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Research Article

COST COMPARISON BETWEEN RCC AND LOAD BEARING EARTHQUAKE RESISTANT RESIDENTIAL BUILDING IN TERAI REGION

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ABSTRACT

This study compares the cost-effectiveness of earthquake-resistant residential construction methods, focusing on RCC framed structures and load-bearing construction in Kanchan Rural Municipality, Rupandehi. Utilizing designs from the NRA design catalogue Volume-I, load-bearing designs were referenced, while RCC framed building designs were intentionally aligned with identical architectural plans, district rate and DUDBC norms for cost estimate, NBC Code 202 and 205 to show the features of earthquake resistant load bearing building and RCC building respectively. The analysis of Load Bearing and RCC framed buildings reveals a consistent trend where an increase in total area is associated with a rise in total construction cost. Interestingly, as the building size increases, there is a corresponding decrease in the cost per square foot. RCC framed structures assign a higher percentage to concrete work and lower weightage to brickwork compared to Load-Bearing buildings. In all building types, reinforced cement concrete construction is found to be costlier than load-bearing construction. An in-depth analysis has been conducted to examine the incremental costs associated with RCC construction compared to load-bearing construction across various house types, categorized by the number of stories. The findings provide valuable insights into the variations in RCC costs based on the number of stories, offering essential information for informed decision-making in construction methods and expenses.

Keywords: NRA design, Reinforced framed building, Load bearing building, DUDBC norms

Introduction

Mostly residential building construction practice has been carried out in Nepal in owner builder system without consulting architects and engineers and without considering the earthquake safety measures. Even with the incident of past huge earthquakes and its adverse effects, people have not yet understood the need of earthquake resistant buildings. The main reason to this might be the lack of awareness and misconception of people [1] .Generally, there is a misconception that load-bearing buildings lack earthquake resistance while only RCC framed structures offer this safety. Additionally, there's belief that RCC buildings are significantly more expensive compared to load bearing ones.

The Himalayas, born from the collision of Indian and Eurasian plates 50 million years ago, are a seismic hotspot with active faults shaping distinct tectonic zones. Stretching 2400 km, Nepal's 800 km section, representing 30%, is highly susceptible to medium to large earthquakes, as seen in events like the 1916 Nepal earthquake and the 2015 Gorkha earthquake. Geologically, Nepal is divided into five zones with unique formations, separated by significant faults and thrusts. An 800 km seismic gap along the Himalayas, highlighted by the Gorkha earthquake, underscores the region's vulnerability to frequent seismic activity [2].

The nation enhanced academic courses for disaster management, engineering, and bureaucracy, promoting idea exchange through conferences for Effective Disaster Risk Reduction (EDRR). Craftsperson training, beginning in 1998, focused on a community-based approach with hands-on sessions and flexible course materials. Post-2015 earthquake, training expanded for civil engineers, but accreditation and quality control were lacking. NSET also conducted Medical First Responder and Collapsed Structure Search and Rescue training, collaborating with government bodies to improve Nepal's seismological network through seismic and GPS stations for monitoring seismic activity and understanding seismic hazards [3].

The Load-Bearing Masonry system, defined by a synergistic relationship between floors and walls, offers a cost-effective and time-efficient alternative to conventional reinforced concrete frame systems. Widely adopted in developed countries like Europe, the LBM system presents advantages such as reduced construction costs, enhanced durability, aesthetic appeal, and flexibility. Despite its potential, research on LBM adoption is limited, particularly in terms of management issues [4]. Masonry structures, utilizing materials like bricks and natural stones, have a historical preference for their simplicity and cost-effectiveness. However, many lack proper engineering standards, leading to challenges in seismic resilience. Walls in these constructions not only define spaces but also bear crucial loads, primarily transferring through materials and mortar. The brittle nature of bricks and mortar results in low ductility, impacting earthquake absorption capabilities. Damages in masonry structures, such as wall cracks and foundation settlements, often stem from low tensile and shear strengths in materials. This paper explores the challenges and solutions in ensuring robust load transfer within masonry constructions [5]. In civil engineering, high-density engineering bricks are preferred for strong projects, while common bricks are used for general construction, prioritizing appearance. Facing bricks offer a blend of attractive looks, color, and durability. Architects are increasingly utilizing non-standard size or shape bricks, known as Specials, for unique designs [6].

Most of researches are based on RCC frame structure rather than load bearing structure. So demand of research on load bearing structure in now days and after earthquake 2015 in remote rural areas is high, Government of Nepal is going to construct large number of load bearing building in village. Therefore, todays' society demands a study or a research to find out actual cost difference between the earthquake resistant load bearing building and RCC framed structure to show the detail estimation of building and cost analysis of most accepted building by the local public.

This study has attempted to collect the information on current practices in the residence building construction within the Kanchan Rural Municipality. The research further compares and analyses the cost of 6 different models of earthquake resistant load bearing residential building with RCC models following identical architectural plans as those used for load bearing masonry designs.

The primary objective of the research is to find cost of 6 different model building with load bearing and RCC framed feature and figure out the cost variation between the earthquake resistant load bearing and RCC residential building in Kanchan Rural Municipality. Furthermore, it seeks to identify cost disparities between RCC and load-bearing buildings, with the overarching goal of enhancing the affordability of construction methods.

Study Area

The Terai region in Nepal is known for its diverse soil types, including soft type soils. Soft type soil in the Terai region typically consists of a mixture of mineral particles, organic matter, water, and air. It is composed of varying proportions of sand, silt, and clay, giving it a balanced texture. Soft type soil in the Terai region generally has a moderate bearing capacity, meaning it can support the weight of structures and foundations. However, specific geotechnical assessments and soil tests should be conducted to determine the precise bearing capacity for construction projects. Type of Foundation material was considered as Fine sand and silt (dry lumps easily pulverized by the fingers); moist clay and sand-clay mixture which can be indented with strong thumb pressure and presumed safe bearing capacity is taken as 100-150 KN/m^2 for this thesis purpose [7]. The selected study area is Kanchan Rural Municipality in Rupandehi district.

Sample and population

This study investigates NBC-compliant Reinforced Cement Concrete (RCC) Buildings and Load-Bearing Buildings situated in the Kanchan Rural Municipality, Rupandehi, Terai region, all built on soft soil. The sample, representing the broader population, includes six distinct architectural plans, encompassing both load-bearing and RCC-framed structures designed to identical specifications. These plans showcase vernacular Nepalese architectural styles, integrating traditional elements like paali and pidis. The population considered for comparative analysis comprises single and multi-storey residential designs complying with Reinforced Concrete Construction (RCC) or Load-Bearing Earthquake Resistant (LBER) techniques, referenced from the NRA Design Catalogue. These designs adhere to Nepal's revised Building Code and hold approval from the Department of Urban Development and Building Construction (DUDBC). Intentional alignment of RCC designs with Load-Bearing Masonry ensures an identical correspondence between spatial configurations and design elements, facilitating a direct and precise comparison between the two construction methodologies.

Building Design

The building sample was meticulously designed in adherence to the stringent guidelines outlined in the revised Nepal Building Code 202 and 205, ensuring compliance with the country's robust structural standards [7,8]. The selection criteria for the sample encompassed residential building requisites while deliberately integrating elements inspired by Nepal's rich vernacular architecture. By merging the specifications mandated by the building codes with the essence of traditional Nepali architectural styles, the design aimed to reflect the cultural heritage while prioritizing safety, functionality, and sustainability. This amalgamation served as a testament to harmonizing modern construction prerequisites with the aesthetic and contextual nuances deeply rooted in Nepal's architectural heritage.

Table 1: Types of buildings with Features

SN	Type of House	No. of storey	Plinth Area (Sq.m)	Total Area (Sq.m)	No. of Rooms	No. of occupancy	Roof	Features
1	BMC 1.1 LB BMC 1.1 RCC	1	31.5	31.5	2	3-5	RCC slab	vernacular architecture design with RCC roof slab
2	BMC 1.2 LB BMC 1.2 RCC	1	16.32	16.32	1	1-3	RCC slab	vernacular architecture design with RCC roof slab
3	BMC 2.1 LB BMC 2.1 RCC	2	31.5	63	4	>4	RCC slab	vernacular architecture design with RCC roof slab
4	BMC 2.2 LB BMC 2.2 RCC	2	37.36	74.72	4	>4	RCC slab	vernacular architecture of Nepal with Pidi, & Pali
5	BMC 2.3 LB BMC 2.3 RCC	2	45.31	90.62	6	>6	RCC slab	verandah in both storey with vernacular architecture
6	BMC 2.4 LB	2.5	50.76	141.94	11	>10	RCC	shop in Ground Floor with

	BMC 2.4 RCC						slab	vernacular architecture

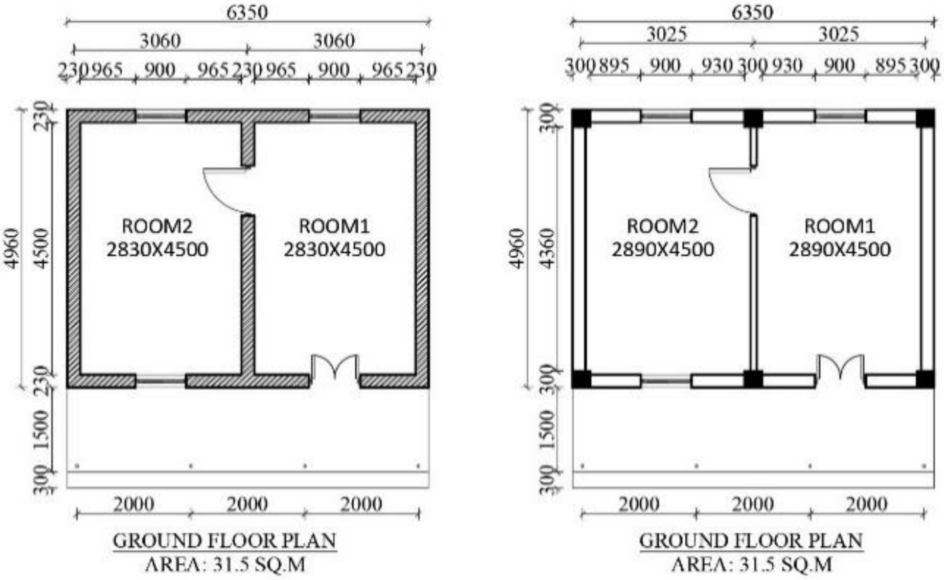

Figure 1: BMC 1.1 LB and RCC

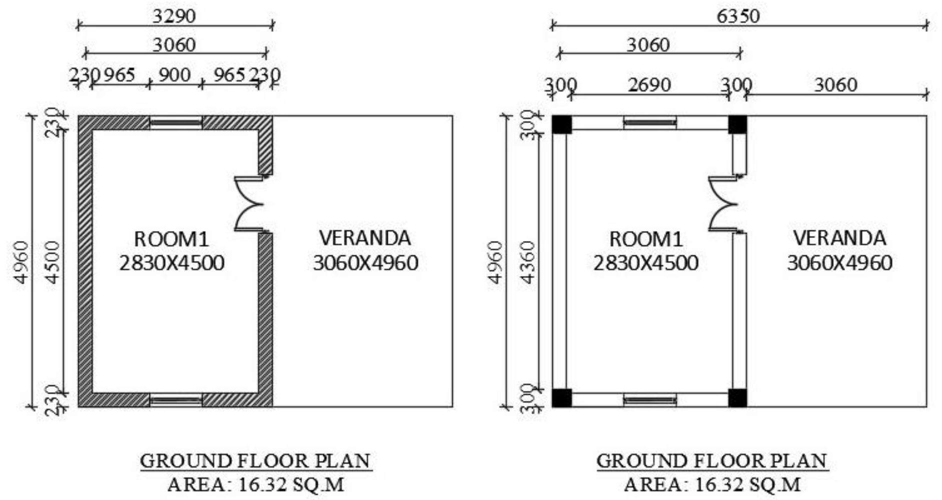

Figure 2: BMC 1.2 LB & RCC

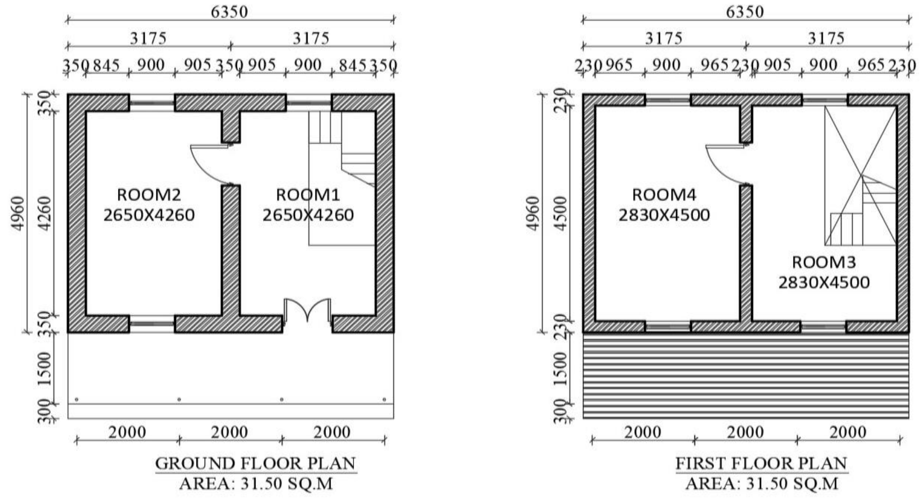

Figure 3: Ground floor and first floor plan BMC 2.1 LB

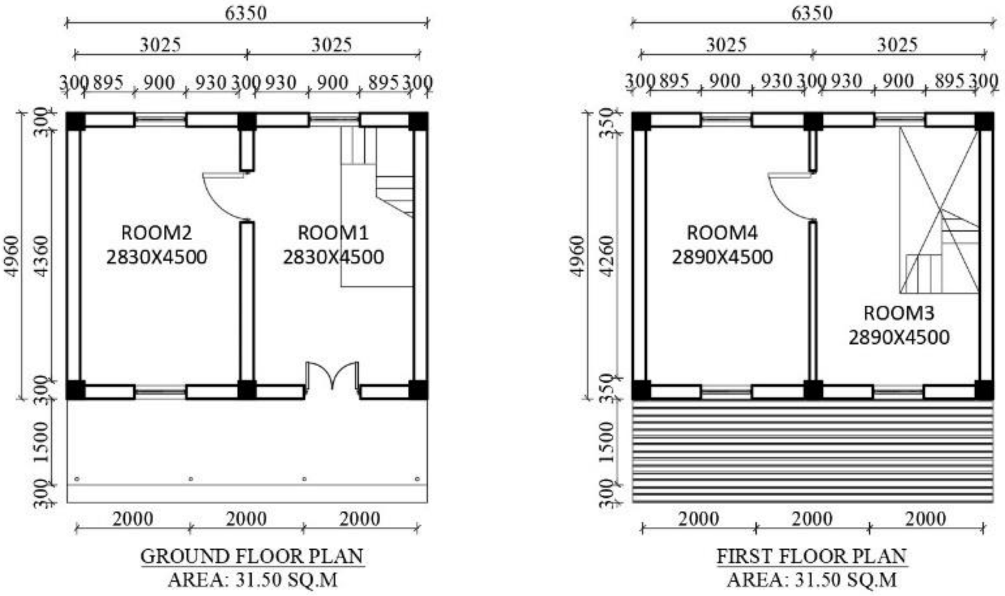

Figure 4: Ground floor and first floor plan BMC 2.1 RCC

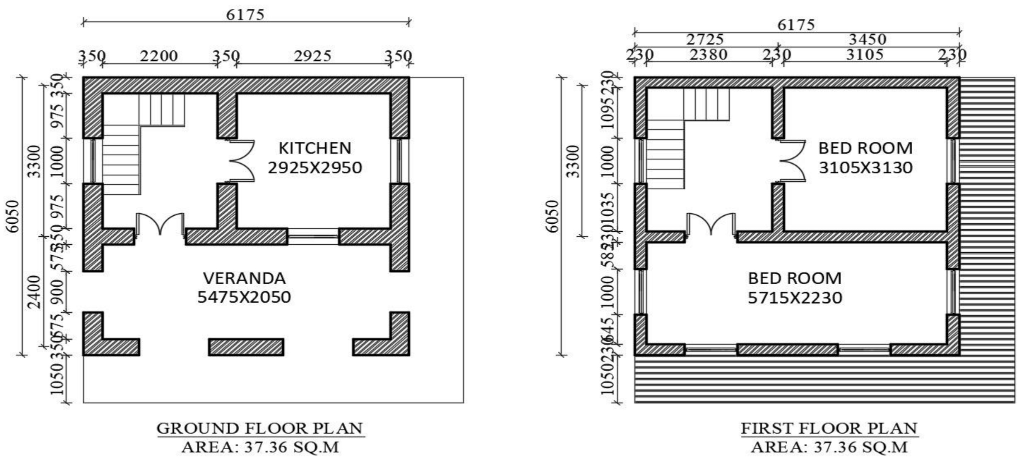

Figure 5: Ground floor and first floor plan BMC 2.2 LB

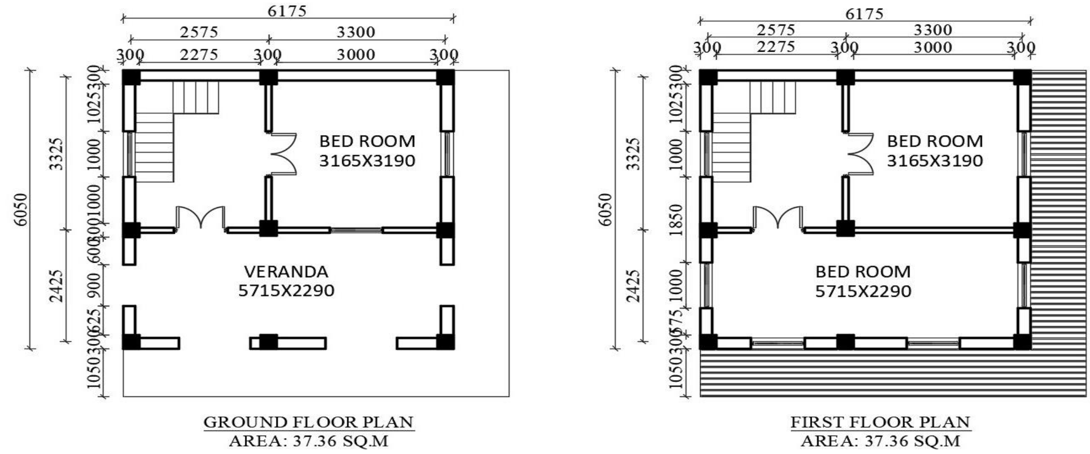

Figure 6: Ground floor and first floor plan BMC 2.2 RCC

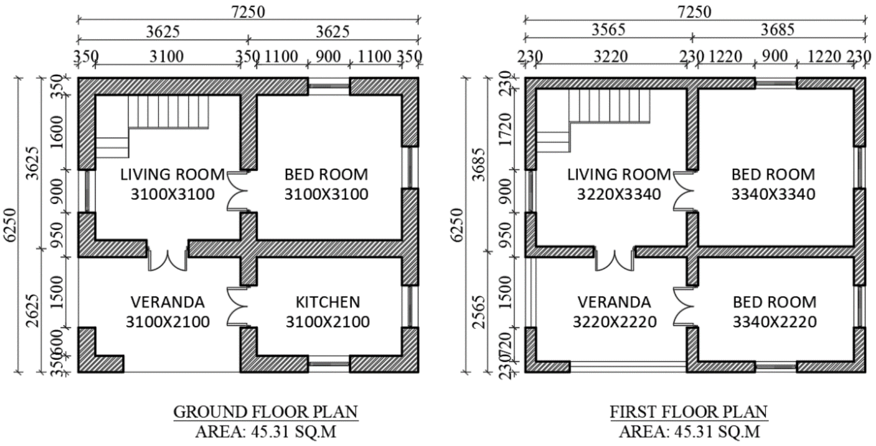

Figure 7: Ground floor and first floor plan BMC 2.3 LB

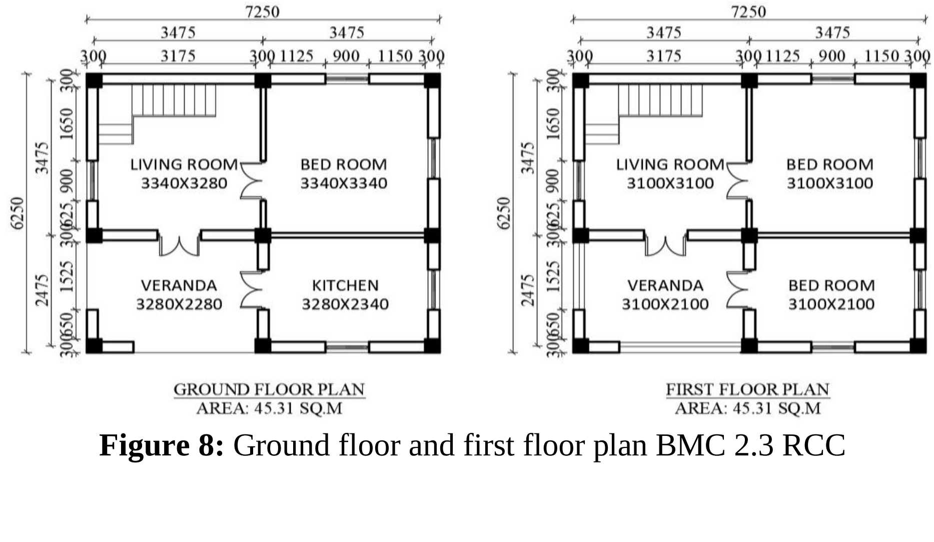

Figure 8: Ground floor and first floor plan BMC 2.3 RCC

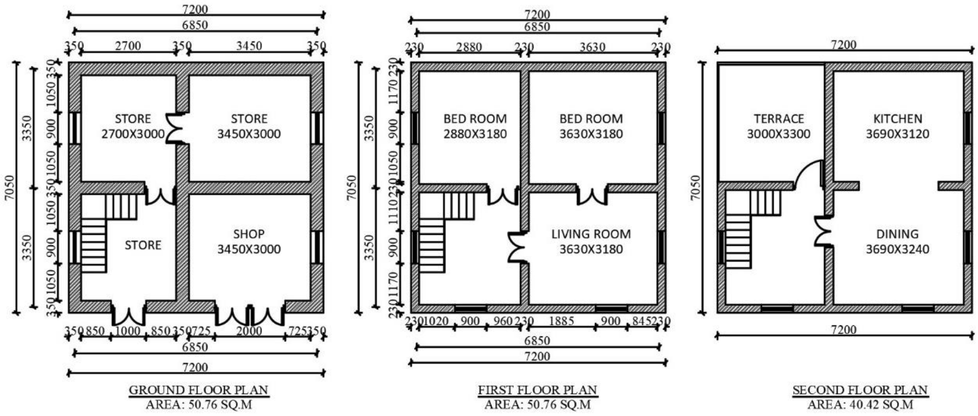

Figure 9: Ground floor, first floor & second floor plan BMC 2.4 LB

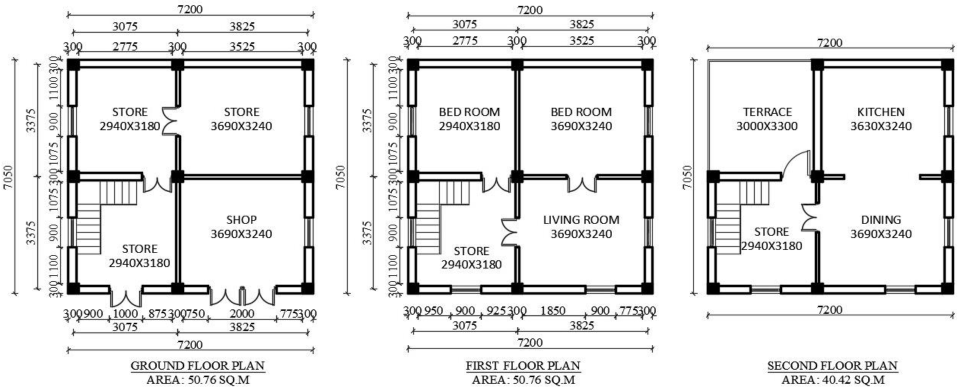

Figure 10: Ground floor, first floor & second floor plan BMC 2.4 RCC

Cost Estimation

The rates employed for cost estimation have undergone careful preparation and approval by the Kanchan Rural Municipality, aligning closely with the norms established by the Department of Urban Development and Building Construction (DUDBC) and Rupandehi District Rates for the fiscal year 2080/81. Adhering to these standards ensures a comprehensive and reliable foundation for estimating costs.

Results and Discussions

Construction cost of Load bearing building

The analysis of data representing six distinct Load Bearing Building types (BMC) unveils noteworthy trends concerning Total Area, Total Construction Cost, and Construction Cost Per Square Foot. Notably, a consistent pattern emerges concerning the number of stories in these BMC types. For instance, smaller single-storey structures like BMC 1.2, spanning 175.58 sq.ft, exhibit a higher Construction Cost Per Square Foot (Rs. 4042.14). In contrast, larger multi-storey buildings like BMC 2.4, covering 1527.05 sq.ft at 2.5 stories, demonstrate a relatively lower Cost Per Square Foot (Rs. 2402.98). This observed correlation between increased total area and decreased Construction Cost Per Square Foot implies potential cost efficiencies or economies of scale within this specific building category.

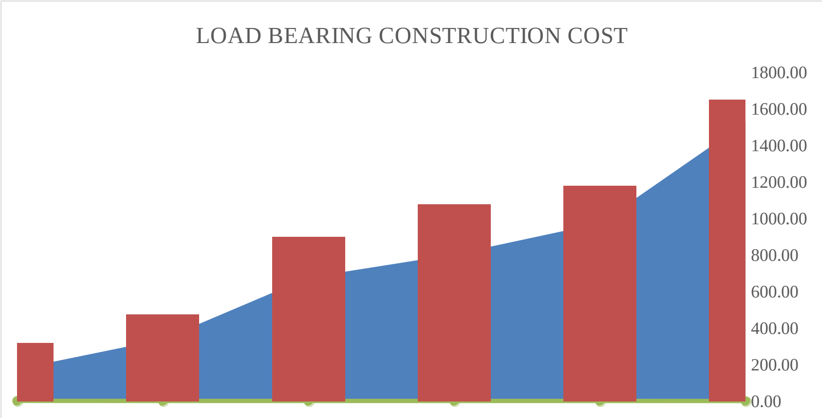

Figure 11: Load bearing building construction cost

Construction cost of RCC Frame building

The examination of data concerning six distinct RCC framed structure types sheds light on notable trends regarding Total Area, Total Construction Cost, and Construction Cost Per Square Foot. Within this analysis, a consistent trend becomes apparent based on the number of stories in these RCC framed structures. For instance, smaller single-storey RCC structures, such as RCC 1.2 covering 175.58 sq.ft, exhibit a higher Construction Cost Per Square Foot (Rs. 4663.44). Conversely, larger multi-storey buildings like RCC 2.4, spanning 1527.05 sq.ft over 2.5 stories, demonstrate a relatively lower Cost Per Square Foot (Rs. 2425.23). This observed correlation between increased total area and decreased Construction Cost Per Square Foot implies potential efficiencies and cost advantages associated with scale within this particular classification of buildings.

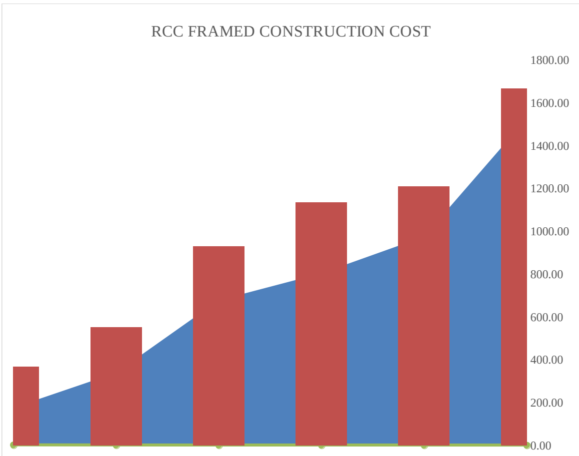

Figure 12: RCC framed building construction cost

Construction Cost Comparison

The data offers a comparative analysis of construction costs between Load Bearing (LB) Building and RCC Framed Building across various house types, considering the number of storeys and the total area in square feet. Notably, the number of storeys seems to impact the construction cost dynamics. For instance, in single-storey structures like BMC 1.2 covering 175.58 sq.ft, the LB Building Construction Cost is 709,707 Nrs., whereas the RCC Framed Building Construction Cost amounts to 818,793 Nrs. The Construction Cost Per Square Foot for LB Building and RCC Framed Building are 4,042.14 Nrs. and 4,663.44 Nrs. respectively. As the number of storeys increases, there appears to be a nuanced impact on construction costs, evident in the varying costs per square foot for LB and RCC Framed Buildings across different house types. This data underscores the influence of storey count on construction expenses, providing essential insights for housing development strategies based on diverse architectural designs.

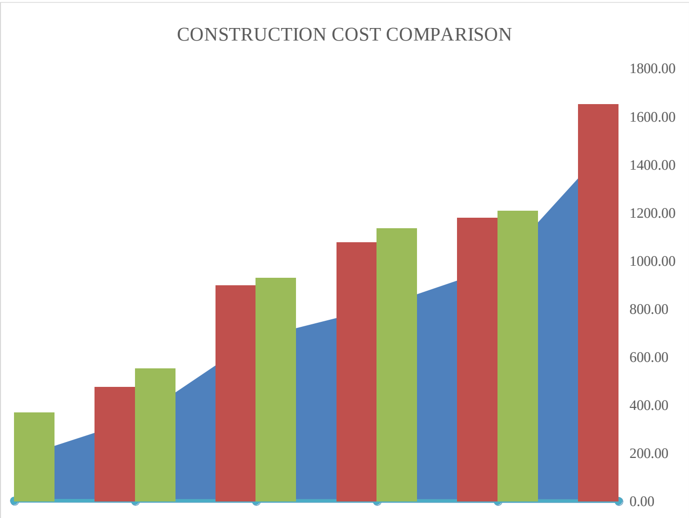

Figure 13: Construction cost comparison LB vs RCC

Percentage Increase in RCC Cost Compared to Load Bearing

Analysis has been done for the increment in Reinforced Cement Concrete (RCC) construction costs compared to Load-Bearing construction for different types of houses based on the number of stories. For one-storey houses, BMC 1.1 exhibits a 16.17% increase in RCC cost compared to Load-Bearing, while BMC 1.2 shows a 15.37% increase. Moving to two-storey structures, BMC 2.1 indicates a 3.30% rise, BMC 2.2 displays a 5.30% increase, and BMC 2.3 reflects a 2.56% increment in RCC costs compared to Load-Bearing counterparts. Moreover, for two-and-a-half-storey buildings, BMC 2.4 demonstrates a 0.93% elevation in RCC costs in comparison to Load-Bearing construction. This bar chart provides a clear perspective on the varying percentage increases in RCC costs based on the number of stories in the building, aiding in decision-making regarding construction methods and associated expenses.

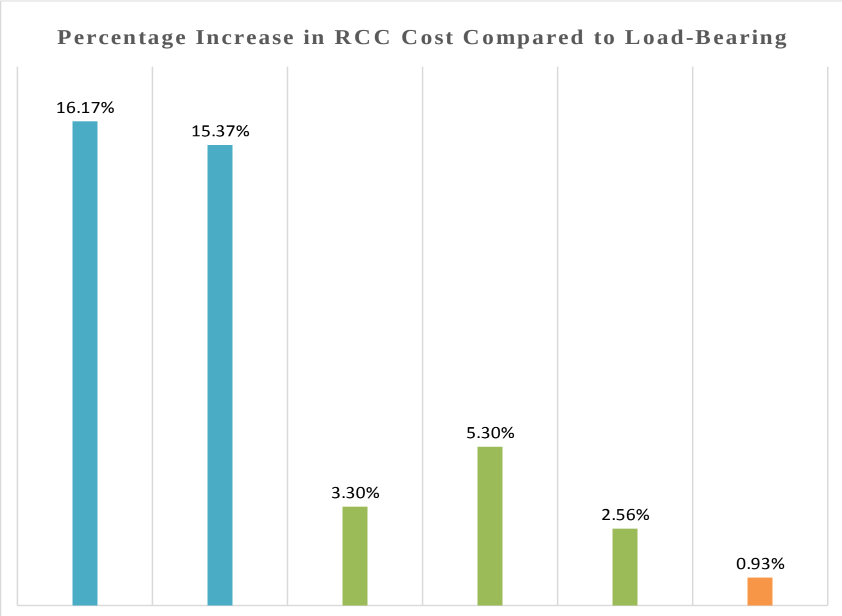

Figure 14: Percentage increase in RCC cost compared to load-bearing

Weightage Percentage Comparison of Major Item of Construction Works

The analysis of the data reveals distinct patterns in construction allocation between RCC framed and Load-Bearing structures across various building types. In RCC frame structures, there's a notable higher weightage for concrete work across all BMC designations. The percentage distribution for RCC work consistently demonstrates a substantial range, with values ranging from 41.65% to 48.42%, indicating the significance of concrete-related tasks in these structures. Conversely, brickwork exhibits comparatively lower weightage in RCC framed buildings, with percentages ranging between 19.05% and 22.05%. Other major components, such as soling, M10 PCC, plastering works, and remaining works, showcase relatively minor deviations in their weightage percentages across different BMC types in RCC framed structures, indicating a more consistent allocation of tasks beyond concrete-related work. On the contrary, in Load-Bearing buildings, there's a contrasting distribution. The weightage for concrete work tends to be lower across BMC types, displaying percentages ranging from 26.86% to 34.55%, showcasing a noticeable difference compared to RCC framed structures. However, brickwork holds a higher weightage in Load-Bearing structures, with percentages ranging between 31.48% and 34.83%, suggesting a relatively more significant role for brick-related tasks in these constructions. Similar to RCC framed buildings, other major components like soling, M10 PCC, plastering works, and remaining works demonstrate more consistent weightage percentages across various BMC types in Load-Bearing structures, showcasing a different allocation of construction tasks compared to their RCC counterparts. The data analysis highlights the clear focus on concrete-related activities within RCC frame structures, showcasing a significant range of percentages dedicated to concrete work. In contrast, Load-Bearing buildings prioritize brickwork, assigning a higher weightage to this aspect. This disparity underscores the contrasting construction priorities and methodologies between these two structural frameworks.

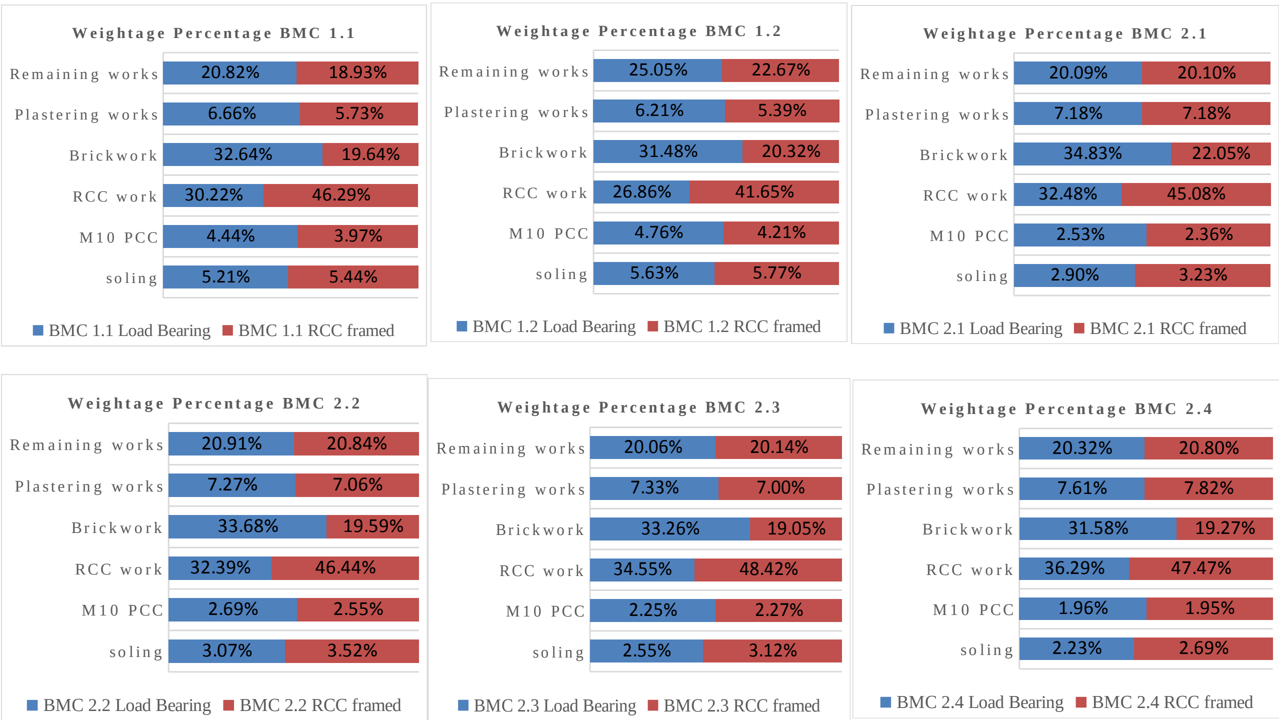

Figure 15: Weightage percentage

Conclusions

In load-bearing constructions, the smaller single-storey BMC 1.2 with an area of 175.58 sq.ft exhibits a higher cost per sq.ft (Rs. 4042.14) compared to the larger 2.5-storey BMC 2.4 spanning 1527.05 sq.ft, which shows a relatively lower cost per sq.ft (Rs. 2402.98). Similarly, in RCC framed structures, the smaller single-storey RCC 1.2 at 175.58 sq.ft presents a higher Construction Cost Per Square Foot (Rs. 4663.44), while the larger 2.5-storey RCC 2.4 spanning 1527.05 sq.ft displays a relatively lower cost per sq.ft (Rs. 2425.23), indicating a correlation between increased area and decreased construction cost within this building classification per square foot. A comparison between Load Bearing (LB) and RCC Framed Buildings across various house types reveals that single-storey LB structures generally exhibit lower Construction Cost Per Square Foot than RCC Framed Buildings, though the impact of the number of storeys varies, showcasing nuanced influences on construction expenses in diverse architectural designs. The analysis further highlights percentage increases in RCC costs compared to Load-Bearing construction across different house types, aiding decision-making in construction methods and expenses based on building stories. RCC framed structures allocate a higher percentage (41.65% to 48.42%) to concrete work compared to Load-Bearing buildings, while brickwork receives lower weightage (19.05% to 22.05%), indicating consistent trends in construction allocation between these building types. Conversely, Load-Bearing buildings present a distinct distribution, allocating lower weightage to concrete work (26.86% to 34.55%) but higher emphasis on brickwork (31.48% to 34.83%), showcasing differing construction task allocations compared to RCC framed structures across various BMC types.

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