# Performance of Existing Building Using Different Approaches

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***Abstract*- Old buildings serve as observable evidence of a community's cultural history, as well as the people and businesses who were instrumental in founding and developing the place. Renovating historic buildings is crucial for preserving the history and culture of the country. Existing structures can be repaired and reused, which saves waste and improves resource efficiency. It is not necessary to produce new materials or discard existing ones that have been dismantled. Additionally, energy is saved for reconstruction. In addition, demolishing buildings discharges pollutants and chemicals into the environment. Some recently developed materials and techniques can play vital role in structural repairs, seismic strengthening and retrofitting of existing buildings, whether damaged or undamaged. The primary concern of a structural engineer is to successfully restore the structures as quickly as possible. Selection of the right materials, techniques, and procedures to be employed for the repair of a given structures have been a major challenge. An existing G+2 story RC framed residential building situated in Kankawali is taken for this study. To study this Structure Non-Destructive Tests and Destructive Tests are taken. When this building was analyzed with Finite Element Software that is SAP 2000, some columns are failed. The failed columns were retrofitted using concrete Jacketing.**

***Index Terms*- Non-Destructive Tests, Destructive Tests, Retrofitting, Finite Element Software (SAP 2000)**

## I. INTRODUCTION

The conventional approach for assessing the quality of concrete in buildings or structures involves conducting tests on specimens that are cast concurrently to measure their compressive, flexural, and tensile strengths. Non-destructive testing of concrete is a technique employed to derive the compressive strength and other pertinent characteristics of concrete from pre-existing constructions. This examination yields prompt outcomes and authentic assessments of the strength and characteristics of concrete structures. Additionally, it is important to acknowledge that the concrete present in specimens may exhibit variations when compared to the concrete found in the actual construction. This discrepancy might arise due to dissimilar curing and compaction circumstances. Lastly, it is crucial to recognize that the strength qualities of a concrete specimen are contingent upon its size and shape. The measuring of strength qualities in structural concrete is not possible through direct means due to the involvement of destructive forces. However, many non-destructive evaluation methods have been developed to address this limitation.

To restore damaged columns Jacketing is used. Jacketing is the most popularly used method for restoring of building columns. Jacketing is the process by which a section of an existing structural member is restored to original dimensions or increased in size by encasement using suitable materials. The Global retrofitting technique targets the seismic resistance of the building. The Global retrofitting both the shear strength and flexural strength and of the column and beam. Retrofitting increases the seismic resistance capacity of the building without any demolition. It increases the shear strength and lateral load capability of the building Strength and also increases confinement of concrete in circular column is also improved. The local retrofit technique includes the concrete, Fibre reinforced polymer steel or Jacketing to the structural members like beams, columns, beam column joint, foundation. Concrete jacketing is made with adding a new layer of concrete with longitudinal reinforcement and closely spaced ties.

Structures over 30 years old must be maintained and renovated for safety and life. Many projects from this century and earlier collapsed due to design faults, material degradation, unexpected loads, and physical infirmities. This crumbling building could hurt inhabitants if used again. Structure viability depends on annual examinations and diagnoses. Codes, non-destructive testing, and auditing standards should govern structural audits. By improving maintenance and repair, audits extend structural life and occupant safety [1]. Reinforced concrete jacketing makes columns stronger and ductile [9]. A close-spaced jacket transverse reinforcement makes columns ductile. This approach guarantees code-compliant reinforced concrete. Axial load P and moment M determine column seismic demand. The projected variable P and M column width and section data meet requirements. Jacketed concrete and steel decrease and strengthen columns. Strength of jacket and column areas. Demand for concrete and steel must rise. Buildings need jacketing to decrease seismic shaking. Public awareness of building inspection and maintenance is crucial. Old civil engineering. Heritage monuments are strong. The motif is gone from modern architecture. Improved collapse mechanisms cause modern buildings to collapse early. Etc., erosion causes splitting, cracking, corrosion, delamination, carbonation. Hire professionals to inspect it occasionally [16]. CFRP affects repaired specimens. Studying bond parameter sensitivity and punching performance. Redesigned connectors increased punch-through shear 20–90% [18]. Many creative retrofitting techniques can strengthen and restore vulnerable structures worldwide. Building hospitals necessitates reinforcing and altering structures. Buildings are stronger, earthquake-, flood-, and disaster-resistant. Building to specs collapsed at six stories. Minor disasters, rising groundwater pressure, and poor craftsmanship suggest early reinforcement [6, 17].

Symptoms greatly affect structural strength and durability. Building was built to last 50+ years. Expected longevity is hard. In addition to maintenance, structures need extensive repairs and restoration. Insufficient skill or money may delay or ignore structural repairs, producing major problems. Learn the best facility repair procedures and materials to save time and money. The study examines structural repair and rehabilitation utilizing various materials and methodologies. Auditing commenced by Indian Structures Engineers. Historical building evaluations benefit from structural audits. Guards the building and grounds. Research advises building maintenance and retrofitting. Home expansions and structural audits are covered. Retrofitting strengthens beams and columns. Retrofit joints are more flexible and reduce shear distortion. Seismic alignment may remove slab reinforcement. Retrofitting RC increases beam and column axial load and moment. Retrofits increase beam and column axial and moment loads [4].

Retrofitting alters structure function, according to this survey. One ambition is to turn the 10-story commercial building into a data center. Most seismic retrofits boost performance. Meeting rising load criteria without a remodel requires innovative solutions that save money, optimise functionality, and demonstrate a strong commitment to energy efficiency and environmental sustainability. The structure was modeled using ETABS and load values. Data center loads impact retrofitting and failure severity. Innovative research examines sustainable construction energy efficiency. Aged structures crack, delaminate, corrode, and separate. Modern materials and equipment can restore historic buildings [8].

## II. STRUCTURAL AUDIT OF EXISTING STRUCTURE

Firstly, the selection of the site is done. The site is located in Kankawali, Maharashtra. Figure 1 displays the final product of the three-dimensional modelling carried out with the assistance of the SAP 2000 software. The two sides of the structure are depicted in Figure 2; the long side has five bays along the X axis, and the short side has four bays along the Y axis. The total built are of exiting RC structure is 359.40 sqm. As was said earlier, the length of the long side is 22.40 m, while the length of the short side is 16.4 m. It is evident from this diagram that the building has a total of three storey, total height 9.6 m.

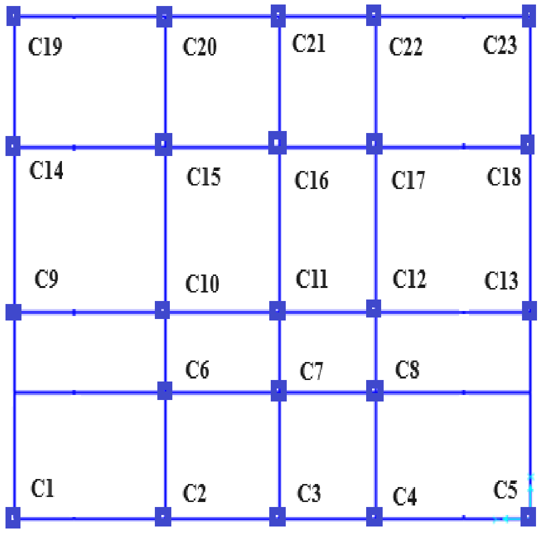



**Fig. No. 1:** The top view of the existing structure.

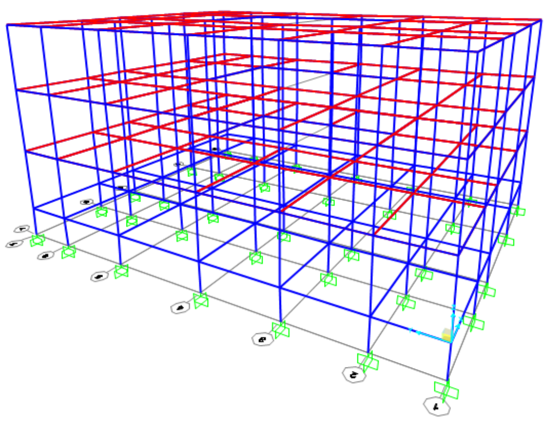


**Fig. No. 2**: Elevation view of G+2 existing structure

The ground and first floor columns and beams were subjected to a rebound hammer test in accordance with IS 13311-2 (1992). The average compressive strength of a GF column is 13.69 MPa, while the average compressive strength of an FF column is 13.69 MPa. Both floor beams have a compressive strength of 13.59 MPa. The depth of carbonation in concrete measured on the concrete core of a 35-year-old structure was 44.9 mm. The Ultrasonic pulse velocity test is performed on concrete to assess the quality of concrete by passing ultrasonic pulse velocity through it as per IS: 13311 (Part 1) – 1992. The average pulse velocity by cross probing is 3288.00 mm/sec, that indicate concrete quality grading is medium on ground floor. Whereas the average pulse velocity by cross probing is 2440.67 mm/sec, that indicate concrete quality grading is doubtful and 2018.33 mm/sec, that indicate concrete quality grading is doubtful for first and second floor respectively. One 75 mm diameter concrete core extracted from existing ground floor columns showing compressive strength is 13.69 MPa. One 75 mm diameter concrete core extracted from existing ground floor columns showing compressive strength is 7.23 MPa.

Carbonation of concrete is a process by which Carbon di Oxide from the air penetrates into the concrete and reacts with calcium hydro-oxide to form calcium carbonates. In the presence of moisture, CO2 changes into dilute carbonic acid which attacks the reinforcement and also reduces alkalinity of concrete. In this test Phenolphthalein solution is used as indicator. One 75 mm diameter concrete core extracted from existing ground floor columns showing depth of carbonation is 05 mm. One 75 mm diameter concrete core extracted from existing ground floor columns showing depth of carbonation is 42 mm. Overall performance of building is unsatisfied, repair and strengthening were needed. Water stagnating areas in a structure attract dampness, leakage etc. and are subjected to alternate wetting/drying cycle. Such areas are more prone to early corrosion of embedded steel reinforcement. Performance of building at Ground Floor is satisfied. Exterior structural members need to be repair on urgent basis. Performance of building at First Floor is unsatisfied. Make up reinforcement may have to be provided in case of deficiencies due to deterioration and Chajja and balcony’s need to be re constructed. Performance of building at Second Floor is very poor. Major Strengthening repair ignoring the original concrete and reinforcement or demolition and recasting

## III. FINITE ELEMENT METHOD APPROACH

For the nonlinear modelling frame elements can be modelled by introducing plastic hinges near the rigid end of the beam and column. In SAP 2000 these hinges (known as auto hinges) are in-built, and it extract the hinge properties. From the non-linear static analysis apart from the Pushover curve, plastic hinges can also be evaluated because it is one of the important assignments in the non-linear analysis. The plastic hinges are based on the default hinge model which is defined in SAP 2000. For beam section, the moment M3 hinge type was used as well as the column section, which is the Interacting P-M2-M3. The computation of the building's dead loads considers the components' individual weights as well as the building itself. It has been taken into consideration that the self-weight of the walls will place an additional pressure on the beams. The additional permanent load of 8.0 kN/m$^2$ that is imposed by the structures outside walls, which are positioned along the perimeter of the structure, must be handled by the perimeter beams of the structure. Beams can carry an additional permanent load of 4.50 kN/m$^2$ that is applied to the internal walls. The slabs have live loads of 2.00 kN/m$^2$ and reinforcement of columns and beams is calculated as per balanced section.

Table No. 1: Information’s of the columns (Calculated as considering balance section)

| Name | Dimensions (mm) | Longitudinal reinforcement | Transverse reinforcement |
|---|---|---|---|
| **Ground Floor** | | | |
| C1, C5, C19, C23 | 230 x 450 | 6#12 | 6 mm # @ 120 mm C/C. |
| C2, C3, C4, C9, C13, C14, C18, C20, C21, C22 | 230 x 525 | 8#12 | 6 mm # @ 150 mm C/C. |
| C6, C7, C8, C10, C11, C12, C15, C16, C17 | 230 x 675 | 8#16 | 6 mm # @ 150 mm C/C. |
| **First Floor** | | | |
| C1, C5, C19, C23 | 230 x 450 | 6#12 | 6 mm # @ 120 mm C/C. |
| C2, C3, C4, C9, C13, C14, C18, C20, C21, C22 | 230 x 450 | 8#12 | 6 mm # @ 150 mm C/C. |
| C6, C7, C8, C10, C11, C12, C15, C16, C17 | 230 x 525 | 8#16 | 6 mm # @ 150 mm C/C. |
| **Second Floor** | | | |
| C1, C5, C19, C23 | 230 x 300 | 6#12 | 6 mm # @ 120 mm C/C. |
| C2, C3, C4, C9, C13, C14, C18, C20, C21, C22 | 230 x 450 | 6#12 | 6 mm # @ 150 mm C/C. |
| C6, C7, C8, C10, C11, C12, C15, C16, C17 | 230 x 450 | 6#16 | 6 mm # @ 150 mm C/C. |

Table No. 2: Information’s of the beams of all floors (Calculated as considering balance section)

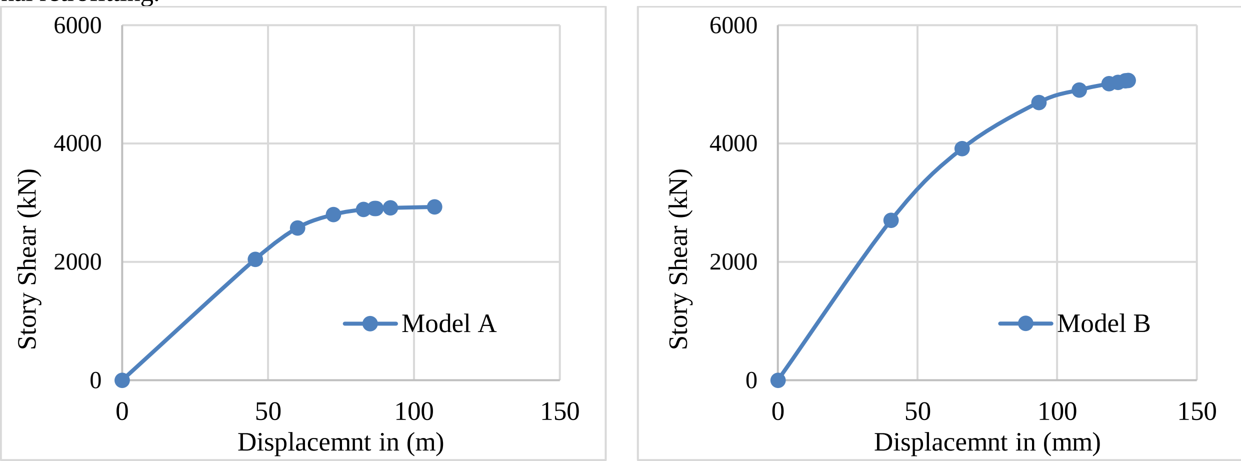
| Name | Dimensions (mm) | Longitudinal reinforcement | Transverse Reinforcement |
|---|---|---|---|
| B1, B2, B3, 4, B5, B7, B8, B9, B10, B11, B12, B13, B14, B23, B24, B25 | 230 x 450 | Top: 2#10, Bottom: 5#12 | #8mm @ 300 mm C/C. |
| B15, B16, B17, B18, B19, B20, B21, B22 | 230 x 600 | Top: 2#10, Bottom: 4#16 | #8mm @ 225 mm C/C. |

| | | | |
|---|---|---|---|
| B26, B27, B28, B29, B30, B31 | 230 x 600 | Top: 2#10,<br>Bottom: 5#16 | #8mm @175 mm C/C. |

## IV. EVALUATION OF DEMAND BY NONLINEAR STATIC ANALYSIS (NSA)

The comparison of the outcomes obtained from a nonlinear static analysis, commonly known as pushover analysis, between an established reinforced concrete structure and a recently constructed structure can yield significant insights regarding the performance and safety of both structures when subjected to seismic or other lateral loads. The comparison of the capacity curves, also known as pushover curves, between the current and new structures indicates that there is a requirement to raise the base shear capacity by 75% and the ductility demand by up to 30%. The current structure's capacity does not fulfill the desired performance targets and code requirements. The ductility of both structures can be analyzed by comparing the displacement demands of the outgoing structure (Model A) at the point of collapse prevention.

The elements within the current structure have surpassed the permissible limits of deformation, whereas the newly devised structure has successfully retained its rigidity and durability. During the process of structural audit and comprehensive examination, weaknesses in the current structure are identified. These vulnerabilities may include localized deterioration, excessive cracking, or inadequate detailing. It is imperative that the design of the new structure incorporates measures to effectively mitigate the identified flaws, hence enhancing its seismic performance. Based on the comparison, it can be concluded that the current structure necessitates retrofitting or strengthening. Evaluate if the new structure is designed to meet current seismic design standards without the need for additional retrofitting.




**Existing structure (Model A)** **Newly design structure (Model B)**

**Fig No. 3.** Capacity curve in Nonlinear Static Analysis (NSA)

## V. RETROFITTING OF EXISTING STRUCTURES

The retrofitting of existing structural parts holds significant importance primarily because it enhances the strength of degraded structural components and mitigates additional distress in concrete structures. The primary cause of strength deficiencies in concrete structural elements can be attributed to design issues, the deterioration of concrete structures resulting from the aggressive actions of harmful agents, and substandard workmanship during construction. Following a thorough examination of the site and careful inspections conducted by authorized individuals, a comprehensive study and diagnosis of the cracks has been undertaken. The commencement of the retrofitting procedure involves the implementation of an appropriate retrofitting approach and the utilization of compatible materials. There are several techniques available for retrofitting structural members, including section expansion, external plate bonding, external post-tensioning, grouting, and the use of fiber reinforced polymer composites. The process of selecting an appropriate retrofitting technique and implementing it is dependent on the extent of damage and the desired capacity to be restored.

The steel jacketing method entails completely encasing the column by utilizing thin steel plates that are positioned at a slight distance from the surface of the column. The resulting space between the plates and the column surface is then filled with non-shrink grout. Steel angles are strategically positioned at the corners of the pre-existing cross-section, upon which either transversal straps or continuous steel plates are affixed through welding. In practical applications, the straps are commonly subjected to lateral stress, either using specialized wrenches or by preheating them to temperatures ranging from around 200 to 400 $^oC$, before the welding process takes place. Typically, any gaps existing between the steel cage and the pre-existing concrete are commonly sealed with non-shrink grout. In situations when there is a need for corrosion or fire protection, it is possible to apply a layer of grout concrete or shotcrete cover. The application of corrugated steel jacketing technology has been found to be effective in the rehabilitation of columns and beam-column joints. The steel jacket encapsulates inadequate connections, while the space between the concrete and the steel jacket is filled with non-shrink grout. A gap is intentionally introduced between the beam jacket and the column face to mitigate the potential increase in flexural strength of the beam. This increase in strength could lead to the development of excessive forces inside the joint and column. In relation to this matter, the retrofitting of the columns is achieved through the utilization of steel plate jacketing with a thickness of 8 mm, as depicted in Figure 4

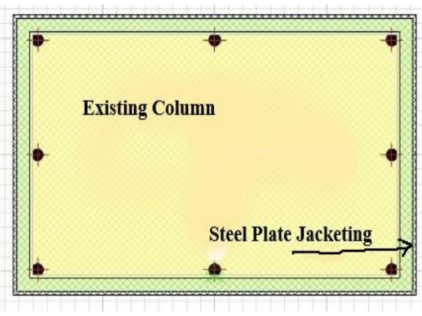
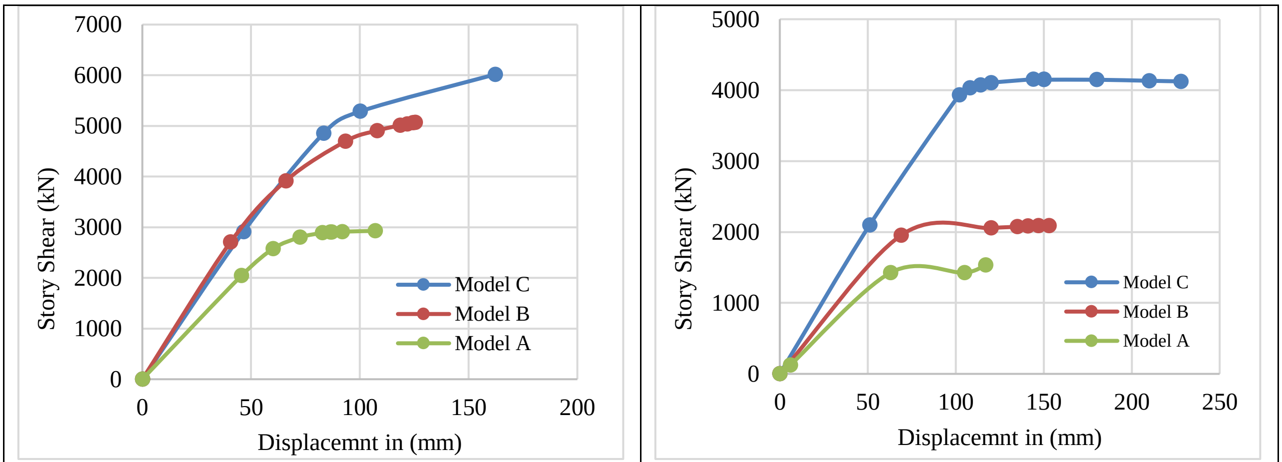



**Fig No. 4.** Existing column with steel plate jacketing

## VI. NSA for Existing Structure with Steel Plate Jacketing

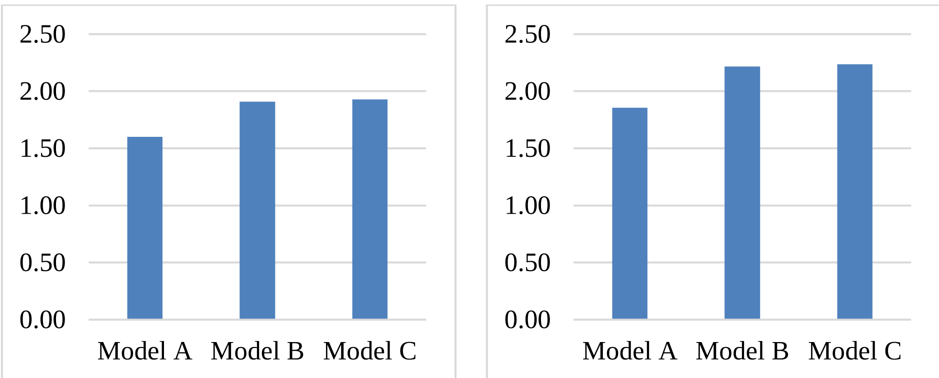
When considering a steel plate jacketing (Model C) applied to an existing structure and analyzing its response using pushover analysis, it can be observed that the base force is directly proportional to the displacement within a specific range. At the onset, there is a minimal amount of displacement observed when the base force is incrementally increased. According to the data presented in Figure 5, the base force exhibits an upward trend, reaching a maximum value of 4850 KN when the spectral displacement is around 0.028 m. Within this region, the curve exhibits a linear behavior. In addition to the force, the displacement exhibits a progressive increase as the base force diminishes.

The NSA for existing structure (Model A) and the retrofitted structure (Model C) is carried out and the curves in 'X' direction obtained as shown in figure 6.2. In the case of model, A, B, & C the base shear in 'X' direction nearly equal to 2574.74, 3914.88 and 4852.73 kN respectively. The corresponding spectral displacements for the same are 0.020, 0.022 and 0.028 m respectively. The ultimate displacements are 0.032, 0.042 and 0.054 m respectively. model A, B, & C the base shear in 'Y' direction nearly equal to 1427.91, 1955.17 and 3933.19 kN respectively. The corresponding spectral displacements for the same are 0.021, 0.023 and 0.034 m respectively. The ultimate displacements are 0.039, 0.051 and 0.076 m respectively.




*a)* 'X' direction. *b)* 'Y' direction.

**Fig No. 5.** Capacity curve of all three models



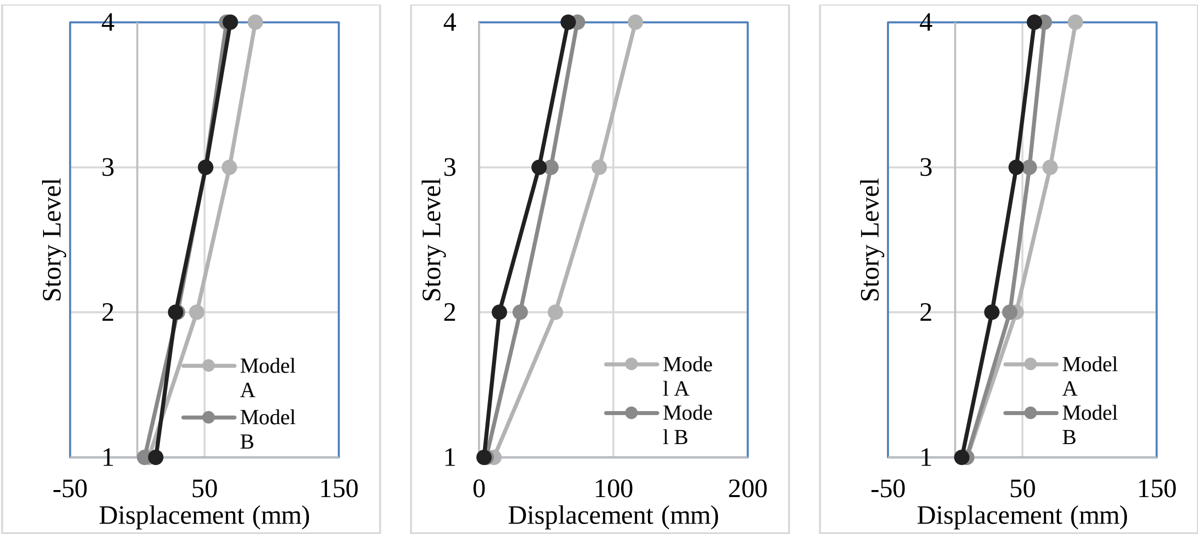

*c)* 'X' direction. *d)* 'Y' direction.

**Fig No. 6.** Ductility ratio obtain in NSA for all three models in

## VII. Nonlinear Time History Analysis

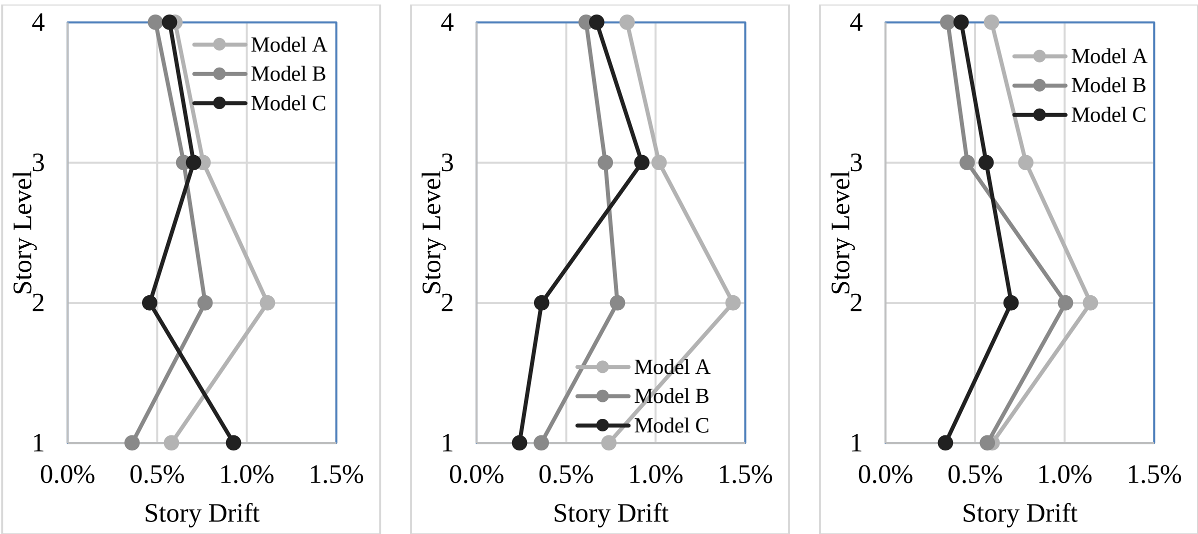
Nonlinear time history analysis is a numerical simulation technique used in structural engineering sand other fields to analyze the dynamic response of structures and systems subjected to time-varying loads or excitations. Nonlinear time history analysis must be done to investigate the precise nonlinear behaviour of structures. The building is subjected to actual ground motion recordings using this technique. It is a step-by-step analysis of dynamic response of a structure to a given loading that may change with time. If the load includes ground accelerations, the velocities, acceleration, and displacement are relative to the ground motion. Vertical loads (dead and live loads), member characteristics, and member nonlinear behaviours are established and allocated to the models that represent the buildings in step one. Ground motion record is described as an acceleration versus time function. Following this, the parameters for the analysis and the time history are established to conduct a nonlinear time history analysis. The number of output time steps times the output time-step size equals the overall analysis time.

Based on the data presented in Figure 7, it is observable that Model A exhibits a story displacement of 87.88 mm, indicating a performance level that prevents structural collapse. Conversely, Model B and Model C demonstrate story displacements of 66.43 mm and 69.30 mm, respectively, based on the Loma Prieta earthquake data. In a comparable manner, Model A exhibits a maximum story displacement of 116.42 mm for the Kobe Earthquake data and 89.72 mm for the Superstition Hills earthquake data. The retrofitting of Model C, which involves the application of steel plates to the structure, demonstrates a decrease in the maximum displacement of the stories by 66.24 mm and 59.03 mm for the Kobe and Superstition Hills earthquake data, respectively as shown in Figure No. 7. The analysis of Figure 8 reveals that Model A demonstrates a peak tale drift of 1.1% when considering the Loma Prieta earthquake data. In contrast, the data from the Loma Prieta earthquake indicates that Model B and Model C have story displacements of 0.9% and 0.8% respectively. Similarly, Model A demonstrates a maximum story drift of 1.4% for the Kobe data and 1.1% for the Superstition Hills earthquake data. The implementation of steel plates on the structure, known as the retrofitting of Model C, is shown to result in a reduction of the maximum story drift of the stories. Specifically, the Kobe and Superstition Hills earthquake data indicate a decrease of 0.9% and 0.7%, respectively, as depicted in Figure No. 8.




*a)* Loma Prieta Earthquake *b)* Kobe Earthquake *c)* Superstition Hills Earthquake

**Fig. No. 7.** Story displacement for all models



*a)* oma Prieta Earthquake *b)* Kobe Earthquake *c)* Superstition Hills Earthquake

**Fig. No. 8:** Story drift for all models

## 6. CONCLUSION

1. A comprehensive examination of the results indicated that the model exhibited enhanced structural performance after undergoing retrofitting. This suggests that the structural approach employed for this modification is a suitable and optimal design for the preexisting building.
2. The purpose of the study was to examine the reaction of a pre-existing structure. The results indicated that the structural integrity of the building was compromised subsequent to the implementation of Model A, which had undergone non-destructive testing (NDT) in the field. Subsequently, reinforced concrete (RC) jacketing was applied.
3. When analyzing the data from the Loma Prieta earthquake, it was shown that the maximum narrative drift fell by 62.11% when comparing Model A with Model B. In a similar vein, when examining the Kobe earthquake data, it was seen that the highest story drift dropped by 97.84% when comparing Model A with Model B. Likewise, for the Superstition Hills earthquake data, the maximum story drift decreased by 83.17% when comparing Model A with Model B

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