DYNAMIC ANALYSIS OF VERTICAL EXPANSION OF EXISTING STRUCTURES USING RETROFITTING TECHNIQUES BY USING ETABS SOFTWARE

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Abstract: - The increase in urbanization and decrease in available land limits have the demand for tall structures. This study investigates the solution at quite low cost for low rise buildings that seems more feasibility and cost effective by means of adding three additional steel storeys to an existing six-storey reinforced concrete (RCC) building. The research focuses on structural retrofitting techniques, ensuring adequate load-bearing capacity through strengthening of footings and columns. Dynamic analysis is performed using ETABS, considering seismic (IS 1893:2016) and wind load (IS 875:2015) provisions for Zone IV and wind speed of 47 m/s. Various retrofitting techniques, including column jacketing, steel bracing and fiber-reinforced polymer (FRP) wrapping methods were introduced to enhance structural integrity but column jacketing has been used in this dissertation. The study compares structural performance parameters such as displacement, storey drift and storey shear forces between the original and expanded model. Results indicates that steel construction reduces additional weight while maintaining stability, making it a viable solution for vertical expansion. Retrofitting measures ensure structural safety and economic feasibility, with cost-effectiveness analysed against alternative methods. The findings contribute to practical guidelines for vertical expansion using hybrid RCC-steel structures, optimizing urban space utilization while maintaining structural safety and efficiency.

Keywords: Vertical Expansion, Retrofitting, RCC-Steel Hybrid Structure, Structural Analysis, ETABS, Seismic Design, Wind Load, Urban Development.

1. Introduction

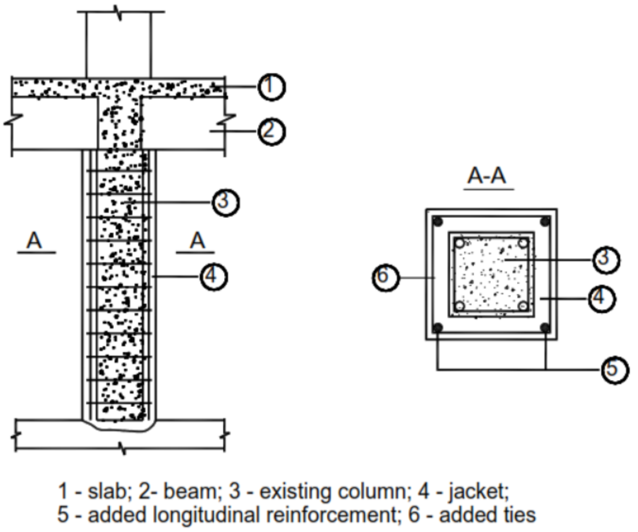
Vertical construction serves as a strategic industry solution to deal with citywide urbanization speed and scarce land availability within urban areas. Current building space needs have initiated upward extension as a proven method to exploit existing infrastructure efficiently. This method enhances land efficiency and cuts down both environmental expenses and construction project economic expenses. The preferred approach for building extensions involves hybrid constructions of reinforced cement concrete (RCC) with steel structure because these methods enable both efficient designs and rapid construction periods as well as adjustable features.

This research shows that a six-story RCC structure can be vertically expanded through the implementation of two additional steel storeys above its existing framework. The original RCC design with columns, beams and slabs establishes a dependable structure to resist all static and lateral forces. The increased weight of two additional storeys puts stress on a structure designed before this modification. So, it needs to strengthened both footings and columns located in the RCC building to handle the additional loads generated by the new steel extension. The lightweight nature and ductility of steel make it a perfect substance for constructing upper levels because this material cuts down structural weight and removes construction delays and design constraints.

Types of Retrofitting Techniques for Vertical Expansion

Several retrofitting approaches can be used to increase the building's strength and load bearing capability when considering the vertical enlargement of an existing structure. By strengthening important structural elements like slabs, foundations, beams and columns, these methods assist guarantee that they can sustain more floors while still adhering to safety standards. Some of the most popular retrofitting techniques are listed below:

1. Jacketing (Column, Beam and Slab Jacketing)
2. Steel Bracing and Strengthening
3. Fiber Reinforced Polymer (FRP) Wrapping
4. Base Isolation and Dampers for Stability
5. Post-tensioning and Strengthening Methods



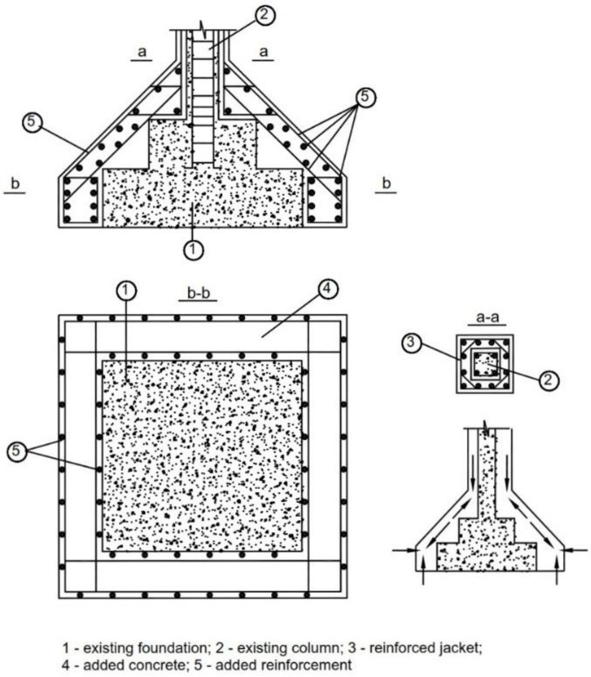


Figure 1 Strengthening of column and footing

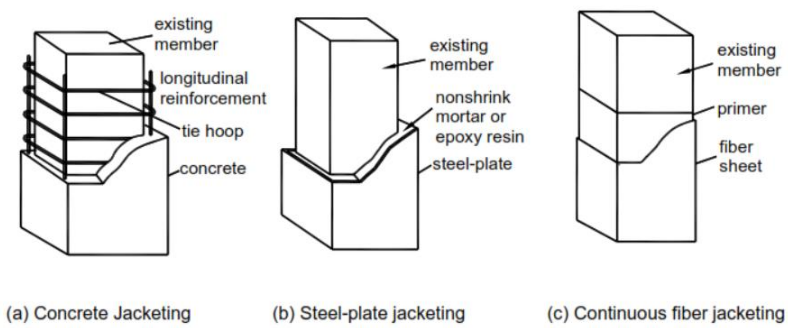


Figure 2 Various jacketing methods for columns

Challenges of Constructing Additional Stories on Existing Buildings

Besides its benefits, vertical expansion has a number of issues that must be resolved:

1. Structural Capacity Limitations: Older structures need to have their structural integrity evaluated by various testing methods like NDT and reinforced properly because they were not intended to support more floors over it.
2. Strength of the Foundation and Load Bearing Capacity: The current foundation needs to be robust enough to support extra weight. For this, proper safety and preparations should be maintained strictly. Various retrofitting methods like foundation strengthening or underpinning might be necessary in this case.
3. Seismic and Wind Load Considerations: Buildings with more storeys are more prone to lateral loads like earthquakes and wind especially in high seismic prone regions. To ensure safety and serviceability, appropriate retrofitting methods are required.
4. Construction Challenges in Occupied Buildings: Since vertical expansion is frequently carried out on buildings that are already in use, it is crucial to schedule construction activities to cause the least amount of disturbance possible in active building.
5. Regulatory Compliance and Approval: Before extending any structure, proper guidance, high qualified structural engineering team, required licenses and permissions must be secured with considerations of local construction codes and regulations must be adhered to.

2. Literature Survey

Arpit M. and Ajay Radke (2024) [1] evaluated the possibility of using retrofitting method for vertical extension of existing RCC residential buildings. They were stated to conclude that the application of structural strengthening technologies like fiber-reinforced polymers (FRP), steel jacketing, and concrete overlay increases load-carry capacity and also resistance to earthquakes. They stressed the required of structure assessment prior vertical extension considering such as foundation depth, material degradation, as well as any contribution loads that is be imposed. They showed that employs lightweight materials in retrofit and enhance structural sustainability and resilience of the scaffolding. They also pointed out these along with financial implications and policy constraints as most important issues affecting the viability of the project. In brief, they suggest that expansion vertically should be undertaken by the ideal mixture of outfitting techniques and materials used which must be both affordable and safe.

M. C. Masera and G. M. Verderame (2023) [2] examined the transformation of environmentally conscious rehabilitation, in terms of material, seismic efficiency, energy experiment among others, inside whatever conventional firewall it may be. For enhanced building performance, the research considered the use of latest simulation tools and green raw materials such as green composites. They also suggested that sustainable retrofitting saves the structural safety and saves the environment from negative impacts by reducing energy and material waste. Moreover, the study highlighted the part that financial motivators and policy regulations have to play in promoting sustainable renovations. The results indicate that for effective long-term building performance and resilience simpler, more sustainable options involving a combination of structural retrofitting and sustainability aren't enough.

M. K. Shariq and S. A. Khan (2023) [3] investigated on design efficiency and economic implications of various fiber cup FRP, steel bracing and jacketing techniques in RC building retrofitting process. Their research provides information on the retrofitting operations and mitigation techniques of which the seismic performance and the load carrying capacity of the structures can be enhanced under extreme conditions. Their investigation shows that the most hydraulically efficient solution to this requirement to be stereo stripping aided by supporting the structural elements' jacketing fabric. This paper expands knowledge in vertical enlargement and rehabilitation of structure with depicting how to improve the retrofit expectation through the particular structural demand and budgetary constraint.

3. Overview of work

In this study two model were analyzed by Etabs software in which first model has taken base model defines existing six storey building and model 2 has taken vertical expansion of steel structure over it by column and footing strengthening of existing RCC building. However, Etabs only analyze frame so footing strengthening analysis has not covered in this but its cost estimation has reviewed. The connection detailing between both type of frame has been covered through RAM connection and found safe in design.

4. Specifications for analysis

The design data which is used in analysis of building is as follows:

Bracing type	-	X-type for Steel structures
Modelling	-	Etabs software
Seismic Zone	-	Zone-IV
Wind Zone	-	Zone-IV (47 m/sec)
Live load	-	4.0 kN/m^2
Roof Live Load	-	1.5 kN/m^2
Floor finish	-	1 kN/m^2
Roof finish	-	1.5 kN/m^2
Earthquake load	-	As per IS 1893 (Part-1):2016
Wind load	-	As per IS 875 (Part-3):2015
Type of soil	-	Type II (Medium soil) as per 1893 (Part-1):2016
Storey height	-	3.0 m
Slab thickness	-	150 mm
Size of beams	-	300 mm x 600 mm

Size of columns	-	300 mm x 600 mm
Size of columns	-	500 mm x 800 mm (For Retrofitting)
Size of Steel columns	-	ISHB 300
Size of Steel beams	-	ISMB 300 (Primary) and ISMB 200 (Secondary)
Size of bracings	-	ISMC 150

5. Modelling and Analysis

Model 1 is RCC structure with Rigid frame

Model 2 is Retrofit frame with upper three storey steel structure

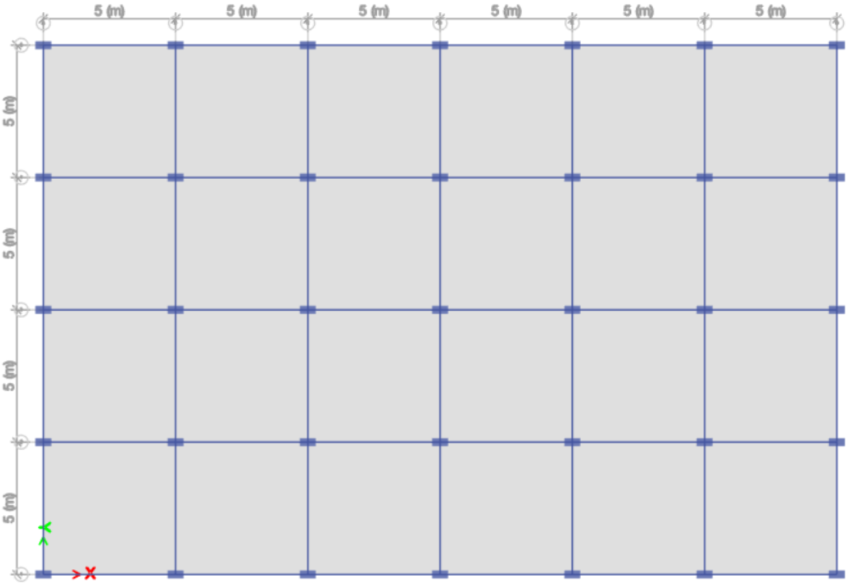


Figure-1 Plan of building for all models

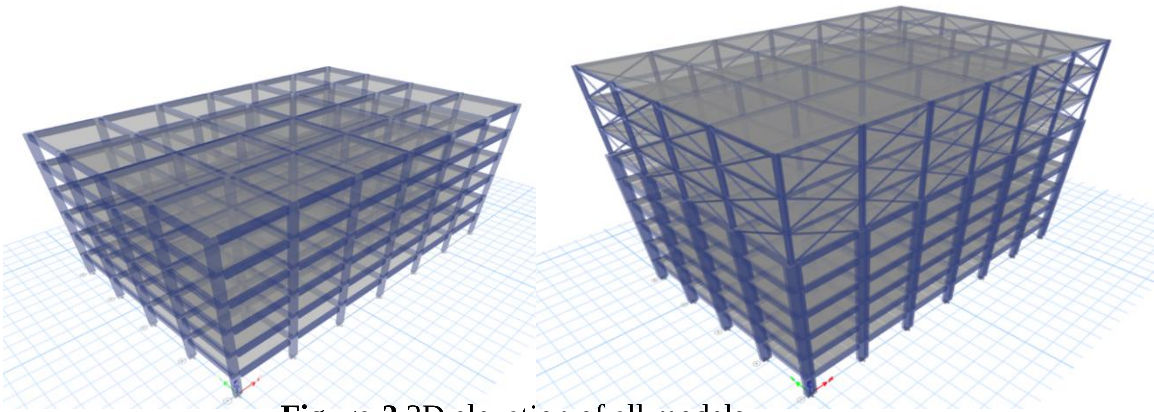


Figure-2 3D elevation of all models

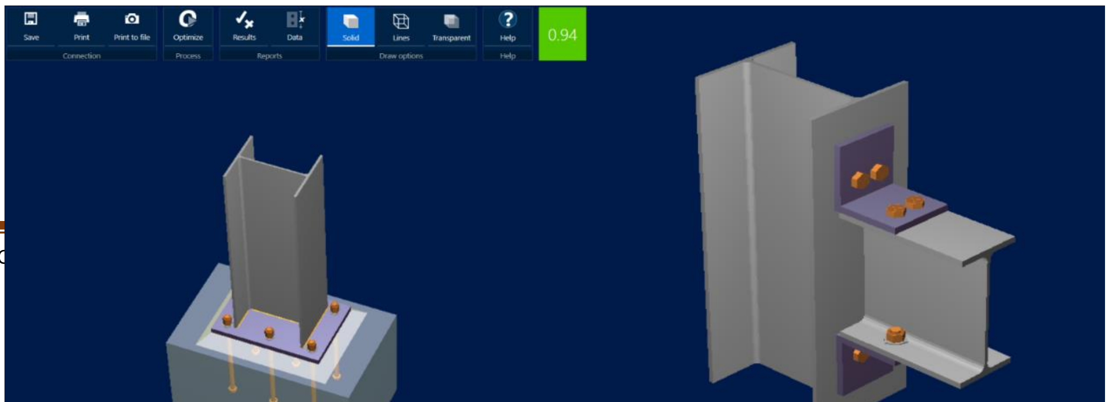


Figure-3 Base plate design and Beam-Column Joint connection detail

6. Results

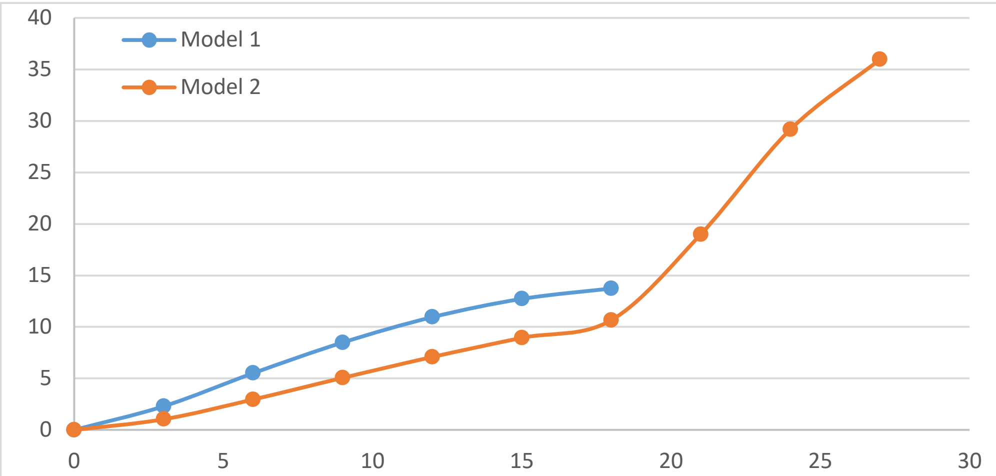


Figure 4 Displacement v/s Storey height for RS-X in X-direction

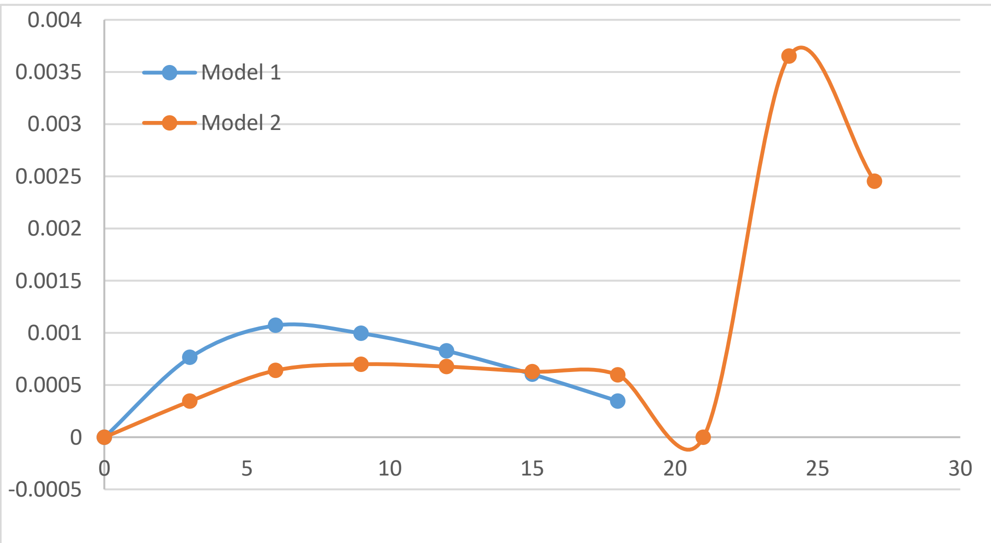


Figure 5 Storey drift v/s Storey height for RS-X in X-direction

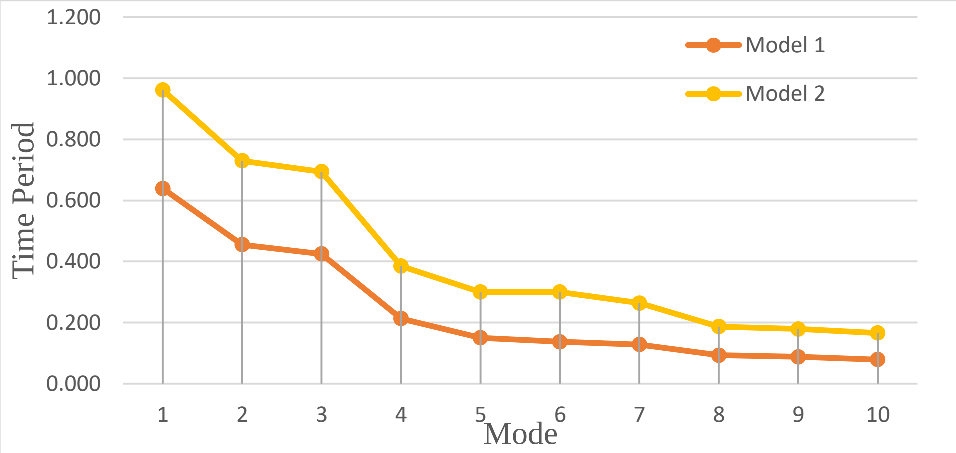


Figure 6 Time period in seconds for both models

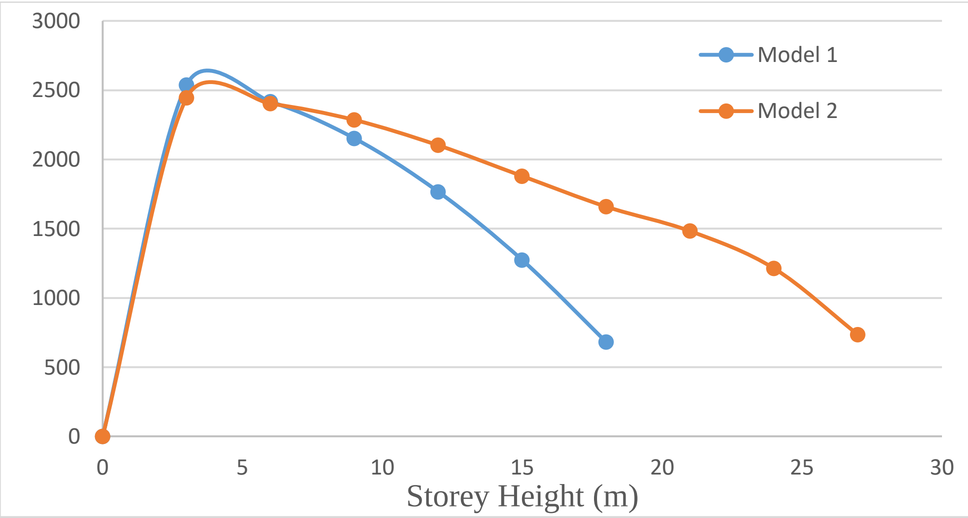


Figure 7 Storey shear v/s Storey height for RS-X in X-direction

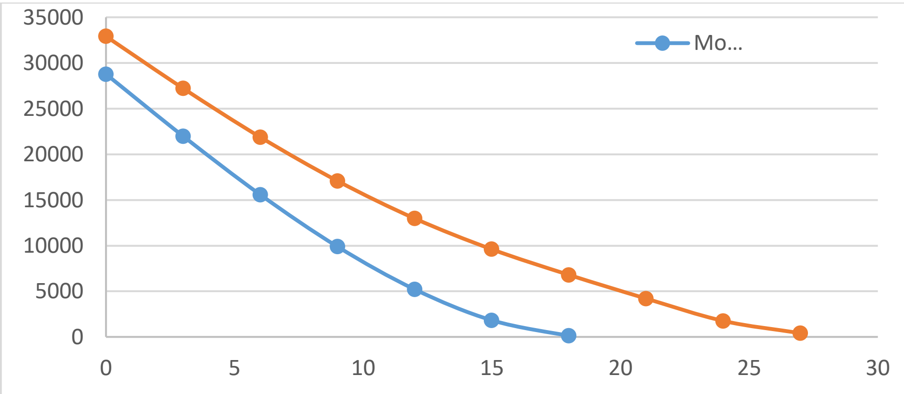


Figure 8 Storey moments for all models in x-direction at load case RS-X

7. Conclusion: The analysis result represents the higher displacement in the upper storeys due to added steel structure and significantly reduced in the lower storeys due to retrofitting. The results of displacement seem better and safe. The storey drift ratio has been found within permissible limits as per IS code, that indicates safe behavior. Also Model 2 represents lower drifts in lower floors due to strengthening of columns but slightly increase at higher level due to steel structure add on but in permissible limit. The time period of Model 2 has found higher than Model 1 which indicates increased flexibility of structure. And lower frequencies in Model 2 due to additional height and steel structure. The Storey shear and moments of model 2 are significantly higher due to increased height and building mass but all these factors are in permissible limit that indicates the vertical expansion on existing structure is safe and found economic in this case without demolition of existing structure. Model 2 successfully accommodates the vertical expansion with manageable displacements and drifts. RCC retrofitting improves stiffness in lower stories, reducing excessive drift. Increased time period and moments indicate a shift in dynamic response, requiring careful detailing in retrofitting.

7. References

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