Retrofitting of Skyscraper Building By Using Time History Analysis

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Abstract: — A skyscraper is a multi-story structure that is tall and constantly habitable. Originally, the word referred to a structure of at least 35-50 stories that was mostly utilized for office, commercial, and residential functions. A skyscraper is sometimes known as a high-rise; however, the term skyscraper is generally reserved for structures taller than 50 meters. Skyscrapers frequently have a steel structure that supports curtain walls. Instead of load-bearing walls, these curtain walls are either supported by or hung from the framework above earthquake is a major natural disaster in which many structures are damaged or collapse due to unacceptable or improper seismic motion design. The nation's economy and pace of growth are both impacted by earthquakes, so it is imperative that effective preventative measures are created for the benefit of both the people and the country.In this study, several retrofitting technologies, such as bracing, shear walls, and infill walls, are applied for symmetrical G+40 high-rise buildings. The same structural properties were used to create 4 different sorts of models. Time history analysis is used in seismic analysis to take varying ground motion intensities into account. In order to determine the optimum retrofitting for the structure, the findings of the analysis are compared.

Keywords: skyscraper, earthquake, steel bracing, shear walls, infill strut, time history

I. INTRODUCTION

Retrofitting is the process of making modifications to an existing structure in order to safeguard it against flooding and other dangers like strong winds and earthquakes. Retrofitting is an improvement in construction technology, including techniques and supplies, to address the effects of natural disasters on buildings and their rising frequency and intensity. Many of the homes created today were constructed at a time when information about the locations and frequency of flooding and other risky phenomena, or how to protect against them Changes depending on what we learn in the future may help homes being constructed now. Therefore, retrofitting has developed as a critical and necessary approach of hazard reduction. [1]

"Rehabilitation" is a term that is frequently used to describe retrofitting specifically for seismic dangers.

The terms "repair," "restoration," and "retrofitting" have taken on the following definitions in the field of earthquake engineering:

Repair

actions are taken to complete the finishes and repair minor flaws.

Restoration

Taking steps to regain the structural parts' lost strength.

Retrofitting

actions to improve the seismic resiliency of an existing structure. such that it is protected from the likelihood of future earthquakes occurring again.

A. Retrofitting Techniques Classification

There are two methods for increasing the seismic capability of existing buildings.

a. Retrofitting at the structural level (global retrofits methods)
b. A member-centric approach (local retrofit methods)

B. Types of Retrofitting

1) Installing a New the Shear Wall

This is a common method for enhancing non-ductile reinforced concrete frame constructions. Concrete components might be cast-in-place or pre-cast. The exterior of the structure is the finest spot for new items. This process is not suggested for the interior of the structure to avoid inner moldings. [3]

2) Steel bracing is included.

Steel bracing is a good option for building retrofitting when large openings are needed. Potential advantages include enhanced strength and rigidity, as well as an opening for natural light. The amount of work is also decreased, allowing for lower foundation expenses while adding significantly less weight to the existing structure.

3) Thickening of the Walls

A structure's existing walls are strengthened by adding bricks, concrete, and steel aligned at particular areas. The weight of the wall increases, and it can resist greater vertical and horizontal strains. It is also designed in such a way that transverse forces do not cause the wall to collapse quickly. If reinforcement is not sufficiently covered by mortar, rust can occur.

4) Method of Base Isolation

The separation of the superstructure from the foundation is referred to as base isolation. It is the most effective method for controlling passive structural vibration. Seismic stresses are decreased when a building is insulated from the ground, resulting in less structural damage and less superstructure maintenance. The fundamental downside of this technique is that, unlike other retrofitting methods, it cannot be applied to structures and is expensive in terms of budget. This approach is inefficient for high-rise buildings and is not appropriate for structures erected on soft soils.

5) Method of Mass Reduction

One or more stories may be eliminated using this approach. It is evident that decreasing the bulk will result in a decrease in loading. such that the structure's load is lowered and the building’s life is extendeds, resulting in an increase in the required strength

6) Jacketing Technique

It is the most common type of building retrofitting. Jacketing is the most common way of strengthening a structure's columns and beams. Jacketing is constructed of extra concrete with longitudinal and transverse reinforcement wrapped around existing columns. It strengthens the column's axial and shear strength while avoiding substantial foundation strengthening. Because foundation strengthening is not required, the amount of effort required is minimized, and the shear strength of the column is enhanced. It also enhances the confinement of concrete in circular columns. Steel jacketing helps to lower the column's significant weight while also saving time during construction.

7) Polymer Reinforced with Fibers (FRP)

A fiber-reinforced polymer is an axial strengthening system that employs fiber-reinforced polymers to augment or increase the capacity of reinforced concrete beams. It may be used for both circular and rectangular columns, however the former is preferable. FRP increases the shear capacity of reinforced concrete elements while also increasing the ultimate load-carrying capacity of reinforced concrete portions. The ductility of a reinforced concrete column is also greatly increased. Due to the fact that all resins and some fiber absorb moisture, the composite must be dried before repair.

8) Bonding of External Plates

A proven method that has been applied for many years is external plate or strip strengthening of reinforced concrete beams. The external plate bonding method can be applied to reinforce reinforced concrete beams by completely or partially wrapping steel plates at the junction of a column and beam. A concrete-reinforced part's shear strength is increased by an exterior plate that is perpendicular to any potential shear cracks. Although the improved shear strength is achieved, it is reliant on the beam design, the strength of the existing concrete, and the wrapping technique utilized

II. OBJECTIVES

1. To analyze the skyscraper structure with various retrofitting methods namely shear walls, bracing, and infill strut.
2. To study the ground motion intensity of the earthquake in a skyscraper by using a nonlinear dynamic method (time history analysis) with the help of different earthquakes.
3. To study the deflection, shear, bending, torsion, base shear, and overturning moment for determining the earthquake-resistant building.

III. STRUTRUAL PARAMETERS

A. Structural Specifications (As Per IS 456:2000)

- Number of Stories = 40
- Typical Storey Height = 3m
- Bottom Storey Height = 3m
- Beam Size = 450mm x 600mm
- Column size = 750mm x 750mm
- Beam Cover = 25mm
- Column Cover = 40mm
- Slab Thickness =150mm
- Concrete Grade = M40
- Steel Grade = Fe 500

B. Design Loads (As Per IS 875 Part 1&Part 2)

- Live load = 4kN/m^2
- Dead Load = 2 kN/m^2

C. Retrofitting Elements

- Infill Strut = 230 x 505 mm
- Shear wall = 300mm & 400mm
- Steel Bracing = ISLB 150

IV. Structural Models

The Modelling of the structure and the loading specifications are done on CSI ETABS 19 Software. The specifications are mentioned above

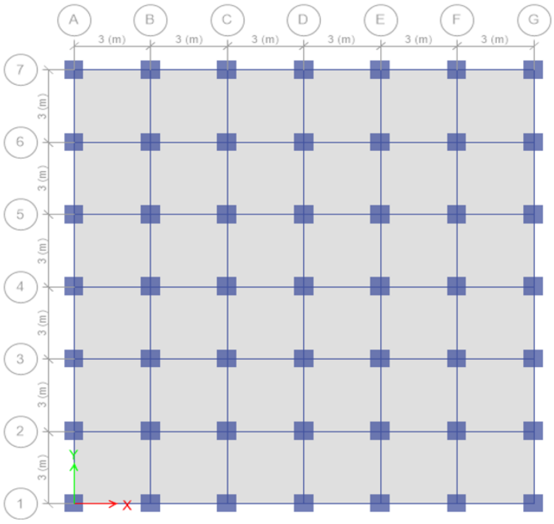


Fig 1 Plan of Building

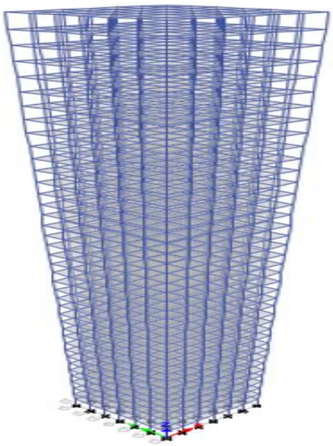


Fig 2 Elevation of Building

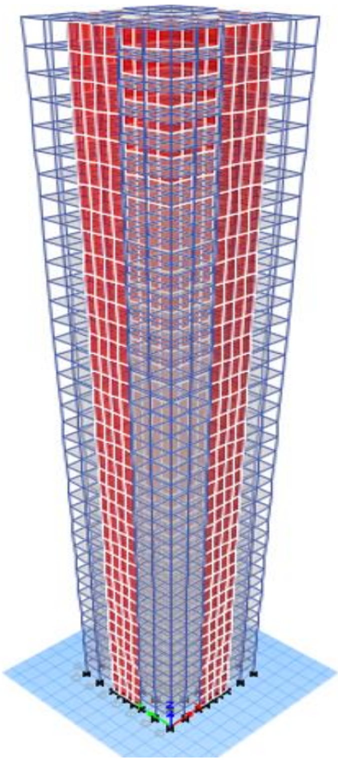


Fig 3 Elevation of Shear Wall Building

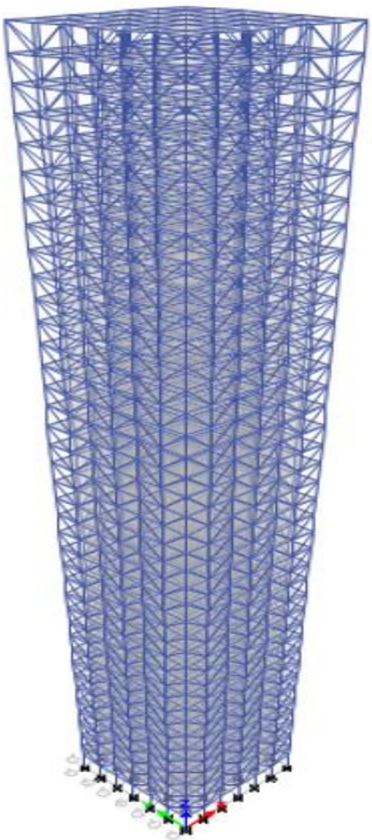


Fig 4 Elevation of Steel Bracing

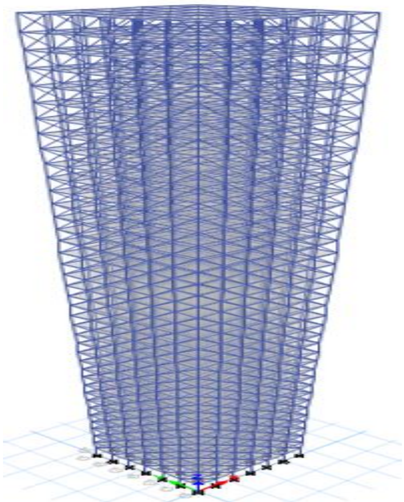


Fig 5 Elevation of Infill Strut Building

V. Seismic Parameters

A. *Seismic Parameters (As Per IS 1893:2016)*

- Seismic Intensity = Very Severe
- Seismic Zone = Zone V
- Zone Factor Z = 0.36
- Soil Type Factor = Soil of Medium Type (II)
- Importance Factor = 1.2
- Building Type = Special RC Moment Resisting Frame
- Response Reduction Factor R= 5

B. *Time History Ground Motion Intensity*

- EL Centro Earthquake
- India-Burma Border N41W
- India-Burma Border N49C

VI. Result

After analysis, the results are presented in graphical formats for optimal comprehension and comparison.

A. *Storey Shear*

A. STORY SHEAR VALUES

Storey Shear (kN)				
Story	***Bare Frame***	***Infill Strut***	***Shear Wall***	***Steel Bracing***
Story40	387.703	416.781	491.9492	434.227
Story35	2585.4886	2779.400	3567.1488	2895.747
Story30	4230.2209	4547.487	5868.5017	4737.847
Story25	5402.0526	5807.207	7508.1595	6050.299
Story20	6181.1363	6644.722	8598.2741	6922.873
Story15	6647.6247	7146.197	9250.997	7445.340
Story10	6881.6704	7397.796	9578.4799	7707.471
Story5	6963.4261	7485.683	9692.8747	7799.037

Story1	6973.0341	7496.012	9706.3212	7809.798

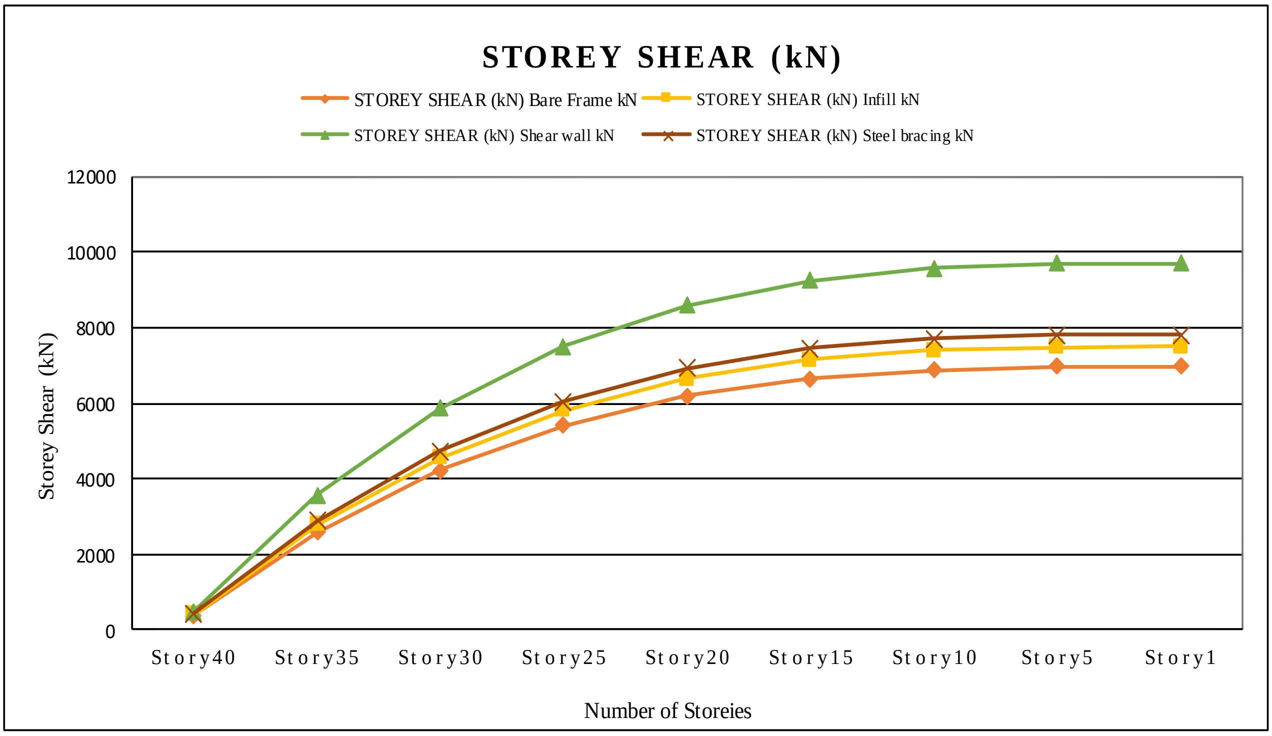


Table 1 and Figure 6 Show the Story Shear Value of different retrofitting methods in this the Difference in

Story shear for infill Struct and steel bracing is 7%, and 12%, and15%respectively as compared to the bare frame.

B. Storey Displacement

B. STORY DISPLACEMENT VALUES

C. Storey Drift

C. STOREY DRIFT VALUES

Story Displacement (mm)				
Story	***Bare Frame***	***Infill Strut***	***Shear Wall***	***Steel Bracing***
Story40	146.1	135.19	115.51	129.09
Story35	129.4	119.05	99.68	113.53
Story30	110.0	100.83	82.79	95.88
Story25	88.9	81.35	65.16	77.01
Story20	67.3	61.55	47.55	57.91
Story15	46.4	42.44	30.91	39.59
Story10	27.3	25.00	16.33	23.06
Story5	11.1	10.22	5.24	9.29
Story1	1.2	1.12	0.38	1.05

Story Drift				
Story	***Bare Frame***	***Infill Strut***	***Shear Wall***	***Steel Bracing***
Story40	0.001035	0.001013	0.001029	0.001024
Story35	0.001233	0.001167	0.001099	0.001189
Story30	0.001373	0.001275	0.001162	0.001301
Story25	0.001437	0.001322	0.001184	0.001345
Story20	0.001424	0.001303	0.001146	0.001319
Story15	0.001334	0.001218	0.00104	0.001221
Story10	0.00117	0.001067	0.000851	0.001054
Story5	0.000932	0.000849	0.000542	0.000819
Story1	0.000385	0.000375	0.000125	0.000367

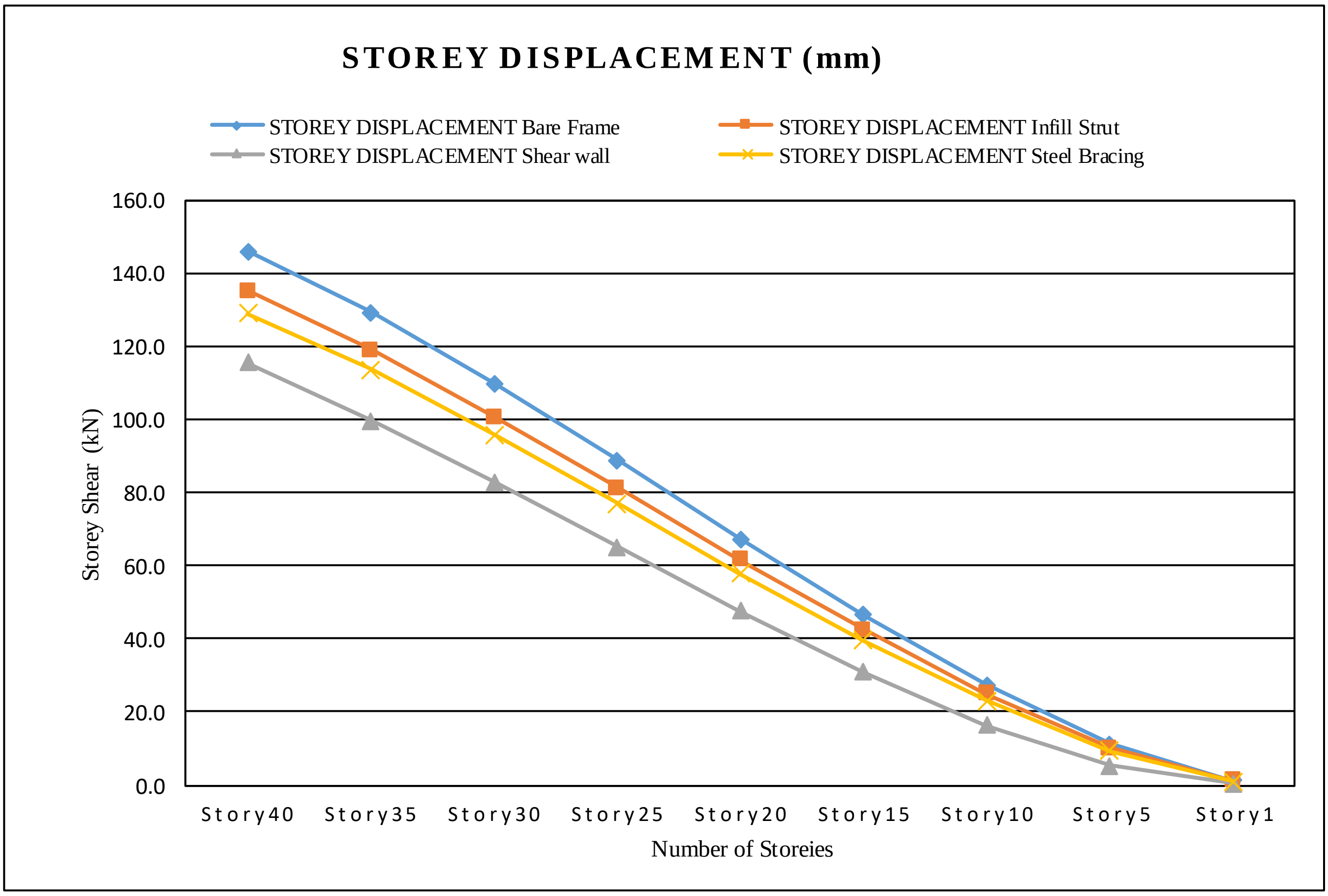


Fig7 Story Displacement Graph for Different Retrofitting

Table 2 and Figure 7 Show the Story displacement value of different retrofitting methods. In this, the difference of story shear for infill strut, shear wall, and steel bracing is 6%, 17%, and 13% respectively as compared to the bare frame structure. The least displacement can be seen in the shear wall method of retrofitting.

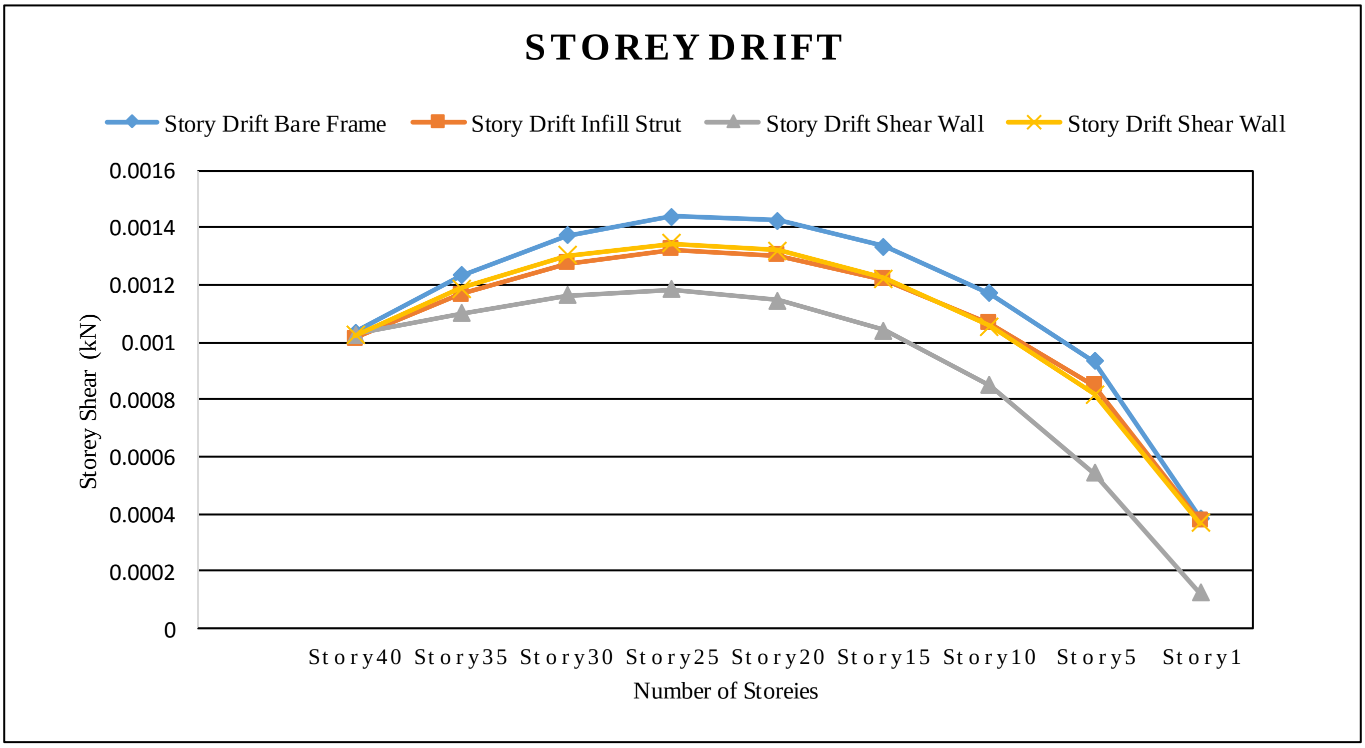


Fig 8 Story Drift Graph for Different Retrofitting

OVERTURNING MOMENT kN-m				
Story	***Bare Frame***	***Infill Strut***	***Shear Wall***	***Steel Bracing***
Story40	33615.20	36136.34	30335.67	37649.02
Story35	341185.16	366774.05	418679.28	382127.38
Story30	648755.12	697411.75	807022.88	726605.73
Story25	956325.08	1028049.46	1195366.49	1071084.09
Story20	1263895.04	1358687.17	1583710.10	1415562.44
Story15	1571465.00	1689324.87	1972053.71	1760040.80
Story10	1879034.96	2019962.58	2360397.32	2104519.15
Story5	2186604.92	2350600.29	2748740.93	2448997.51
Story1	2432660.89	2615110.45	3059415.81	2724580.19
Base	2460559.68	2645101.65	3106748.87	2755826.84

Table 3 and Figure 8 Shows the Story drift value of different retrofitting methods. In this the difference of story shear for infill strut, shear wall and steel bracing are 6%,17%, and 13% respectively as compared to the bare frame structure

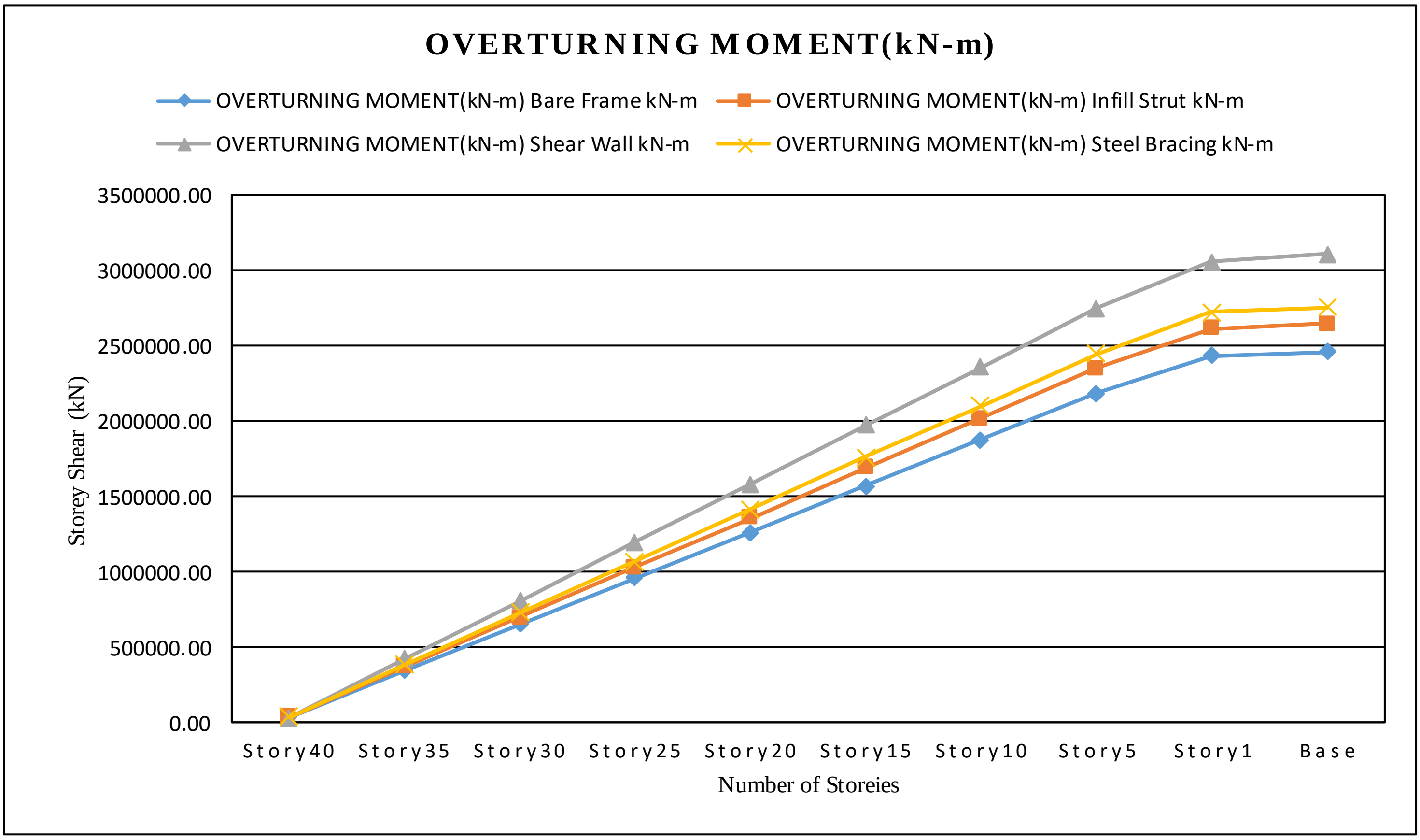
. The Story drift is the difference of the top story to bottom story.

D. Overturning Moment

D. OVERTURNING MOMENTS VALUES

Fig 9 Overturning Moment Graph for Different Retrofitting

Table 4and Figure 9 Show the Overturning Moment value of different retrofitting methods. In this, the difference of story shear for infill strut, shear wall and steel bracing are 4.5%, 11 % and 14% respectively as compared to the bare frame structure. The overturning value of the structure is the maximum at the base and least at the top. It is necessary to determine the overturning moment value for safe design of foundation with retrofitting.



E. Time History Elcentro Ground Motion

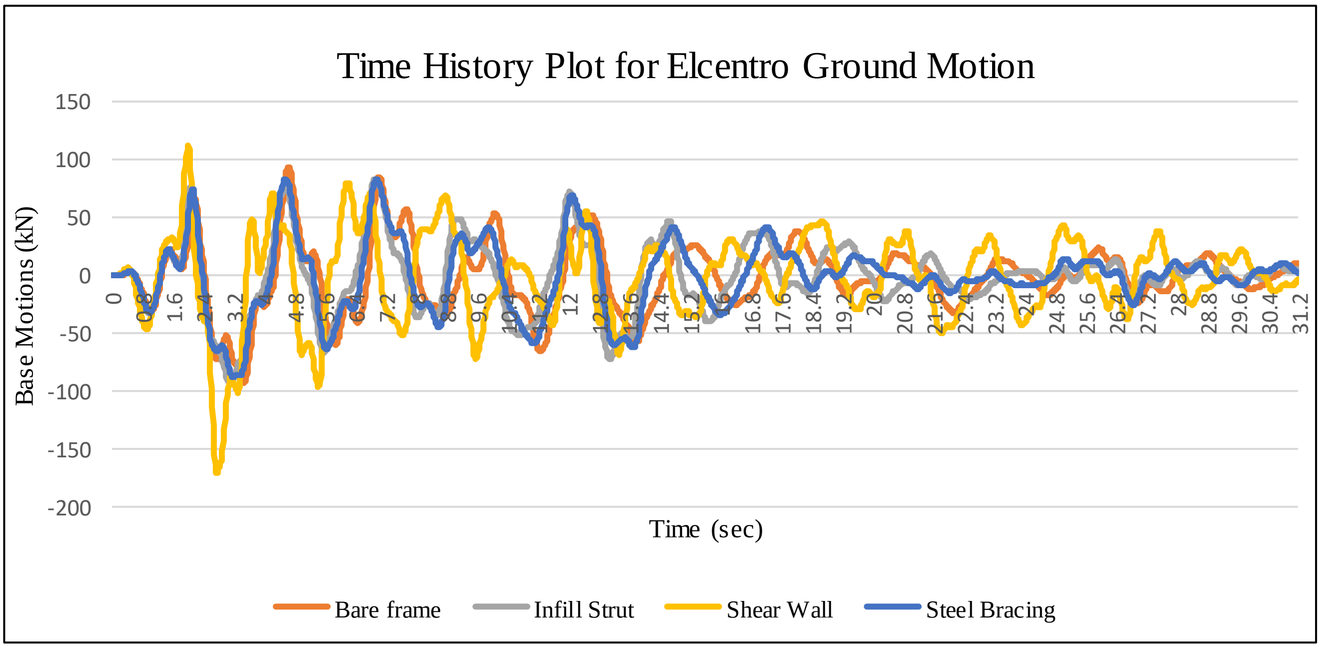


Fig 10 Ground Motion Graph of El Centro for Different Retrofitting

Figure 10 shows the base motion vs time graph for El Centro ground motion of time history value. In this the shear wall ground motion with respect to the time is maximum as compared to the other retrofitting ground motion.

The maximum the ground motion the more time it takes to complete the time period.

F. Time History India-Burma N49E Ground Motion

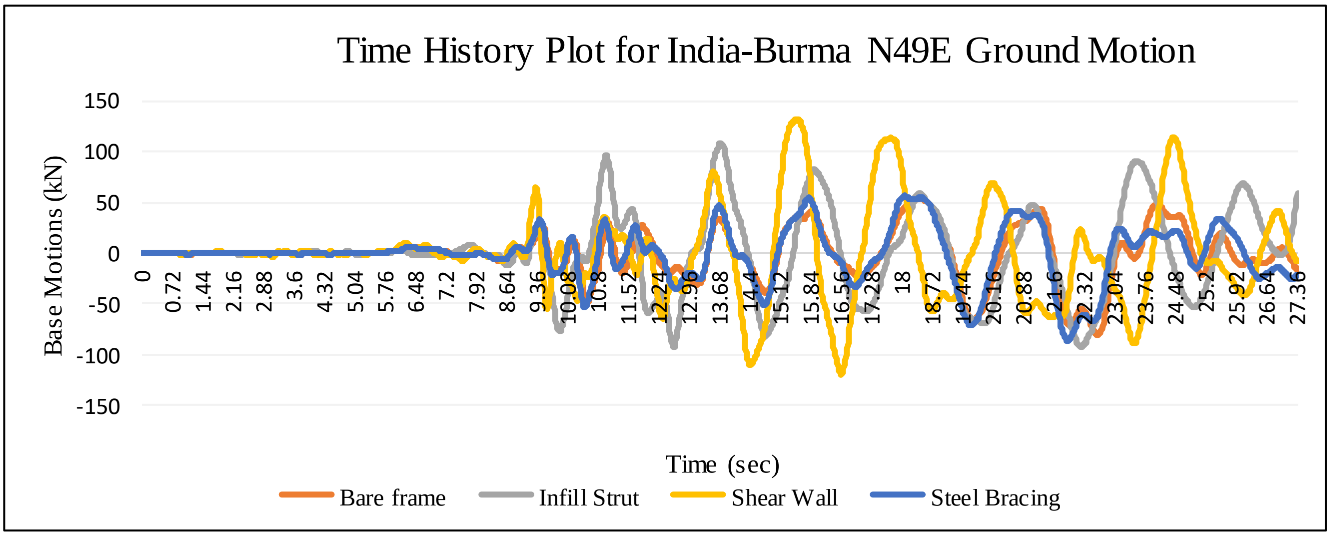


Fig 11 Ground Motion Graph of INDIA-BURMA N49E for Different Retrofitting

Above figure 11 shows the base motion vs time graph for India-Burma N49E ground motion of time history value.

In this the shear wall ground motion with respect to the time is maximum as compared to the other retrofitting ground motion. Whereas the infill strut has the second highest values of the ground motion.

G. Time History India-Burma N49W Ground Motion

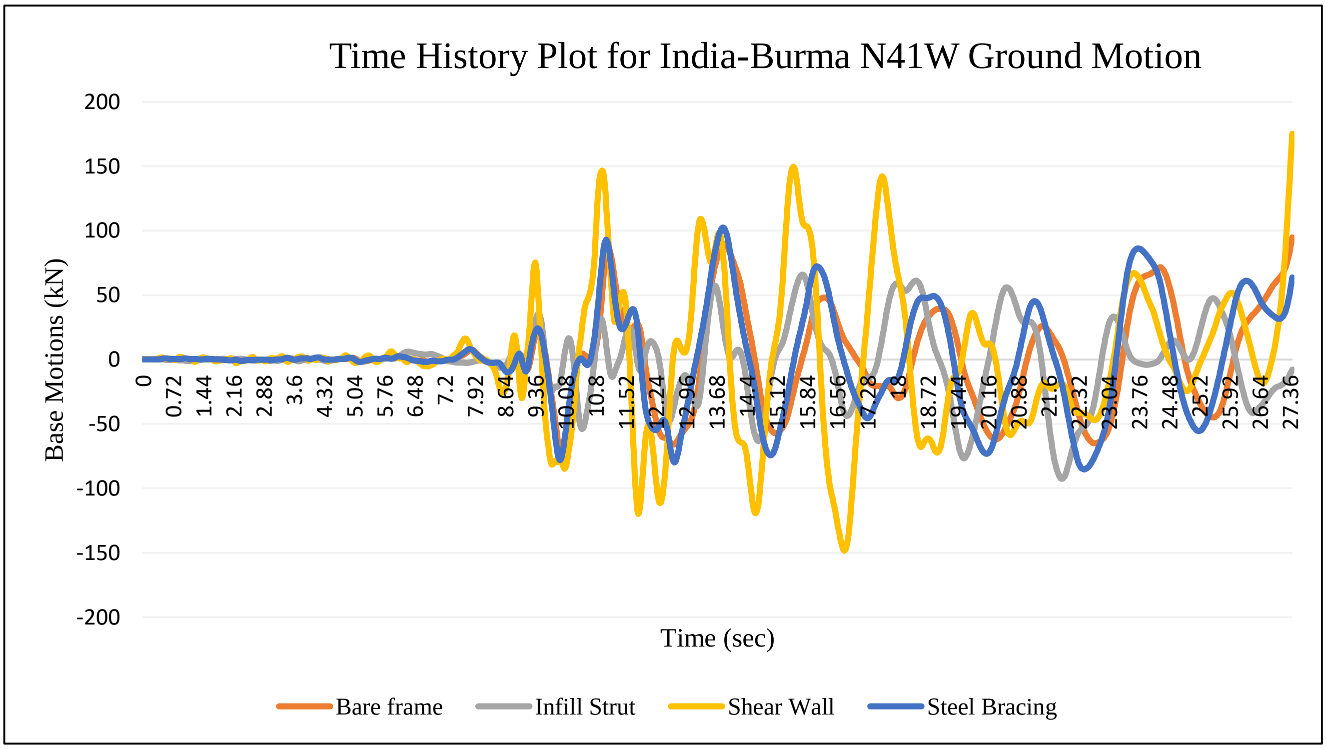


Fig 12 Ground Motion Graph of INDIA-BURMA N49W for Different Retrofitting

Figure 12 shows the base motion vs time graph for India-Burma N49W ground motion of time history value. In this the shear wall ground motion with respect to the time maximum as compared to the other retrofitting ground motion. Whereas the Steel bracing has the second highest values of the ground motions.

VII. CONCLUSION

From the above results of analysis from ETABS Software the following points are concluded.

A. In story shear result the shear wall shows more shear because of the excess structural load but it results in reducing the story displacement in that case of shear wall.

B. Whereas the story drift and also reduces as it is directly proportional to the displacement of upper story to lower story.

C. The infill strut and steel bracing retrofitting has overall 7.5 % and 12 % difference in result as compared to the bare frame result.

D. The ground motion data obtained from the analysis shows the shear wall retrofitting has more ground motion i.e. takes more time for its oscillation to complete which helps in reducing the time of seismic ground motion movement.

E. Whereas the bare frame takes very less time which might result in failure of structure due to ground movement.

F. Overall the shear wall retrofitting is more suitable for the retrofitting of the building as compared to the infill strut or steel bracing.

VIII. REFERENCES

s K. P.Santhosh Babu, "Study of different retrofitting techniques on skyscraper building," in *Material Today Proceding* , 2022.

[2] S. PawanKumara, "Progressive collapse resistance of reinforced concrete frame structures subjected to column removal scenario," in *Material Today* , 2022.

[3] E. R. a. I. Holtz, "Elastic Analysis of Shear Walls in Tall Buildings," vol. 56, no. 6, pp. 1209-1222, 6 1 1960.

[4] Chiyyarath V. Girijavallabhan, "Analysis of Shear Walls With Openings," *Journal of the Structural Divsion,* vol. 95, no. 10, 1969.

[5] IS 456:2000 INDIAN STANDARD "Plain and Reinforced Concerte -Code of Practice", vol. 4, New Delhi: Bureau of Indian Standards, 2000.

[6] IS 800:2007 Indian Standard General Construction in Steel -Code of Practicse, vol. 3, New Delhi : Bureau of Indian Standards , 2007.

[7] INDIAN STANDARDS, IS 4326:1993 Earthquake Resistant Design and Building Construction of Buildings, vol. 2, New Delhi: Bureau of Indian Standards, 1993.

[8] Indian Standards, IS 1893 (Part 1 Criteria for Earthquake Resistant Design, vol. 6, NewDelhi : Bureau of Indian Standards, 2002.

[9] Indian Standard, IS 875 (Part 1) DESIGN LOADS (OTHER THAN EARTHQUAKE), New Delhi: BUREAU OF INDIAN STANDARDS, 1981.

[10] Indian Standards, Criteria for earthquake Resistant Design of Structures, 6, Ed., New Delhi: Bureau of Indian Standards, 2016.

[11] Seth Frost-Tift, Amit Mahadevia, Deborah Mills,Adam Reeder,Adrienne Sheldon,John Squerciati,, "Homeowner's Guide to Retrofitting Six Ways to Protect Your Home From Flooding", 3, Ed., Dewberry: Federal Emergency Management Agency, JUNE 2014.

[12] Clough.R., King I.P., and Wilson. E.I, "Strucural Study of Multi Story Structures," 1964.

[13] Sharma, R., & Dhabliya, D. (2019). A review of automatic irrigation system through IoT. International Journal of Control and Automation, 12(6 Special Issue), 24-29. Retrieved from www.scopus.com

[14] Vadivu, N. S., Gupta, G., Naveed, Q. N., Rasheed, T., Singh, S. K., & Dhabliya, D. (2022). Correlation-based mutual information model for analysis of lung cancer CT image. BioMed Research International, 2022, 6451770. doi:10.1155/2022/6451770