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Study of Shear Wall and Flag Wall of a G+10 Building in Meghalaya by Linear Analysis

Arbisha Rani[1], Raisa Tamsin Hussain[2], and Jemima Yasmin[3]

M. Tech student, Civil (Structural Engineering), The Assam Royal Global University, Guwahati-281035, India[1]

Assistant Professor, Department of Civil Engineering, The Assam Royal Global University, Guwahati-781035, India[2]

Assistant Professor, Department of Civil Engineering, The Assam Royal Global University, Guwahati-781035, India[3]

Abstract*:* The main objective of this study is to find out the structural performance of a (G+10) building between conventional, shear wall, and flag walls in North East India (Meghalaya). As per IS 1893:2016, the building is located in Zone V. The ETABS software is used for seismic analysis, focusing on the response spectrum. The models are compared based on natural period, base shear, storey drift, stiffness, and lateral displacement in the X and Y directions. This study compared a 10-storey building with different wall types and found that flag walls improve performance by reducing vibration time by 50%, base shear by 2%, storey drift (14% along the X-direction and 41% along the Y-direction), storey displacement (44% along the X-direction and 54% along the Y-direction), and stiffness (98% along the X-axis and 99% along the Y-axis). Using a central shear wall and flag walls on the 3rd, 7th, and top floors (model M19 SW+FW) saves space and performs better than conventional systems, making the structure stronger and more stable during earthquakes. Model M19 SW+FW gives a good result compared to 22 models.

Keywords: Base Reaction, Shear wall, Flag wall, Response Spectrum Analysis, Storey Displacement, Storey Drift, Storey Stiffness.

I. INTRODUCTION

Tall buildings must be designed to support both gravity and lateral loads. Structural systems aim to transfer gravity loads and withstand vertical and lateral loads caused by wind and seismic activity. High-rise buildings require sufficient stiffness to resist lateral stresses and strength to withstand vertical loads **[15]**. In addition to these vertical loads, lateral loads brought on by wind and seismic activity are also experienced by buildings. Lateral loads may result in vibration, sway movement, or excessive stresses. Thus, the structure must be sufficiently stiff to withstand lateral stresses and strong enough to withstand vertical loads. The distributions of transverse shear stiffness and bending stiffness per storey control high-rise buildings' static and dynamic structural responses **[15][19]**. Getting around this drawback of traditional outrigger systems is possible by including flag walls in the design. Flag walls are more economical to install than conventional outrigger systems because they eliminate the need for rentable space which is a disadvantage of using a typical outrigger system **[12][16]**.

1.1 Shear Wall

Shear wall: Shear walls are used in engineering to resist lateral stresses from seismic events. They extend the entire building height and have greater stiffness in their primary axis. Collectors transfer diaphragm shear to other vertical components. Shear walls resist forces parallel to their plane and are highly resistant to both vertical and horizontal forces. They develop complex strain distributions under mixed loading conditions by moving masses vertically to the building's base. [4]

1.2 Flag wall

"Flag walls are reinforced concrete walls (RC walls) in selected floors, not reaching the foundation which provides additional stiffness, strength, and ductility to the overall structure" **[16]**. Like outriggers, they can be useful in minimizing total lateral drifts, inter-story drifts, and building durations. Flag walls have the primary benefit of not requiring any room for operations because they function similarly to outriggers. An alternative to utilizing trusses to tie together the core of a typical outrigger structure is to use isolated RC walls, sometimes called flag walls, which would reduce the wasted space between the columns.

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II. METHODOLOGY

First, start by creating the building plan in Autocad. Then, gather the necessary data and find a suitable location for the construction. Next, use ETABS software to design the model, with the help of the Response Spectrum Analysis. After all the members have passed, start placing the shear wall and flag wall and compare the results. If it fails redesign the model.

2.1 Plan and Modelling

In this study, the shear wall and flag wall have been considered for modeling and designing. By using Khlainbok Jyrwa data, design a building in AutoCAD. In Meghalaya, utilize ETABS software to design and model a G+10 building. Columns can be utilized to replace shear walls in a variety of configurations. Flag walls are being erected in numerous locations. Placing lift in the **open to the sky.** Next, combine the flag and shear walls, and utilize response spectrum analysis to confirm the results. If it does not work, modify the design.

2.1.1 This research considers a (G+10) storey high-rise construction.

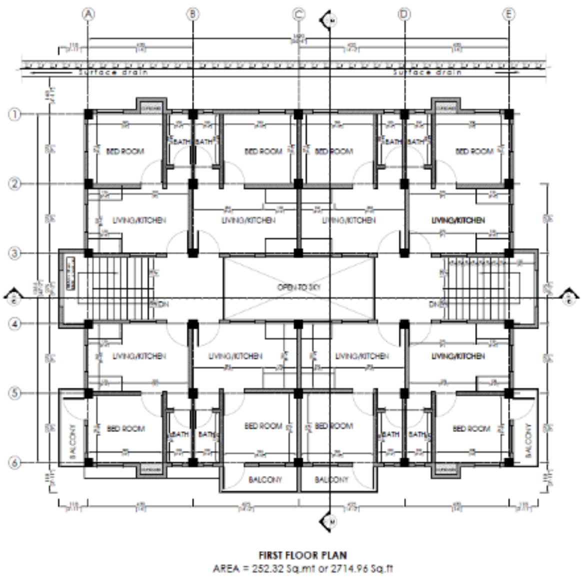

Fig- 2.1 Floor plan (Khlainbok Jyrwa) [9]

2.2 Location (AT SEM MASI, SANGSHNONG, MAIRANG, EASTERN WEST KHASI HILLS, DISTRICT) Meghalaya.

Fig- 2.2 Twinklety Marbaniang Residential (Google Maps) [9]

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2.3 Structural Configuration

The overall configuration considered for the design and analysis of the various models has been listed below:

Table 2.1 Parameters of G+10 building model

PARAMETERS	CONFIGURATION
Structure Type	Concrete Structure
Number of Storey	G+10
Building area	2714.96sq.ft
Height of the storey	3m
Location	AT SEM MASI, SANGSHNONG, MAIRANG, EASTERN WEST KHASI HILLS, DISTRICT, MEGHALAYA
Beam size	350mm X 250mm
Column size	350mm X 350mm
Slab thickness	125mm
Shear wall Thickness	150mm
Lift size	1.5m X 1.65m
Zone	V
Grade of concrete	M20
Grade of steel	Fe415
Soil type	II, Medium
S.B.C	160KN/m^2

Table 2.2 Parameters considered for all the models

PARAMETERS	SIZE TAKEN AT MODELING	SIZE FOR IMPROVISED MEMBERS
Beam size	350mm X 250mm	350mm X 300mm
Column size	350mm X 350mm	350mm X 350mm
Fail beam size	350mm X 300mm	400mm X 300mm
Slab thickness	125mm	150mm
Grade of concrete	M20	M30
Grade of steel	Fe415	Fe500

2.4 Seismic Specifications

Table 2.3 Seismic Specifications for Design

PARAMETERS	VALUE
Zone	V
Zone Factor, Z	0.36
Response reduction factor, R	5
Damping Ratio	0.05
Important Factor, I	1
Type of soil	II (Medium Soil)
Response Spectrum	As per IS 1893(Part-1):2016
RCC Design	As per IS456:2000
Dead Load	As per IS875(Part 1):1987
Imposed Load	As per IS875(Part 2):1987

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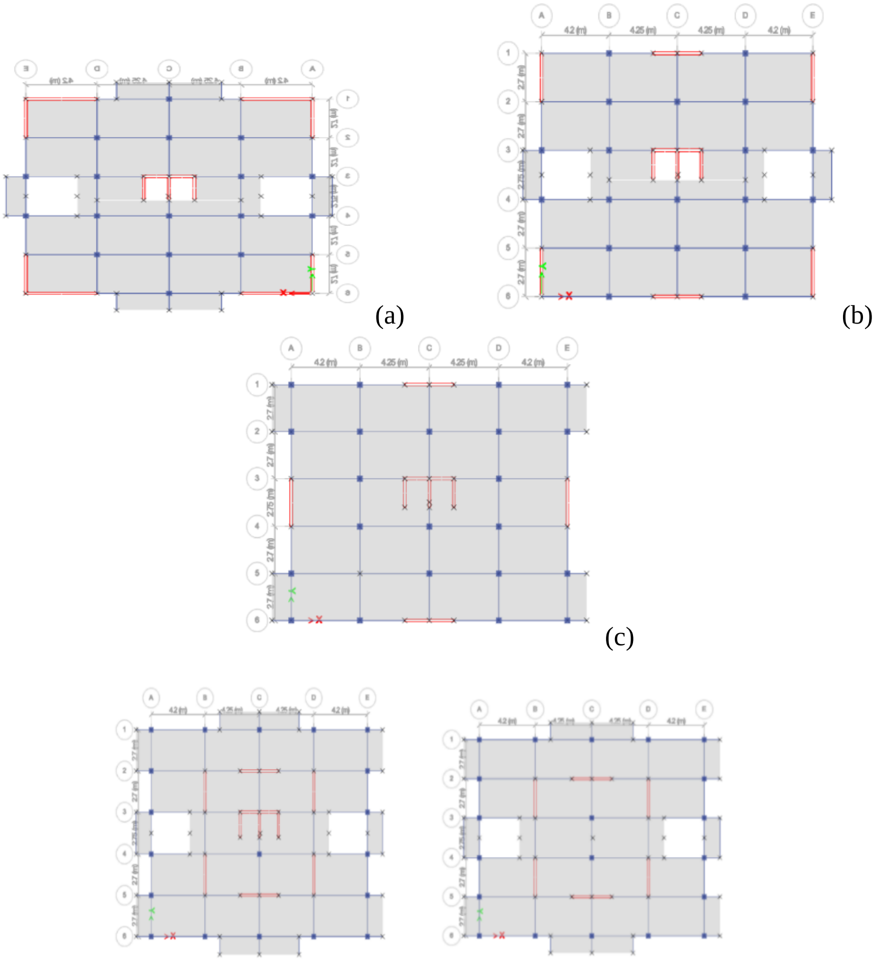
2.5 Loading Specifications

Table 2.4 Loading Specification for Design

LOADS	VALUE
Dead Load	As per IS875(Part 1):1987
Live Load (Balconies, Staircase, and Passage)	3KN/m
Live Load (Bedroom, Kitchen, Toilet and Washroom)	2KN/m
Wall Load	6.625KN/m
Floor Finish Load	1.5KN/m

2.6 Placing a shear wall for a column in a different position.



(a) (b) (c) (d) (e)

Fig- 2.3 Placing shear wall at different positions: (a) M3SW, (b) M4SW, (c) M5SW, (d)M6SW, and (e) M7SW)

2.7 Placing flag walls at different locations

First, place the flag wall on the 1st floor, 5th floor, and 9th floor. Then, place at the 2nd floor, 6th floor and 10th floor. Lastly, place on the 3rd floor, 7th floor, and at the top floor. Continue the same procedure for all the models near the shear wall.

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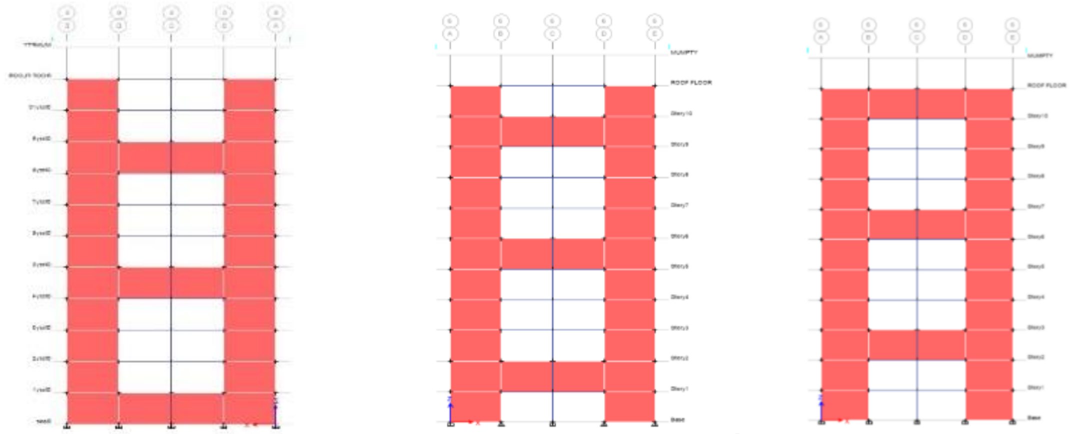

(a) (b) (c)

Fig -2.4 Placing flag wall on the; (a) 1st floor, 5th floor and 9th floor, (b) 2nd floor, 6th floor and 10th floor, and (c) 3rd floor, 7th floor, and the top floor

2.8 Perform the Linear Analysis

Linear analysis uses the elastic properties of materials to assess how structures respond and behave dynamically. This includes the linear static analysis and linear dynamic analysis (RSA) **[11]**.

1. Equivalent Static Analysis

The simplified equivalent static lateral force method assesses the potential impact of an anticipated earthquake on a structure. It uses a single lateral force "V" and assumes that the primary motion during an earthquake is lateral. The building should have moderate height and uniform proportions to ensure its effectiveness and minimize torsional effects. It should be designed to withstand earthquakes from any direction, though not simultaneously from both directions **[2]**.

2. Response-Spectrum Analysis

Response-spectrum analysis (RSA) is a method used to measure the likely maximum seismic response of a structure by considering the contribution from each natural mode of vibration. It provides insight into dynamic behavior by measuring pseudo-spectral acceleration, velocity, or displacement as a function of structural period for a given time history and level of damping. The analysis can also be used to envelope response spectra to represent the peak response for each realization of the structural period **[3]**.

III. RESULTS AND DISCUSSION

This chapter will discuss the results of analyzing various models' responses. We studied the seismic response of buildings, focusing on story displacement, story drift, and building stiffness.

A total of 22 models were analyzed, with different shear wall positions and flag wall locations. We used the response spectrum method for dynamic analysis in seismic zone V, considering type II soil. The parameters analyzed included storey displacement, storey drift, and storey stiffness. The results are outlined below:

3.1 Comparison of G+10 building of the conventional structure, shear wall, and flag wall

3.1.1 Maximum Base Reaction

The model (M18 SW+FW) experienced only a 0.24% decrease in base reaction after adding a flag wall on the 2nd floor, 6th floor, and 10th floor.

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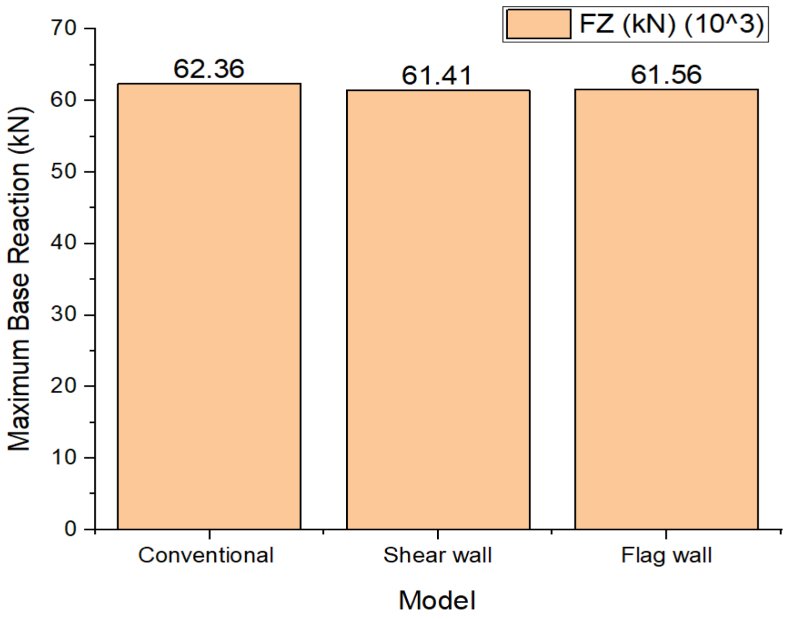

Fig- 3.1 Maximum Base Reaction

3.1.2 Natural Time Period

The model with a flag wall exhibited a 29% decrease in the period, indicating that the building vibrates more quickly in response to lateral forces. This suggests that buildings with shorter natural periods are more susceptible to dynamic loads.

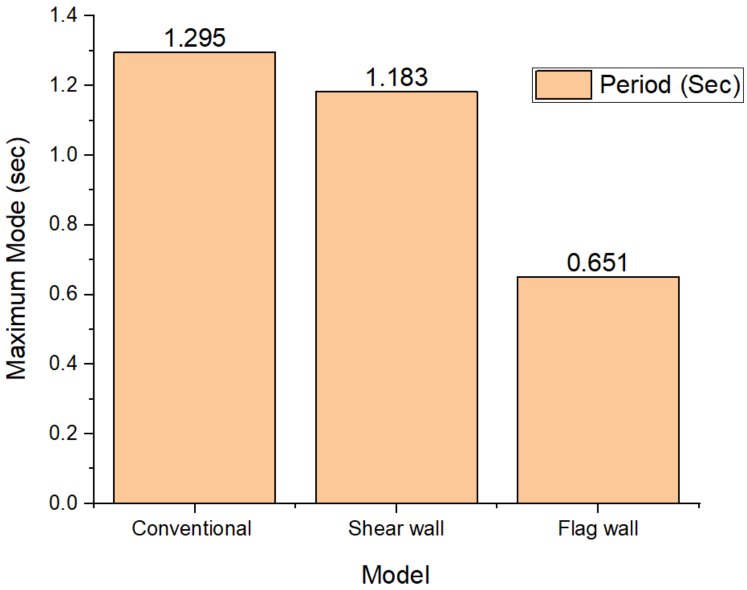

Figure 3.2 The Natural Time Period

3.1.3Maximum Displacement

Models without shear walls and flag walls showed larger maximum displacements. A comparison revealed a 24% reduction when flag walls were incorporated into the design.

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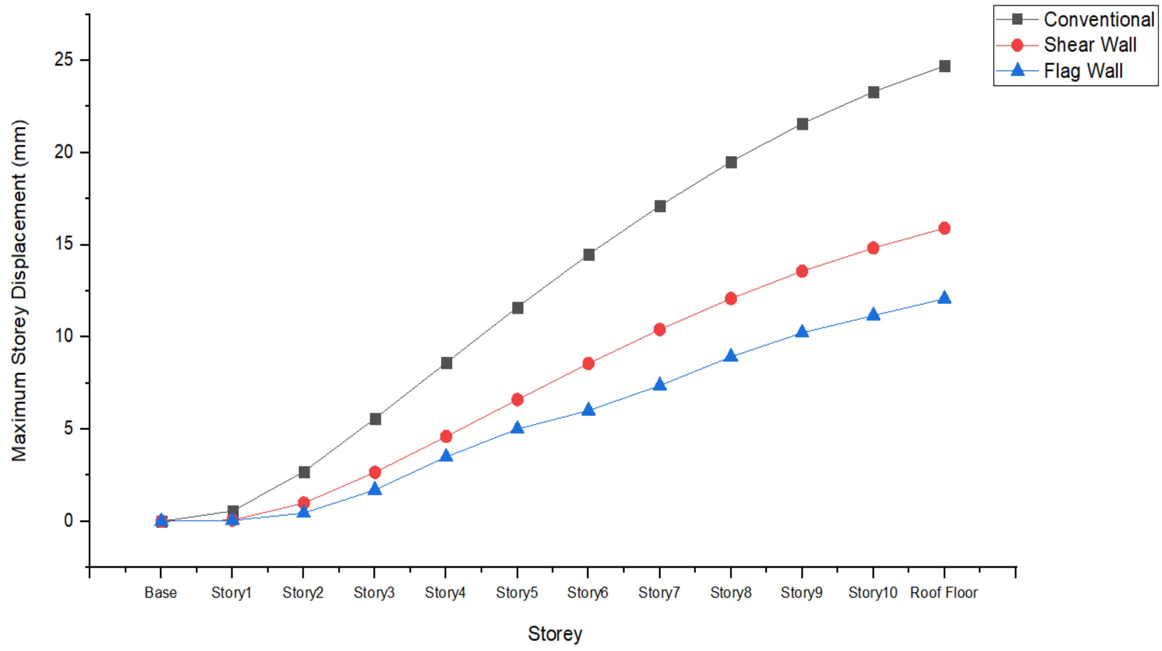

Figure 3.3 Maximum Storey Displacement

3.1.4 Maximum Storey Drift

Storey drifts increased without shear walls and flag walls. However, placing a flag wall on the 2nd floor, 6th floor, and 10th floor reduced up to 11%.

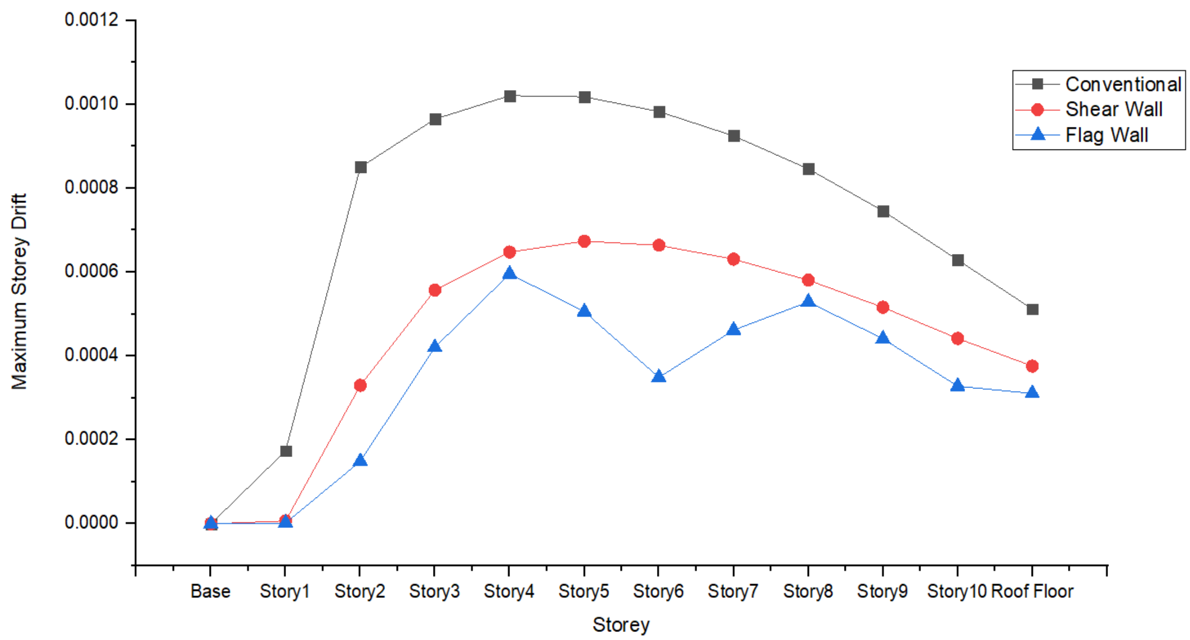

Figure 3.4 Maximum Storey Drift

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3.1.5 Maximum Stiffness

The storey stiffness of the flag wall model was found to be higher compared to the conventional model and the shear wall models. The building's stiffness increased by up to 43% with the addition of a flag wall.

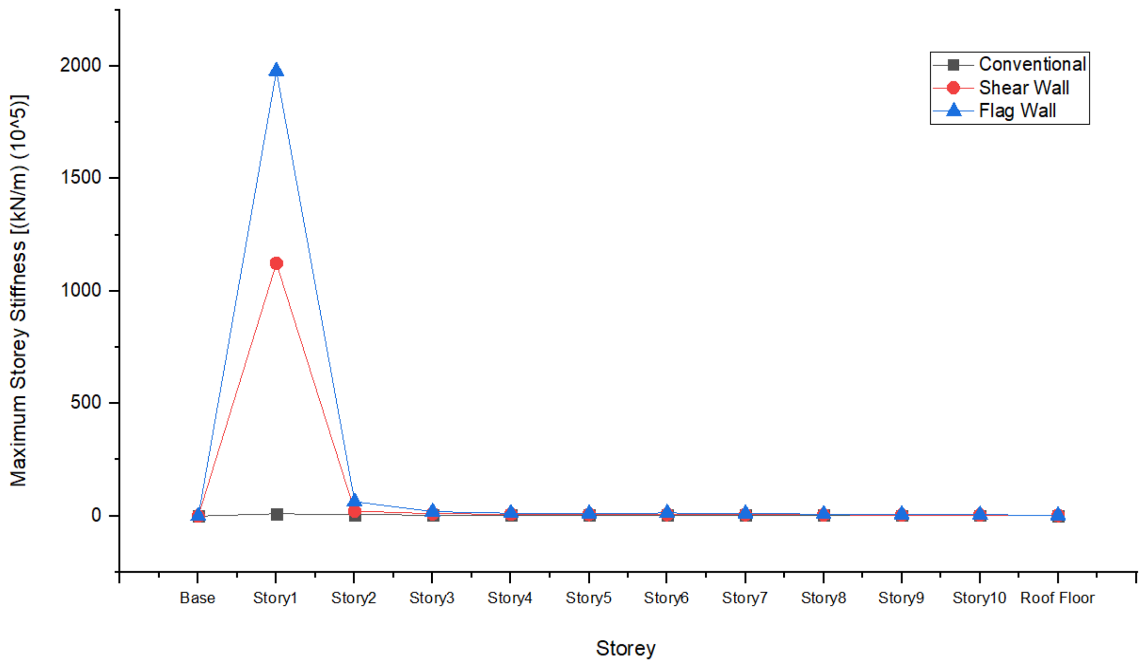

Figure 3.5 Maximum Storey Stiffness

IV. CONCLUSION

The following conclusions are drawn after the dynamic analysis**:**

- The model (M18 SW+FW) experienced only a 0.24% decrease in base reaction after adding a flag wall on the 2nd floor, 6th floor, and 10th floor.
- The model with a flag wall exhibited a 29% decrease in the period, indicating that the building vibrates more quickly in response to lateral forces. This suggests that buildings with shorter natural periods are more susceptible to dynamic loads.
- Models without shear walls and flag walls showed larger maximum displacements. A comparison revealed a 24% reduction when flag walls were incorporated into the design.
- Storey drifts increased without shear walls and flag walls. However, placing a flag wall on the 2nd floor, 6th floor, and 10th floor reduced up to 11%.
- The storey stiffness of the flag wall model was found to be higher compared to the conventional model and the shear wall models. The building's stiffness increased by up to 43% with the addition of a flag wall.

It can be observed that applying a shear wall in the center of this particular building and applying a flag wall on the 2^{nd} floor, 6^{th} floor, and 10^{th} floor, i.e., model M18 SW+FW, could be used as an alternative to conventional RCC systems as they save space and the performance of flag wall systems is better than conventional systems. An increase in stiffness and structure can be more efficient when subjected to dynamic seismic load during flag wall use.

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