466<br>(15.34%) |
| Storey 10 | 0.000489 | 0.000544<br>(11.24%) | 0.000555<br>(13.49%) | 0.000426 | 0.000473<br>(11.03%) | 0.000483<br>(13.38%) | 0.000386 | 0.000427<br>(10.62%) | 0.000437<br>(13.21%) |
| Storey 5 | 0.000372 | 0.000406<br>(9.13%) | 0.000413<br>(11.02%) | 0.00033 | 0.000358<br>(8.48%) | 0.000365<br>(10.60%) | 0.000302 | 0.000328<br>(8.60%) | 0.000334<br>(10.59%) |

| Storey | Model-10 | Model -11 | Model -12 |
|---|---|---|---|
| | Drift. (mm) | Drift. (% inc.) | Drift. (% inc.) |
| | | | |
| | | | |
| Storey 25 | 0.000264 | 0.000305 (15.53%) | 0.000314 (18.93%) |
| Storey 20 | 0.000331 | 0.000361 (9.06%) | 0.000369 (11.48%) |
| Storey 15 | 0.000377 | 0.000402 (6.63%) | 0.00041 (8.75%) |
| Storey 10 | 0.000374 | 0.000391 (4.54%) | 0.000397 (6.14%) |
| Storey 5 | 0.0003 | 0.000307 (2.33%) | 0.000311 (3.66%) |

From table 3, Model 1, 33 Storey drift is 0.000369 Model 2 & Model 3 top Storey (Storey 33) drift increased by 23.30% & 27.64%, while mid-storey level such as Storey 30 & Storey 28 also increased by 19.41% and 17.61%, then Model 4, at 30 Storey drift is 0.000312, Model 5 & Model 6 drift slightly increased by 23.07% & 27.56, In Model 4 While at mid -Storey level such as storey 28 drift is 0.000335 Model 5 & Model 6 increases by 20.59% & 24.77%. Model 7 storey 28 drift is 0.000278 Model 8 & Model 9 drift is increase by 22.66% & 26.97%, While at Mid-Storey level such as storey 25drift is 0.000314 Model 8 & Model 9 storey drift is increased by 17.83% & 21.33%. Model 10, storey 25 drift is 0.000264 & Model 11 & 12 Increases by 3.68% & 5.99%

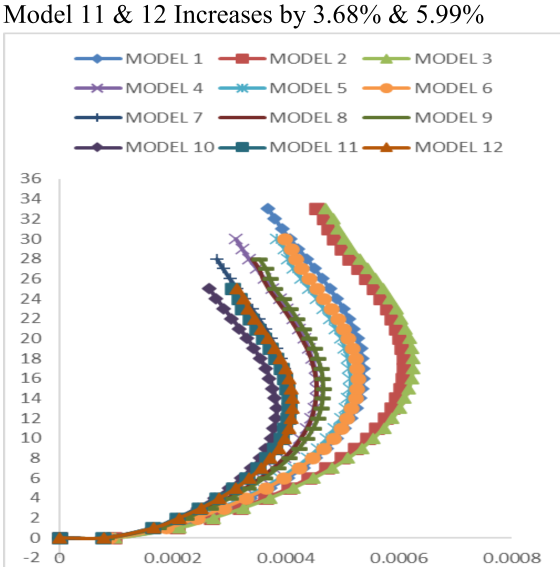


Fig. 5: Storey Drift Y– Direction

Table 4: Storey Displacement X– Direction

| MODEL | TOP STOREY DISPLACEMENT IN X- DIRECTION |
|---|---|
| | Displacement (mm) |
| Model 1 | 38.084 |
| Model 2 | 39.965 |
| Model 3 | 40.641 |
| Model 4 | 29.749 |
| Model 5 | 31.213 |
| Model 6 | 31.766 |
| Model 7 | 25.31 |
| Model 8 | 26.183 |
| Model 9 | 26.661 |
| Model 10 | 21.793 |
| Model 11 | 22.081 |
| Model 12 | 22.439 |

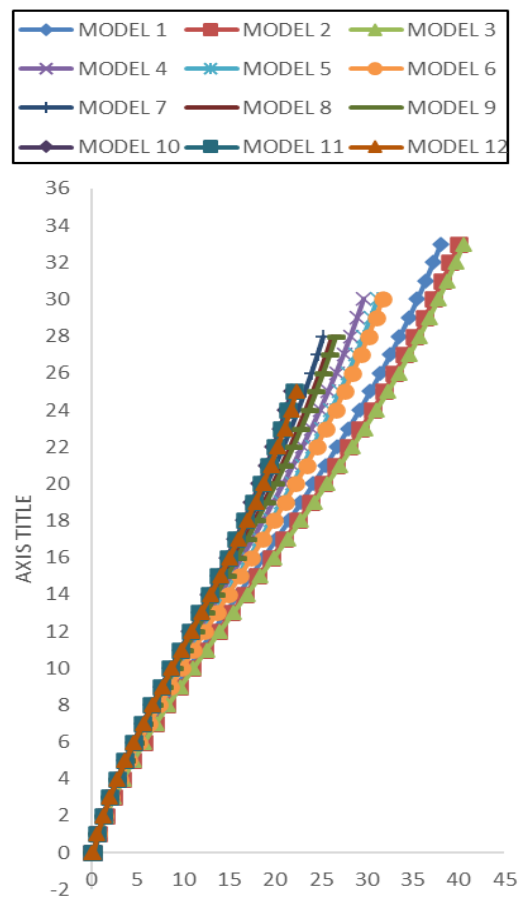


Fig. 5: Storey Displacement X – Direction

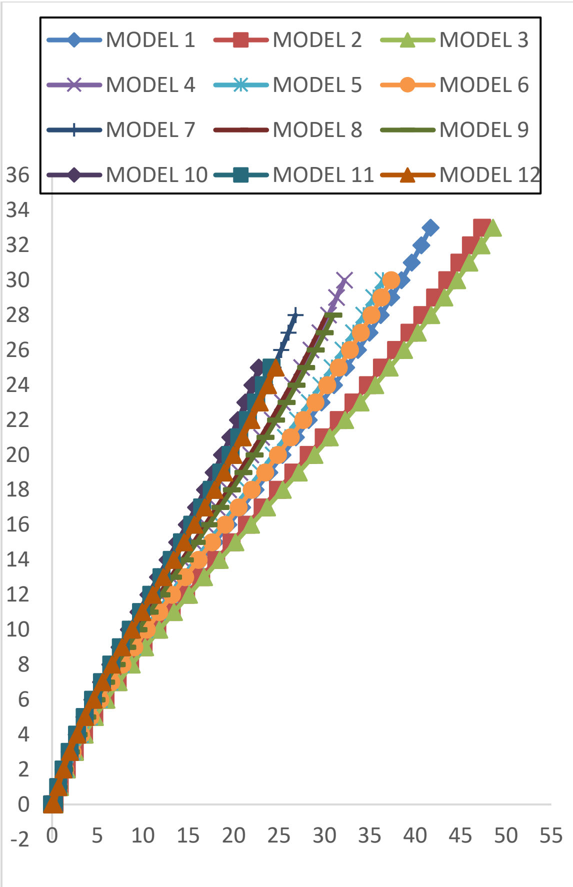


Fig. 6: Storey Displacement Y – Direction

Table 5. Storey Displacement Y – Direction

| MODEL | TOP STOREY DISPLACEMENT IN X- DIRECTION |
|---|---|
| | Displacement (mm) |
| Model 1 | 41.684 |
| Model 2 | 47.37 |
| Model 3 | 48.564 |
| Model 4 | 32.202 |
| Model 5 | 36.449 |
| Model 6 | 37.355 |
| Model 7 | 26.809 |
| Model 8 | 30.233 |
| Model 9 | 30.979 |
| Model 10 | 22.787 |
| Model 11 | 24.173 |
| Model 12 | 24.624 |

From table 4, Model 1, 33 storey displacement is 238.084mm. Model 2 top storey (Storey 33) displacement increased by 4.93%, while mid-storey levels such as Storey 28 and Storey 30 showed increases of 4.74% and 4.86%, respectively. Model-3, Storey 33 showed a 6.71 displacement, and Storey 28 and Storey 30 showed increases of 6.60% and 6.54%, respectively. Model-4, The top storey displacement is 29.749. Models 5, 6 showed moderate increases in displacement values, typically ranging between 5–7% at upper Storey, and around 3–4% at lower storeys. As we Reducing the storey height for further models gradually decreasing displacement values.

From table 5, At the topmost level (Storey 33), Model-3 exhibited the higher displacement of 48.564mm while significant Decrease were observed in Models 1, 2, and 4, with displacements falling to 541.684 mm, 47.37 mm (16.50%), and 32.202mm, models (5–9), the slightly decreasing the displacement , around 25–38 mm. Model 8-9 followed a similar pattern with displacement is 30.233 &30.979mm. Model-10 which has Stiffness modifier is 1 as compared to other Model 11 & Model 12 displacement is slightly increasing by6.08% and 8.06%

## VII. CONCLUSION

The present study investigated, the effects of stiffness modifier variations with height in multistorey R.C.C. buildings, addressing critical parameters such as storey displacement, storey drift, under seismic loads using advanced modelling techniques in ETABS 2022 software. The study includes analysis of a series of residential building configurations (G33, G30, G28, G25 floors) to compare structural responses, systematically evaluating the impact of stiffness modifications and shear wall arrangements as recommended by IS 16700:2017 and IS 1893:2016.

The present comparative study of 12 structural models reveals that tall storey buildings generally exhibit higher displacements and drifts, especially in the Y-direction, indicating increased seismic vulnerability. Model 2, with Same storeys but Different modifiers value, showed the Increase drift values, emphasizing the detrimental effect of vertical irregularities on seismic performance. Models 3 to 8 also reflected elevated displacements compared to the Model 1, 4,7,10 Further, models incorporating Different modifier Values these models significantly increasing both displacement and drift, Varying stiffness modifiers according to real-world conditions, such as material variation, geometric irregularity, and cracking effects, results in more realistic assessment of lateral force resistance, deformation behavior, and serviceability performance. Models incorporating these modifier variations demonstrate improved accuracy in estimating story displacement, drift, and base shear compared to models with constant stiffness.

The results further emphasize the essential role of strategic shear wall placement, notably at building corners, in enhancing seismic resilience. Shear walls substantially reduce lateral displacements and drift, helping structures remain within permissible limits even when slab stiffness is reduced due to cracking or other deterioration mechanisms.

REFERENCES


[1] M. Ahmed, M. K Dad Khan and M. Wamiq "Effect of Concrete Cracking on the Lateral Response of R.C.C. Buildings" *Asian Journal of Civil Engineering* (Building and Housing) vol. 9, no. 1 (2008) pages 25-34

[2] Sang-Whan Han, Young-Mi Park and Seong-Hoon Kee "Stiffness Reduction Factor for Flat Slab Structures under Lateral Loads" *Journal of Structural Engineering,*135(6),743–750. https://doi.org/10.1061/(asce)st.1943-541x.000000

[3] Bing Li "Initial Stiffness of Reinforced Concrete Columns and Walls" School of Civil and Environmental Engineering, Nanyang Technological University, Singapore 639798

[4] Prashant Sunagar and S. M. Shivananda "Evaluation of Seismic Response Modification Factors for RCC Frames by Non-Linear Analysis" International *Conference on Advances in Architecture and Civil Engineering* (AARCV 2012), 21st – 23rd June 2012 322 Paper ID SAM191, Vol. 1

[5] Rupali Kavilkar and Shweta Patil "Study of High-Rise Residential Buildings in Indian Cities" IACSIT *International Journal of Engineering and Technology,* Vol. 6, No. 1, February 2014

[6] K.K. Tolani, Pravin A. Nikam "Infill Wall Stiffness Consideration in Earthquake Analysis" International Research Journal of Engineering and Technology (IRJET) Volume: 02 Issue: 02 | May-2015

[7] P. N. Kontoni, A. A. Farghaly "Stiffness Effects of Structural Elements on the Seismic Response of Rc High-Rise Buildings" archives of civil engineering vol. lxiv issue 1 2018

[8] M. Jesse Leo Pragnan, Anirudh Maddi "Seismic Analysis of Multi-Storied Regular Building by Response Spectrum And P-Delta Methods Using IS 16700:2017" *International Journal of Recent Technology and Engineering* (IJRTE) Volume-8, Issue-1, May 2019

[9] Vijayashree N, Ramya B V "Comparative Analysis on Seismic Behaviour of Multistoreyed Rcc Building in Different Soil Strata Considering the Position of Shear Wall" International Journal of Recent Technology and Engineering (IJRTE) Volume-7, Issue-8, Aug 2020

[10] Sagar Laxman Belgaonkar, Prof. Ravi Basavaraj Tilaganji, Miss. Priyanka P Hegade, Miss. Raghavi B Indaragi "Comparative Study of Story Displacement and Stiffness Under Different Seismic Zones for Rc Structure" *International Journal of Engineering Research & Technology (IJERT)* IJERTV1 www.ijert.org Vol. 10 Issue 07, July-2021

[11] K.K. Tolani, Mr. Pravin A. Nikam "Infill Wall Stiffness Consideration in Earthquake Analysis" *International Research Journal of Engineering and Technology (IRJET)* Volume: 02 Issue: 02 | May-2015

[12] Kirtikumar Nareshchand Jain, Rohan Kumar Choudhary "Nonlinear Analytical Study of Tall Building Using Is 16700-2017" *International Journal of Recent Technology and Engineering (IJRTE)* Volume-7, Issue-12, Dec 2020

[13] Samiksha H P, Rutuja A P, Vinaya M P, Bhavna N P, "Dynamic Analysis of Multistoried Building with And Without Shear Wall." *International Journal of Recent Technology and Engineering (IJRTE)* Volume-8, Issue-5, Dec 2021

[14] Kishan b. Champaneriya, Vishal B. Patel, Atul N. Desai "Effect of Backstay on Tall Structure with Podium Structure" *International Journal of Advanced Research in Science, Communication*

*and Technology (IJARSCT)* Volume 7, Issue 2, July 2021

[15] Parth v Bhavsar, Abbas Jamani "Analytical Study on The Effect of Stiffness Modifiers on The Performance of Rcc Building Subjected to Seismic Force as Per Is 1893(2016)" International Journal of Recent Technology and Engineering (IJRTE) Volume-8, Issue-5, Aug 2021

[16] Abhishek Yadav, Prince Yadav "Analysis of High-Rise Multistoried Building with and Without Shear Wall by Response Spectrum Method" *International Journal of Recent Technology and Engineering (IJRTE)* Volume-9, Issue-8, Aug 2022

[17] Jesal Morbia, Prof. Sumant B. Patel, Prof. Dr. Elizabeth George "Stiffness Modifiers in Rc and Pt Beams and Their Impact on Structural Behavior" *International Advanced Research Journal in Science, Engineering and Technology* Vol. 9, Issue 5, May 2022

[18] Sneha S. Darekar, Prof. P. R. Barbude, Dr. S. A. Rasal "Impact of Reduction in Stiffness of Slab on The Behaviour of Rcc Structure" International Research Journal of Engineering and Technology (IRJET) Volume: 10 Issue: 04 | Apr 2023

[19] Mustafa E. Mithaiwala, Prof. Amol A. Patil, Dr. Navnath V. Khadake "A Review on Effect of Different Set of Stiffness Modifiers Varying Through Height of Structure on Analysis of Multistory R.C.C. Structure" *International Research Journal of Engineering and Technology (IRJET)* Volume: 7 Issue: 08 | Aug 2020