

# Vertical Extension & Retrofitting of the Existing R.C.C. Commercial Building

## – A review

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### Abstract

*This study explores the feasibility of vertically extension of existing buildings as a sustainable solution to urban densification, particularly focusing on the structural implications and potential benefits of such extensions. Through structural analysis using advanced software like ETAB, and SAFE. as well as examination of cost-effectiveness, the research evaluates the viability of vertical extensions in different contexts. Case studies from various regions, illustrate the technical challenges and benefits associated with vertical extension projects. The analysis encompasses considerations such as structural stability of existing building after floor extensions, and cost implications, offering insights into the most efficient methods for extending buildings vertically. This research underscores the importance of vertical extension as a sustainable urban development strategy and calls for greater awareness and adoption of this approach within the construction industry. It emphasizes the need for collaborative efforts among stakeholders and proposes a development process to streamline the implementation of vertical extension projects.*

**Keywords:** Floor Extension, Sustainable solution, Structural stability, Retrofitting, FEM-based Software.

### 1. Introduction

Expanding vertically by adding floors to existing structures offers a promising approach to addressing the critical need for space efficiency in densely populated areas. This strategy not only facilitates the optimal use of limited urban land but also contributes to the reduction of carbon emissions associated with new constructions. This paper examines the potential of vertical expansion in existing buildings as a sustainable solution to urban space constraints. It explores the practicality, environmental benefits, and the overall impact of such initiatives on urban development. This study focuses on establishing a comprehensive structural design for a proposed building, ensuring it meets essential criteria like structural integrity, performance under various loads, and durability.

The building was constructed in 2007 as a commercial structure, having 2-Basement Floor + Ground Floor + 6-storey + Terrace, now will be having Extension of 10-Floor Above Existing Terrace Level. The proposed structural design involves meticulous planning, including the preparation of framing plans and consideration of methods like concrete jacketing to strengthen existing columns. The ultimate goal is to enhance the building's structural health, accommodate additional floors, and ensure long-term viability through effective repairs and reinforcement measure.

### 2. Applications of Vertical Extension

This literature review covers what other researchers have studied out about vertical extension of

building. A. BAHRAMI et.al 2022 Executed work on Gävle, Sweden, where the vertical extension of a reinforced concrete building is explored as a solution to meet housing demands. The research methodology involves comprehensive modelling, analysis, and design using the StruSoft FEM-Design program, adhering to Eurocodes and Swedish national annex standards. A reference building in Gävle serves as the basis for the study, with detailed specifications provided for its structural elements, including load-bearing walls, slabs, and roof design. Load cases, including snow, dead, and imposed loads, are considered in the analysis, with various load combinations generated to assess structural performance. Results from the analysis of the reference building demonstrate acceptable stress distributions, utilization ratios, and deflections, indicating structural stability and performance within desired limits. However, when extending the building vertically by adding a storey, some load-bearing elements exhibit higher utilization ratios, necessitating strengthening to mitigate the risk of failure. Proposed strengthening solutions include increasing reinforcement content and introducing steel columns, beams, and braces to enhance structural capacity and ensure compliance with safety standards. Comparative analysis between the reference and extended buildings reveals increases in vertical reaction forces and deflections post-extension, yet within acceptable limits. Despite the additional loads imposed by the extension, the structural integrity and stability of the building are maintained, validating the feasibility of vertical extension as a viable solution for meeting housing demands in urban areas. [1] Joan Artés et.al 2017 methodology entailed a detailed analysis of the existing building's load-bearing capacity to accommodate vertical extensions. This includes assessing the condition of the foundation, load-bearing walls, and structural elements, as well as conducting geotechnical studies to determine soil properties and foundation requirements. Joan Artés et.al emphasizes the importance of structural reinforcement where necessary, such as underpinning foundations or strengthening load-

bearing walls, to ensure the structural integrity of the building during and after the vertical extension process. In terms of construction, outlines a streamlined process that combines on-site refurbishment of existing buildings with off-site fabrication of modular vertical extensions. Industrialized construction methods, utilizing steel and wood materials, are employed to prefabricate modular components in a factory setting. These components, such as 3D pods and 2D panels, are then transported to the construction site and assembled on top of the existing building using cranes. Study highlights the advantages of this approach, including rapid construction timelines, reduced on-site disruption, and improved environmental sustainability through waste reduction and energy-efficient design. Overall, Joan Artés et.al provided a technical roadmap for the implementation of vertical extension projects in urban areas, addressing structural, environmental, and logistical considerations to achieve sustainable urban regeneration. [2] Charles Gillott et.al 2021 explained the imperative for sustainable housing solutions amidst burgeoning demand, particularly in the UK, underscoring the necessity for vertical extension as an urban densification strategy. Charles Gillott et.al explained the structural integrity of multi-storey steel-framed buildings, examined their abundance, durability, and adaptability to vertical extension. The analytical methodologies, including the modified effective length method, are applied to assess reserve buckling capacities and structural robustness under varying design scenarios. Through analysis, Charles Gillott et.al delineates the intricate interplay between column continuity, design limitations, and structural retrofitting potential, providing quantitative insights into the feasibility and efficacy of vertical extension as a sustainable housing provision strategy. [3] Michael palmer et.al 2016 Carried out the vertical expansion project at the Carey Building in Ithaca, NY, presents a complex structural engineering endeavour aimed at accommodating additional commercial and residential spaces atop an existing two-story reinforced concrete structure. the expansion

involves a meticulous design strategy to support the new five-story steel superstructure above the existing columns while maintaining the integrity of the first-floor retail space throughout construction. To address lateral forces resulting from the eccentric positioning of the concrete and masonry elevator shaft, a hybrid lateral force resisting system is implemented, necessitating the incorporation of steel braced frames to manage building drift within acceptable limits. The initial phase of the project focuses on analysing and reinforcing the existing foundation, With the load capacity of the foundation needing augmentation to accommodate the increased structural demands, a methodology is devised to enlarge the existing foundations using reinforced concrete "footing extensions." Ground Penetrating Radar (GPR) testing and selective destructive inspections are conducted to assess the condition of existing concrete columns, leading to the implementation of reinforced concrete collars to increase their capacity to support the additional vertical load. [5] In India Qureshi Mohammad Naved et.al 2022 undertakes a detailed exploration of structural design principles with a particular focused on enhancing the functionality of an existing building erected in 1986. Originally intended as an industrial facility, the structure now encompasses various levels including a basement, ground floor, and multiple office floors extending up to the third level, along with additional features such as a terrace, overhead tank, and lift machine room. The study aims to evaluate the feasibility of incorporating new floors into the building while ensuring its structural integrity and resilience. Central to the investigation is the comprehensive assessment of the building's structural health, necessitating a thorough examination of its load-bearing capacity and potential reinforcements needed to support additional floors. However, several challenges impede this process, including the absence of crucial documents such as structural reinforcement drawings and uncertainties regarding the foundation type and concrete quality. To address these obstacles, the researchers employ a strategic approach involving on-site measurements, visual

surveys, and non-destructive and destructive tests to ascertain vital information about the building's structural composition and condition. In response to the identified challenges, the study proposes a systematic action aimed at preparing detailed structural framing plans and conducting rigorous tests to assess concrete quality and reinforcement presence. Furthermore, innovative solutions tailored to the specific context are recommended, such as leveraging existing reinforcement capacities to accommodate additional floors and selectively removing non-essential elements like loft slabs and terrace waterproofing to optimize structural performance. Through this methodical approach, the study endeavours to furnish practical insights and methodologies for fortifying existing buildings and prolonging their operational lifespan. [4]

### **3. Application in strengthening of footing and RC column**

Alaa Jaleel Naji 2021 et.al explored various techniques for rehabilitating and strengthening reinforced concrete (RC) columns, which are crucial load-bearing elements in buildings prone to deterioration. These techniques address issues like dynamic loads, poor maintenance, corrosion, and design flaws that compromise the structural integrity of RC columns. The methods discussed include steel jacketing, concrete jacketing, ferrocement jacketing, each technique is assessed for its performance, advantages, disadvantages, and factors influencing its design and applicability. Steel jacketing involves encasing the column with steel plates or angles, enhancing its load-bearing capacity. Studies demonstrate that the presence of steel head connections significantly influences the load transfer mechanism, affecting the ultimate load capacity. Additionally, the dimensions and arrangements of steel angles impact the strengthening effectiveness. However, steel jackets may degrade in corrosive environments and present aesthetic issues when large steel sizes are used. Concrete jacketing entails adding a reinforced concrete shell around the column to improve its seismic performance and load-bearing capacity. The bonding between the old and new concrete layers is

critical, often achieved through surface roughening and adhesive materials. Studies reveal that the ultimate load capacity increases with the thickness of the concrete jacket and the use of high-performance materials like Ultra-High Performance Self-Compacting Concrete (UHSPCC). However, concrete jacketing adds weight and requires skilled labour, making it time-consuming and costly. Ferrocement jacketing offers a cost-effective alternative for strengthening RC columns, utilizing thin mortar walls reinforced with wire mesh. This technique enhances the column's compressive strength, impact resistance, and resistance to seismic events and corrosion. Unlike steel and concrete jacketing, ferrocement jacketing is less labour-intensive and provides comparable benefits at a lower cost. Similarly, CFRP jacketing techniques offer lightweight, corrosion-resistant solutions with high strength-to-weight ratios, suitable for aggressive environments and seismic retrofitting. [6] Zumrawi M. M. E et.al 2018 investigated the strengthening of pad foundations for storey extension in existing buildings, addressing the critical need for effective engineering solutions to accommodate additional loads. Various techniques for strengthening concrete structures are explored, including sectional enlargement with additional reinforced concrete, externally mounted steel, and fibre-reinforced polymers (FRP). The selection of a suitable strengthening system depends on technical factors such as serviceability, strength, and durability, as well as non-technical factors like constructability and cost-benefit analysis. Notably, the study emphasizes the importance of maintaining uniform stiffness distribution in the strengthened structure to avoid structural irregularities. The case study conducted at the University of Khartoum focuses on a complex lecture hall building that underwent a storey extension in 2009. The study involves field surveys, data collection, and structural analysis to evaluate the effectiveness of the foundation strengthening. The new foundation design, which incorporates sectional enlargement techniques, is presented. Detailed guidelines for footing strengthening by sectional enlargement are

provided, including excavation, dowel bar insertion, concrete casting, reinforcement placement, and bonding agent application. The study concludes that the strengthened foundation is capable of supporting the additional load from the storey extension, affirming the efficacy of sectional enlargement with concrete and steel reinforcement as a cost-effective strengthening technique. [7]

### Conclusion

In conclusion, this review paper highlights the significance and benefits of floor extension in RCC buildings and emphasizes various techniques for strengthening and retrofitting of structural elements like footing & RC column. Through an in-depth examination of various methodologies, materials, and structural considerations, it becomes evident that floor extension offers numerous advantages in terms of cost-effectiveness, sustainability, and structural integrity. By carefully evaluating the limitations and challenges associated with this process, as well as exploring innovative solutions and best practices, stakeholders in the construction industry can make informed decisions to optimize the performance and longevity of RCC buildings.

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