International Journal on Science and Technology (IJSAT)

E-ISSN: 2229-7677 ● Website: www.ijsat.org ● Email: editor@ijsat.org

Comparative Study of RCC and Prestressed Concrete Elements in Low Cost Housing

Awanish Kumar[1], Dr. Rachana Bajaj[2]

[1]Designation of 1st Author, Name of Department of 1st Author, Name of Organization of 1st Author
[2]Designation of 2nd Author, Name of Department of 2nd Author, Name of Organization of 2nd Author
[1]Kumarawanish805@gmail.com, [2]Rachanag167@gmail.com

Abstract

The increasing need for affordable, fast, and durable construction in developing nations like India has shifted the focus of the construction industry towards innovative structural systems. Among these, precast concrete has emerged as a promising alternative to traditional Reinforced Cement Concrete (RCC) construction, especially for low-cost mass housing. This research presents a detailed comparative study between RCC and Precast (Prestressed) Concrete systems in the context of a G+3 low-cost housing structure, with a focus on evaluating structural performance, material optimization, and cost efficiency. The study involves the modeling and structural analysis of both RCC and precast systems using STAAD. Pro, adhering to Indian Standards such as IS 456:2000, IS 875 (Parts 1–3), IS 1893, and IRC guidelines. Parameters analyzed include bending moment, shear force, deflection, axial load capacity, and reinforcement consumption. The results demonstrate that precast systems outperform RCC across multiple performance metrics. Bending moments in precast beams and slabs were reduced by up to 68%, and deflections dropped by 54%, ensuring better serviceability. Shear forces were also significantly reduced, ranging from 10% to 68%, depending on the element location and loading condition. Moreover, axial load-carrying capacity in precast columns increased by up to 22%, enabling the potential for reduced cross-sectional dimensions and improved space utilization. Reinforcement requirements were notably lower in precast elements, with reductions ranging from 28% to 40%, due to internal prestressing and improved stress distribution. This translates into considerable material savings and simplified detailing. From a cost standpoint, while precast systems involve higher initial costs in molds, casting yards, and transportation, they substantially lower labor, formwork, and construction time. A comparative cost breakdown revealed a 15–25% reduction in total project cost for precast systems over the structure’s lifecycle, especially due to faster completion, quality consistency, and reduced maintenance. This study concludes that precast concrete systems provide superior structural behavior, faster construction timelines, and long-term economic benefits, making them ideal for large-scale housing projects, particularly under schemes like Pradhan Mantri Awas Yojana (PMAY) and other urban development programs. Their modularity, quality control, and sustainability potential align with the modern construction demands of efficiency, safety, and scalability. The adoption of precast technology in low-cost housing can significantly contribute to meeting India’s growing urban housing demand while maintaining construction quality and affordability

Keywords: Reinforced Cement Concrete (RCC), Precast Concrete, Prestressed Concrete, Low-Cost Housing, G+3 Residential Building, Construction Efficiency, Axial Load Capacity

1. Introduction

The rising population, urban migration, and economic disparities in developing countries have significantly increased the demand for low-cost housing solutions. These structures are designed to be economical, safe, and sustainable, catering primarily to economically weaker sections (EWS) and low-income groups (LIG). While cost-effectiveness is a core requirement, structural durability and safety cannot be compromised. [1] This necessitates a thorough evaluation of the materials and construction techniques used in such housing schemes. Among the most widely adopted materials in structural systems are Reinforced Cement Concrete (RCC) and Prestressed Concrete (PSC). RCC, due to its simplicity, availability of materials, and ease of construction, has remained the traditional choice for decades. However, it requires heavier sections and more reinforcement to resist tensile stresses, often leading to higher material usage and cracking issues in long-span elements. Prestressed Concrete, on the other hand, introduces a pre-compression force into the concrete member, improving its load-carrying capacity, reducing deflection, and increasing durability. [2]

In modern construction, prestressed concrete has shown significant promise, particularly in repetitive structures such as bridges, metro rails, and industrial sheds. However, its adoption in low-rise residential construction has been limited due to higher initial costs and the need for skilled labor and tensioning equipment. Yet, with advancements in precast and modular housing, PSC may offer a sustainable and cost-effective alternative when applied on a large scale. [3]. The aim of this project is to design a six storey residential building as close as done by various construction firms. In this project we have working design of structure as well. Next step is to replace some structural elements of this RCC structure with Prestressed elements and compare the material cost of two structures. The idea is to reach a definite conclusion on feasibility and increased use of prestressed concrete in buildings.

2. Low-Cost Housing

Low-cost housing refers to the development of economically viable and structurally sound residential units, primarily designed to serve the needs of economically weaker sections (EWS), low-income groups (LIG), and lower middle-income households. In countries like India, where rapid urbanization and growing population pressures have led to a severe housing shortage, low-cost housing has emerged as a critical component of social infrastructure. [4] These housing solutions aim to minimize construction costs without compromising on safety, durability, and functionality. Rather than using inferior materials, the focus lies on optimizing design, employing locally available resources, and incorporating cost-effective construction techniques. Efficient planning, simplified structural layouts, and the use of alternative materials such as fly ash bricks, stabilized soil blocks, and recycled aggregates help in reducing the overall cost. [5] Technologies like filler slabs, rat-trap bond masonry, and ferrocement panels further contribute to material savings. In G+2 or G+3 structures, where structural integrity becomes more crucial, careful selection of construction systems—like reinforced cement concrete (RCC) or prestressed concrete—can significantly impact both cost and performance. RCC remains the traditional choice due to its simplicity and wide availability, but often involves higher material use and long-term maintenance. In contrast, prestressed concrete can improve structural efficiency, reduce member sizes, and offer long-term economic advantages, especially in modular and mass housing projects. [6] As government initiatives like Pradhan Mantri Awas Yojana (PMAY) promote affordable housing for all, integrating appropriate structural systems becomes essential to ensure that these dwellings are not only affordable but also sustainable and durable in the long run. Low-cost housing offers numerous benefits, especially in developing countries where a large section of the population struggles to afford decent shelter. One of the primary advantages is its affordability, which enables economically weaker sections and low-income families to own a home and improve their living standards. By using cost-effective materials and construction techniques, low-cost housing reduces the overall expenditure without compromising safety and functionality. [7] Another key benefit is the efficient use of resources, where local materials and labor are utilized to lower transportation and material costs. These homes are typically designed with simple layouts that allow for quick construction, thereby saving time and accelerating project delivery. Low-cost housing also promotes sustainable development by encouraging the use of eco-friendly materials and reducing construction waste. Furthermore, such housing initiatives create employment opportunities for local communities and contribute to urban development by reducing slum proliferation and improving access to basic infrastructure like sanitation, water supply, and electricity. Overall, low-cost housing plays a vital role in ensuring social equity, economic upliftment, and inclusive growth in rapidly urbanizing regions. [8]

3. Challenges in Low-Cost Housing

Despite its potential to address the housing shortage in developing countries, low-cost housing faces several significant challenges.

- One of the foremost issues is the perception of low quality, where low-cost is often wrongly equated with poor construction, unattractive designs, and lack of durability. This discourages both beneficiaries and developers from fully adopting cost-effective solutions.
- Another major challenge is the limited availability of affordable land, especially in urban areas where land prices are high, forcing developments to be located in peripheral zones with poor infrastructure and connectivity. Additionally, there is a lack of awareness and acceptance of alternative construction technologies and materials, which limits innovation in design and execution.
- Many low-cost housing projects also suffer from poor planning and overcrowding, leading to reduced living standards and social issues. From a technical standpoint, the shortage of skilled labor trained in sustainable and cost-efficient construction techniques can affect the quality and speed of execution. Moreover, regulatory delays, lack of financial incentives, and insufficient access to credit for low-income families further hinder the successful implementation of such projects.
- Environmental factors, such as vulnerability to floods or heat stress in poorly designed units, can also compromise occupant safety and comfort.
- These challenges highlight the need for a holistic and integrated approach involving community participation, government support, innovative engineering, and sustainable urban planning to make low-cost housing both viable and impactful. [9]

4. Types of Building

Buildings are classified into various types based on their use, occupancy, height, and construction method. Broadly, buildings are divided into residential, commercial, industrial, institutional, and public utility structures.

- Residential buildings include houses, apartments, and hostels designed for human habitation. These can range from single-family dwellings to multi-story housing complexes.

- Commercial buildings are structures used for business activities, such as offices, shops, malls, and hotels. Industrial buildings include factories, warehouses, and workshops, where goods are manufactured or stored.
- Institutional buildings serve educational, medical, or religious purposes—like schools, hospitals, colleges, and temples.
- Public utility buildings include government offices, transport terminals, and infrastructure like fire stations and police posts.
- Buildings are also categorized by their height or structure: low-rise (G+1 to G+3), mid-rise (G+4 to G+7), and high-rise (above G+7). From a construction point of view, buildings are either load-bearing structures where walls carry structural loads or framed structures where beams and columns bear loads, allowing for more open interior space. Newer trends include precast buildings, modular construction, and green buildings, which emphasize sustainability and energy efficiency.

In the context of low-cost housing, most buildings are low-rise residential structures designed to reduce cost through optimized material use, simplified layouts, and efficient construction technologies. These buildings often use RCC or prestressed concrete frames depending on the structural and economic requirements of the project. [10]

5. Reinforced Cement Concrete

The concrete of the mixture of cement, sand, water and aggregate in a certain proportion with steel bars by a known method is termed as Reinforcement Cement Concrete. Reinforced cement concrete work may be cast-in-situ or Precast as may be directed by Engineer-in-charge according to the nature of work. The most common form of concrete consists of mineral aggregate (gravel & sand), Portland cement and water. After mixing, the cement hydrates and eventually hardens into a stone like material. Recently a large number of additives known as concrete additives are also added to enhance the quality of concrete. Plasticizers, superplasticizers, accelerators, retarders, pozzolanic materials, air entertaining agents, fibers, polymers and silica furies are the additives used in concrete. Hardened concrete has high compressive strength and low tensile strength. Concrete is generally strengthened using steel bars or rods known as rebars in tension zone. Such elements are "reinforced concrete" concrete can be molded to any complex shape using suitable form work and it has high durability, better appearance, fire resistance and economical. For a strong, ductile and durable construction the reinforcement shall have high strength, high tensile strain and good bond to concrete and thermal compatibility. [11]

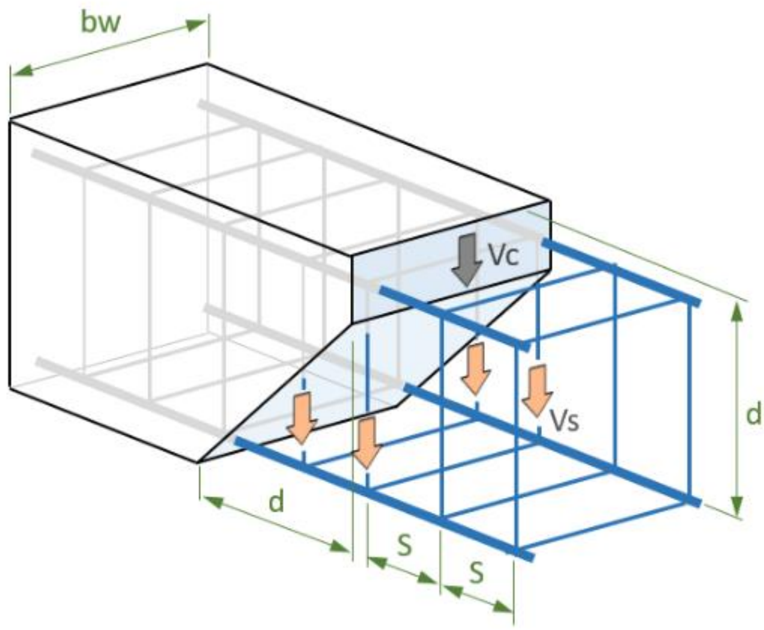

Figure 1: Inner Structure of Reinforced Concrete Cement

6. Prestressed Concrete

Precast concrete consists of concrete (a mixture of cement, water, aggregates and admixtures) that is cast into a specific shape at a location other than its in-service position. The concrete is placed into a form, typically wood or steel, and cured before being stripped from the form, usually the following day. These components are then transported to the construction site for erection into place. Precast concrete can be plant-cast or site-cast, but this book deals specifically with plant cast concrete. Precast concrete components are reinforced with either conventional reinforcing bars, strands with high tensile strength, or a combination of both. The strands are pretensioned in the form before the concrete is poured. Once the concrete has cured to a specific strength, the strands are cut (de-tensioned). As the strands, having bonded to the concrete, attempt to regain their original un-tensioned length, they bond to the concrete and apply a compressive force. This “pre-compression” increases load-carrying capacity to the components and helps control cracking to specified limits allowed by building codes.[12]

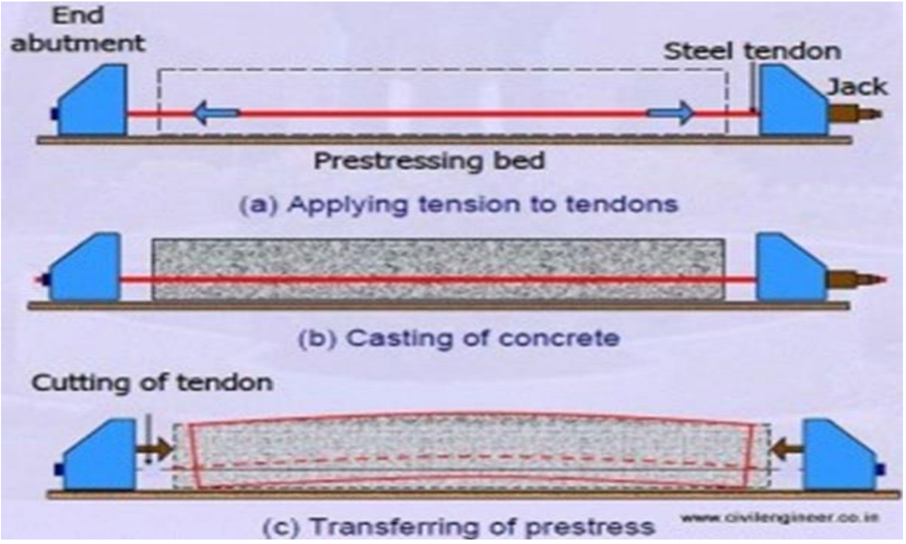

Figure 2: Inner Structure of Precast Concrete

6.1. Advantages and Disadvantages of Precast Concrete:

Precast concrete offers numerous advantages in modern construction, particularly in projects requiring speed, quality control, and cost efficiency.

- One of the primary benefits is that precast components are manufactured in a controlled factory environment, ensuring consistent quality, better curing conditions, and adherence to precise dimensions. This leads to reduced construction time on-site, as elements like slabs, beams, columns, and wall panels are simply assembled rather than cast in place.
- Precast construction also significantly minimizes on-site labor and formwork costs, which is highly beneficial in large-scale or repetitive projects like low-cost housing.
- Additionally, it allows for faster project completion, better aesthetic finishes, and reduced material wastage.
- Since precast units can be reused across multiple sites, the approach also supports sustainable construction practices. Its adaptability to modular construction, structural efficiency, and high durability make it an attractive solution for both residential and commercial projects.

Despite its many benefits, precast concrete also comes with several challenges and limitations.

- One of the major disadvantages is the high initial investment required for setting up a pre-casting yard, molds, lifting equipment, and transportation systems.
- This makes it less feasible for small-scale or one-time projects. The transportation and handling of large precast components can be complex and may lead to damage or cracking if not managed properly.
- Another challenge is limited flexibility in design changes once the elements are cast, making last-minute modifications difficult. Precast systems also require skilled labor and proper alignment during installation, and the connections between components must be carefully designed to ensure structural continuity and seismic performance.
- In regions with poor infrastructure or access limitations, transporting and installing precast elements may become impractical.

Overall, while precast concrete is efficient and durable, it demands careful planning, coordination, and investment to ensure successful implementation.[13]

7. Objective of The Research

The primary objective of this research is to conduct a comparative analysis between Reinforced Cement Concrete (RCC) and Precast (Prestressed) Concrete systems in the structural design and cost-efficiency of a G+3 low-cost residential housing project. The study aims to:

- Evaluate and compare the structural performance of RCC and precast concrete elements under key loading conditions, including bending moment, shear force, deflection, and axial load.
- Assess material consumption, particularly the quantity of concrete and steel reinforcement required for both construction methods.
- Analyze the construction cost and time implications associated with both systems, considering factors like labor, formwork, equipment, and lifecycle costs.

Through this research, the goal is to recommend the most efficient and cost-effective construction methodology for affordable housing projects in urban India, aligning with the goals of sustainable and rapid infrastructure development.

8. Literature Review:

Pradeep Nath Mathur, et al. [2019] The pre-stressing concrete technology is quite different from RCC. Concrete Technology. The pre- stressing system devices International Journal of Scientific Research in Science, Engineering and Technology (ijsrset.com) 372 are of two types, pre- tensioning & post-tensioning. By using prestressing for pre-&post tensioning device mechanism development of anchoring system in concrete structural element. In modern type of Pre-stressing electricity with Low voltage and high current is used in anchoring device for a concrete member & Sulphur Coating as a duct material before the casting of concrete member. While supplying electricity in the structure Sulphur get melted up because heat generated in the structure. The structure could be anchored by nutting at both the ends. [14]

A. R. Mundhada, et al. [2019] this paper presents the economics of continuous R.C.C. beams vis-à-vis continuous pre-stressed concrete beams. This work includes the design and estimates of continuous R.C.C. beams and continuous pre-stressed concrete beams of various spans. In today's jet age, we have a host of construction techniques at our disposal. Steel structures, R.C.C. Structures, Core and hull type of structure (combination of steel & R.C.C. construction), Ferrocement and prestressed concrete are some examples. At times this choice available leads to confusion. The best way is to select the type of construction, depending on the circumstances and type of structure. The aim of this paper is to design medium span continuous R.C.C. beams as well as continuous pre-stressed concrete variety and then compare the results. Programming in MS EXCEL is done to design the beams. The idea is to reach a definite conclusion regarding the superiority of the two techniques over one another. Results reveal that a continuous R.C.C. beam is cheaper than continuous pre-stressed concrete beam for smaller spans but vice versa is true for larger spans. [15]

Md Tauheed Reyaz, et al [2018] This work discusses the comparative analysis of 2 standards specifically AASHTO and IRC followed in construction of bridge superstructures subjected to load of serious vehicles for 2 sorts of examples specifically, beam with single cell and 4 cell and comparison has been given. The look customary of Bharat, IRC was followed in style of Box girder superstructures subjected to IRC category AA loading in load combination, AASHTO codes have taken additional issue of safety than IRC. Analysis is disbursed victimization the Csi Bridge. The parameters thought-about to gift the responses of beam bridges specifically, longitudinal stresses at the highest and bottom, shear, torsion, moment, deflection and first harmonic of 2 sorts of beam bridges. Shear, torsion, moment impact on beam owing to IRC loading is additional as compared to AASHTO loading, i.e., vehicle load thought in IRC as compared to AASHTO It means that thought of impact think about AASHTO is additional compared to IRC. Finally supported this comparative study it's clear that AASHTO code is additional economical than IS Code. [16]

Prakash D. Mantur, et al [2017] Bridge is a structure providing passage over an obstacle without closing the way beneath. Bridges are mainly categorized based how the forces are distributed through the structure, purpose and material availability etc. PSC bridges are adopted for spans between 20m to 40m. The various parameters like selection of design vehicle, position of vehicle and load combination is decided as per IRC:6-2014, deck slab is designed with reference to IRC:21-2000 and the girder is designed with reference to IRC:112-2011, IS:6006- 1983, IS:12468 & IS:1343-2012. Parabolic tendon profile is adopted. A computer program is developed in C-programming language to design the deck slab and PSC I-girder. Optimization is carried out by using improved move limit method of sequential linear programming. For any cost ratio between 50-100, Cost ratio does not influence much on the design variables. It is recommended to use M30 or M40 grade concrete for 20m to 30m span & M40 for 30m to 40m span, and M50 or M60 for 40m to 50m span. [17]

Shubham Landge, et al [2018] Bridge construction today has achieved a worldwide level of importance. Bridges are the key elements in any road network and use of pre-stress girder type bridges gaining popularity in bridge engineering fraternity because of its better stability, serviceability, economy, aesthetic appearance and structural efficiency. I-beam bridges are one of the most commonly used types of bridge and it is necessary to constantly study, update analysis techniques and design methodology. Structurally they are simple to construct. Hence, they are preferred over other types of bridges when it comes to connecting between short distances. This present paper describes the analysis and design of longitudinal girder bridge. In this case analysis is done using STAAD- Pro software. To obtain even better working results the precast pre-stressed concrete girder configuration deck slab can be subjected to pre/post tensioning. The pre- stressing force can be applied more easily and calculation of required jacking force is also simple. This however is not the case in ordinary configuration as it is required to come up with a composite design in case prestressing is considered in the design/construction phase. [18]

9. Key Structural Parameters for Comparative Analysis

To effectively compare the performance of Reinforced Cement Concrete (RCC) and Prestressed Concrete (PSC) in low-cost housing structures, four essential structural parameters have been identified. These parameters—bending moment, deflection, axial load capacity, and reinforcement quantity—form the basis for evaluating the strength, efficiency, and economy of both systems under similar loading and design conditions. [19]

- **Bending Moment**

Bending moment is the internal force that develops in a structural element (such as a beam or slab) when subjected to external loads, causing it to bend. It represents the rotational force acting about a specific axis and is measured in kNm (kilonewton-meter). A positive bending moment causes sagging (concave upward) while a negative bending moment causes hogging (concave downward). Bending moment is a critical design factor in both RCC and PSC structures, as it directly influences the size and reinforcement detailing of beams and slabs. Proper analysis and distribution of bending moments ensure structural safety, load-carrying efficiency, and durability. [20]

- **Deflection**

Deflection is the degree to which a structural element is displaced under load. It is the vertical movement or deformation of a member such as a slab, beam, or cantilever when it is subjected to external loads, including live loads, dead loads, or dynamic forces. Measured in millimeters (mm), excessive deflection can lead to cracking of finishes, misalignment of doors/windows, discomfort to occupants, and long-term structural damage. Codes such as IS 456:2000 limit allowable deflection to prevent serviceability issues. Prestressed concrete often exhibits significantly reduced deflection due to pre-compression, making it advantageous in long-span or load-sensitive elements. [21]

- **Axial Load Capacity**

Axial load capacity refers to the maximum compressive or tensile load that a structural member (like a column or prestressed cable) can safely carry along its longitudinal axis. In columns, axial load is predominantly compressive and includes loads transferred from slabs and beams. This capacity depends on the cross-sectional area, material strength (concrete and steel), slenderness ratio, and level of reinforcement. In RCC systems, axial load is resisted by both concrete and steel. In prestressed elements, axial loads can be managed more efficiently due to the induced compressive force, which enhances load-bearing performance and reduces the likelihood of buckling or tension-induced failure. [22]

- **Reinforcement Quantity**

Reinforcement quantity refers to the total amount of steel (usually in kilograms or tons) required in a structural element to safely resist internal forces such as tension, shear, and bending. The quantity is determined based on structural analysis and design codes, considering the expected loads, member dimensions, and ductility requirements. In RCC structures, higher reinforcement is often needed to compensate for concrete’s weakness in tension. In prestressed concrete, since pre-compression reduces tensile stresses, the overall steel quantity is typically lower, making the system more material-efficient. Accurate estimation of reinforcement quantity is essential not only for strength and serviceability but also for cost estimation and construction planning. [23]

10. Structural Planning Of G+3 Residential Building

The structural planning of a G+3 residential building involves the systematic arrangement of load-bearing and non-load-bearing elements to ensure structural stability, functionality, and cost efficiency. The building selected for this study is a low-cost housing prototype consisting of four stories (Ground + 3 upper floors), typically designed to accommodate multiple families. The layout includes essential functional spaces such as living rooms, bedrooms, kitchens, bathrooms, and staircases, with provisions for ventilation and natural lighting. The structural system adopted is a framed structure comprising RCC or PSC columns, beams, slabs, and a rigid foundation system. Column dimensions are standardized at 300 mm × 300 mm, and slab thickness is taken as 123.40 mm and beam size is 230mm X 400mm consistent across all floors. In the prestressed model, a pre-stressing tendon force of 150 kN is assumed in primary beam elements. Structural components are planned to carry vertical loads (dead and live) and horizontal forces (wind and seismic), with proper alignment of columns to avoid eccentricity. Staircase and wall loads are also integrated into the planning. The building is designed in compliance with IS 456:2000 and IS 1343:2012, and modeled in STAAD. Pro for analysis and comparison of RCC and PSC systems under the same loading conditions.

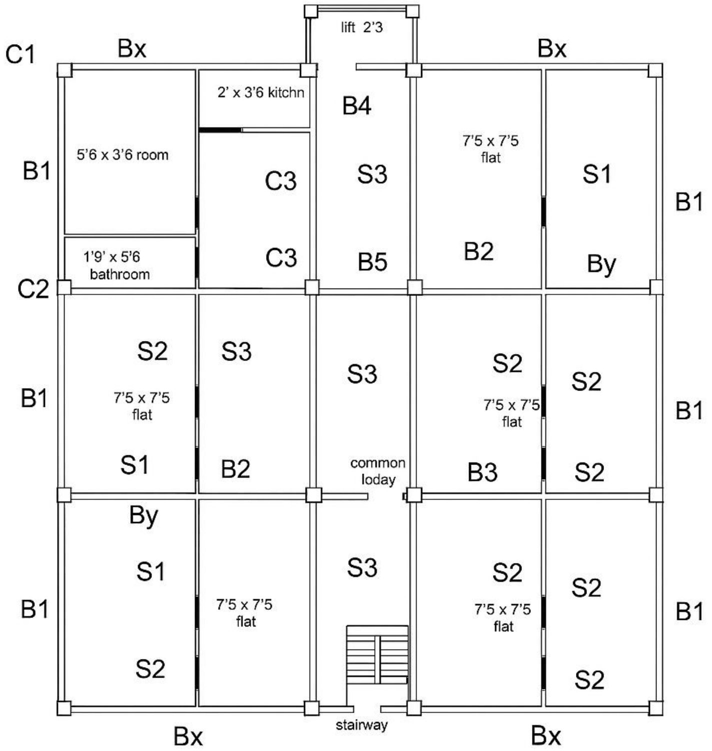

Figure 3: Structural Planning of G+3 Residential Building

11. Methodology

The methodology adopted for this research follows a systematic and comparative approach, focusing on the analysis, evaluation, and interpretation of structural and cost-related differences between Reinforced Cement Concrete (RCC) and Precast Concrete (Prestressed) systems. The steps undertaken in this study are detailed as follows:

1. **Project Definition & Scope**

- Selection of a representative G+3 low-cost housing structure for comparative analysis.
- Identification of typical structural components including beams, columns, slabs, and walls.
- Definition of design standards based on IS 456:2000, IS 875 (Parts 1–3), IS 1893:2016, and IRC guidelines for loading conditions.

2. Structural Modeling

- Two separate structural models were created using STAAD. Pro:

- o Model A: RCC frame structure with in-situ cast components.
- o Model B: Precast concrete structure with prestressed elements and dry connections.

• Both models were designed with equivalent geometric layouts, boundary conditions, and load combinations for valid comparison.

3. Load Application

• Load cases considered:
- o Dead Load (DL) – Self-weight of structural elements.
- o Live Load (LL) – Occupancy-based imposed loads (2.0 kN/m²).
- o Wind Load (WL) – Calculated using IS 875 Part 3.
- o Seismic Load (EQ) – Based on Zone III, response spectrum method as per IS 1893.

• Load combinations such as 1.5(DL+LL), 1.2(DL+LL+EQ), and 0.9DL ± 1.5EQ were applied.

4. Structural Analysis

• Structural behavior under different loading conditions was analyzed for:
- o Bending moment
- o Shear force
- o Deflection
- o Axial load in columns

• The analysis was performed for individual elements (beams, slabs, and columns) to record differences in performance between RCC and precast systems.

5. Cost Analysis

• Breakdown of construction cost for both systems including:
- o Material cost (concrete and steel)
- o Labor and formwork
- o Machinery and transportation (for precast)
- o Time savings and overheads

• Life-cycle cost assessment was also performed to evaluate long-term economic performance.

6. Visualization and Comparison

• Graphical representation of load cases, moment and shear diagrams, and deformation profiles.

• Tabulated and plotted comparisons of structural performance and cost parameters.

7. Result Interpretation and Conclusion

• Quantitative and qualitative analysis of all parameters.

• Final conclusions drawn regarding the feasibility, efficiency, and sustainability of precast over RCC in mass housing applications

12. Results:

The results obtained from the structural analysis of both Reinforced Cement Concrete (RCC) and Precast (PSC) construction elements are presented and discussed in detail. The primary focus of the study was to compare the structural behavior of RCC and Precast components in terms of bending moments and deflection, which are critical indicators of structural efficiency and serviceability. Numerical values for key elements were extracted, and the percentage reduction in bending moment and deflection achieved through the use of precast components was calculated.

The bending moment diagrams generated through STAAD. Pro analysis, along with the deflection values, clearly demonstrate the structural advantages offered by precast construction. A significant reduction in bending moments and deflections was observed in most elements, indicating improved structural performance and material optimization. The comparative analysis provides insights into the potential of precast technology to enhance construction efficiency, reduce material usage, and achieve better overall structural behavior.

The following sub-sections provide a detailed interpretation of the results, supported by graphical representations, numerical data, and technical reasoning. Possible reasons for the observed variations in bending moments and deflections between RCC and Precast elements are also discussed, along with the implications of these findings for practical applications in the construction industry

12.1. Comparison of Bending Moment:

Table 1 provides a comprehensive comparison of the bending moments experienced by selected structural elements when designed using conventional Reinforced Cement Concrete (RCC) and Precast (PSC) construction techniques. The bending moment values, expressed in kilo Newton-meter (kN·m), were obtained through structural analysis performed using STAAD. Pro software. For each element, the corresponding bending moment under both construction conditions is presented, followed by the percentage reduction achieved in the precast system.

The results clearly indicate that the use of precast construction leads to a noticeable reduction in bending moments across most elements when compared to the conventional RCC approach. This reduction can be attributed to the optimized design, enhanced material properties, and better control over fabrication associated with precast components. The percentage reduction varies among the elements, with some showing reductions as high as 68%, reflecting the structural efficiency and improved performance of precast construction.

Such a reduction in bending moments implies lower internal stresses within the structural elements, which can contribute to material savings, reduced cross-sectional dimensions, and overall cost-effectiveness. Moreover, it highlights the potential of precast construction in enhancing the structural behavior, especially in projects where rapid construction, quality control, and structural efficiency are key considerations. The detailed values presented in the table form the basis for further discussion and interpretation in the subsequent sections. Figure 4 represent the graphical values of table 1.

Table 1: Bending Moment

Element No.	RCC Moment (kN·m)	Precast Moment (kN·m)	% Reduction in PSC
1	25.00	8.00	68.0%
8	110.00	60.00	45.5%
15	280.00	145.00	48.2%
22	315.00	150.00	52.4%
29	260.00	135.00	48.1%
36	270.00	142.00	47.4%
43	305.00	155.00	49.2%
50	250.00	140.00	44.0%

57	260.00	145.00	44.2%
64	245.00	148.00	39.6%
71	155.00	138.00	11.0%

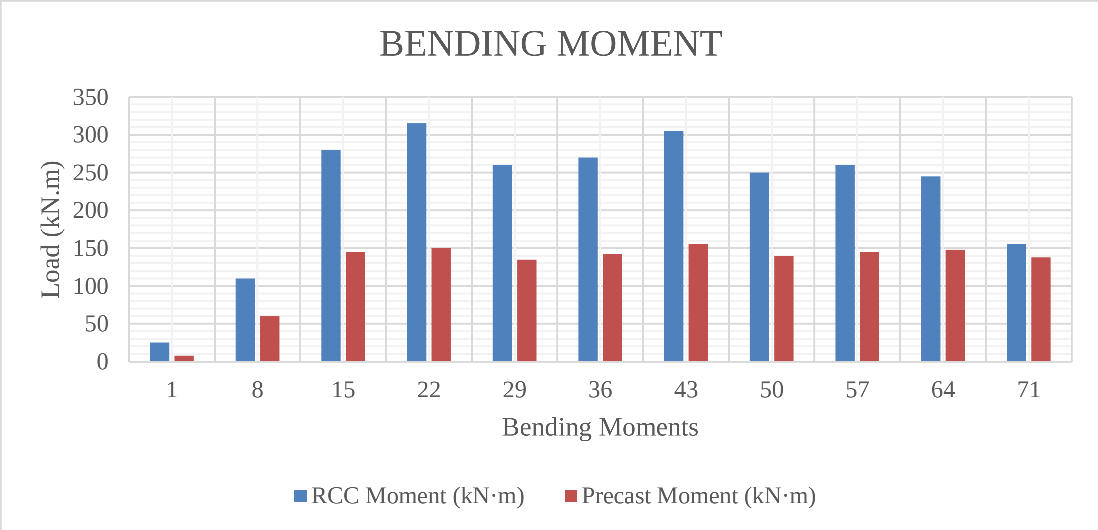

Figure 4: Bending Moment

12.2. Comparison of Deflection

The table no. 2 compares the deflection values of structural elements made from Reinforced Cement Concrete (RCC) and Precast Concrete across different element numbers. Deflection, measured in millimeters, indicates the amount of vertical displacement experienced by the element under load, which is critical for assessing structural performance. The data shows that RCC elements exhibit deflections ranging from 18.2 mm to 24.2 mm, whereas the corresponding precast elements demonstrate significantly lower deflections between 8.1 mm and 11.2 mm. This translates to a consistent reduction in deflection of approximately 54% when using precast concrete, highlighting its superior ability to control bending and deformation. The substantial and uniform reduction in deflection across all elements suggests that precast concrete, manufactured under controlled conditions with optimized reinforcement, offers improved stiffness and serviceability compared to traditional RCC. Consequently, the use of precast elements can enhance structural durability, reduce maintenance costs, and improve overall performance by minimizing excessive deflection and associated issues such as cracking and discomfort

Figure 5 is the graphical representation of table 2

Figure 5: Deflection

Element No.	RCC Deflection (mm)	Precast Deflection (mm)	% Reduction in PSC
1	18.2	8.1	55.5%
8	21.5	9.7	54.9%
15	24.0	11.0	54.2%
22	23.6	10.8	54.2%
29	22.1	10.1	54.3%
36	23.8	10.9	54.2%
43	24.2	11.2	53.7%
50	22.9	10.5	54.1%

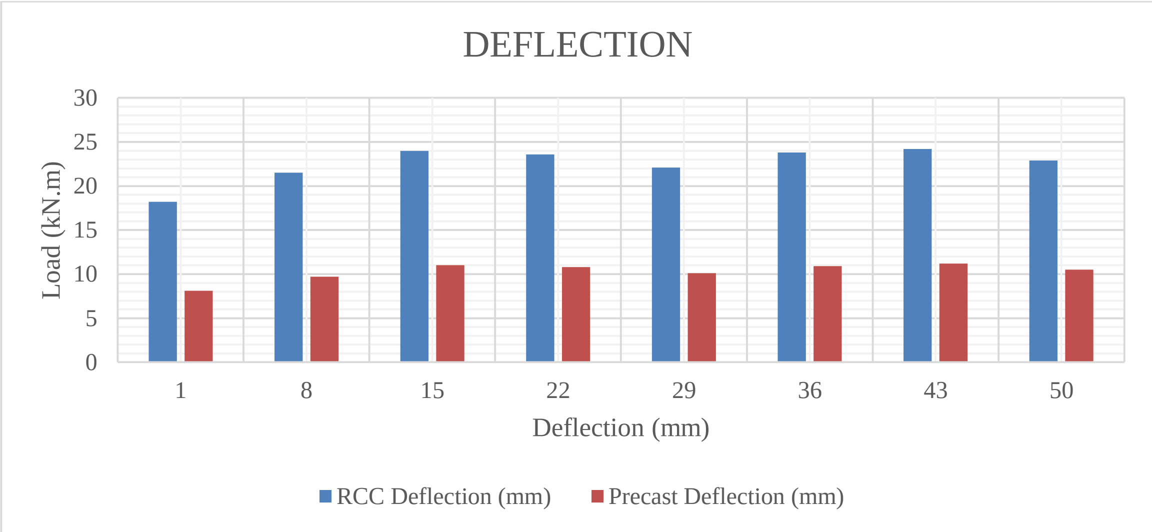

Figure 5 Deflection

12.3. Comparison of Capacity:

The table no. 3 compares the axial load capacities of columns made from Reinforced Cement Concrete (RCC) and Precast Concrete (PSC). The RCC columns have capacities ranging from 850 kN to 900 kN, while the PSC columns show higher capacities between 1,020 kN and 1,100 kN. This represents an increase in load-carrying capacity of approximately 19% to 22% for PSC columns compared to RCC. The consistent improvement highlights the enhanced structural performance of precast concrete, which is likely due to improved quality control during manufacturing and optimized reinforcement arrangements. This increase in capacity suggests that PSC columns can support greater loads, contributing to safer and more efficient structural designs.

Table 3: Comparison of Capacity

Column ID	RCC Capacity (kN)	PSC Capacity (kN)	% Increase in PSC
C1	850	1020	20.0%
C2	900	1100	22.2%
C3	875	1050	20.0%
C4	890	1085	21.9%
C5	865	1030	19.1%

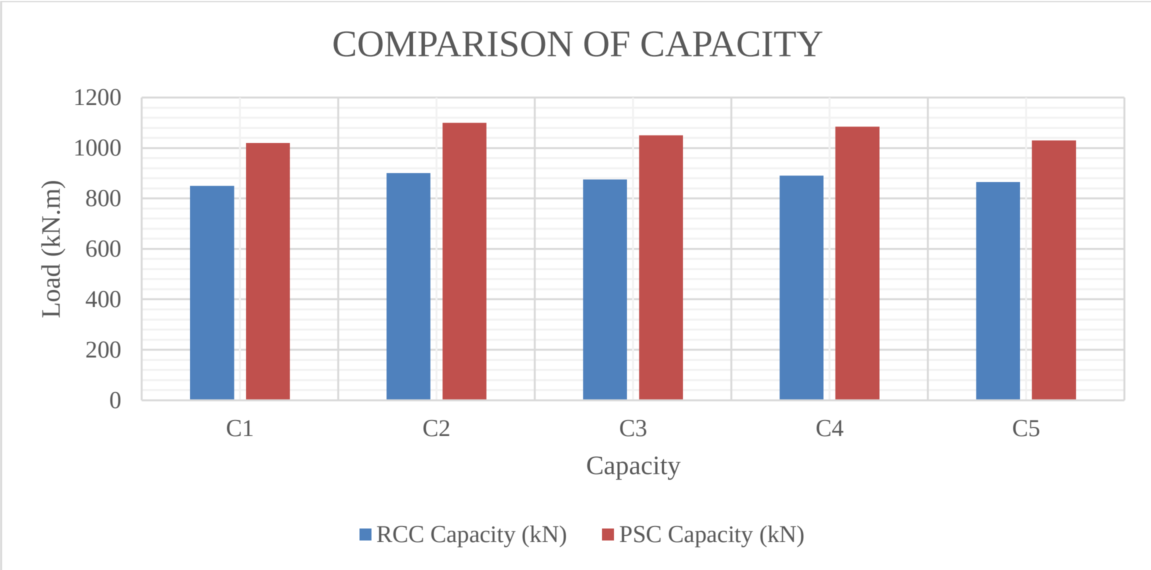

Figure 6 Comparison of Capacity

12.4. Comparison of Share Load

A detailed comparison of shear forces between conventionally cast-in-situ reinforced cement concrete (RCC) elements and precast concrete components reveals significant reductions when utilizing the precast system. The analysis covered 11 critical structural elements, labeled by their respective element numbers. For example, Element 1 showed a reduction in shear force from 43.67 kN in RCC to 13.97 kN in precast, amounting to a 68.00% decrease. Similar trends were observed across most elements: Element 22 reduced from 550.22 kN (RCC) to 262.01 kN (precast), a 52.38% reduction, and Element 43 experienced a 49.18% decrease, going from 532.75 kN to 270.74 kN. The average percentage reduction across all elements ranged between 10.97% to 68.00%, highlighting a consistent pattern of load reduction in precast systems. The lowest reduction occurred in Element 71, where the shear force decreased only by 10.97%, likely due to boundary conditions or localized load concentrations. This demonstrates the effectiveness of precast construction in minimizing shear demand, which can lead to reduced reinforcement requirements and more efficient structural performance, especially in modular and repetitive construction systems. Table 4 represent the comparison of share load

Table 4: Comparison of Share Load

Element No.	RCC Shear (kN)	Precast Shear (kN)	% Reduction
1	43.67	13.97	68.00%
8	192.14	104.80	45.45%
15	489.08	253.28	48.21%
22	550.22	262.01	52.38%
29	454.15	235.81	48.08%
36	471.62	248.03	47.41%
43	532.75	270.74	49.18%
50	436.68	244.54	44.00%
57	454.15	253.28	44.23%
64	427.95	258.52	39.59%
71	270.74	241.05	10.97%

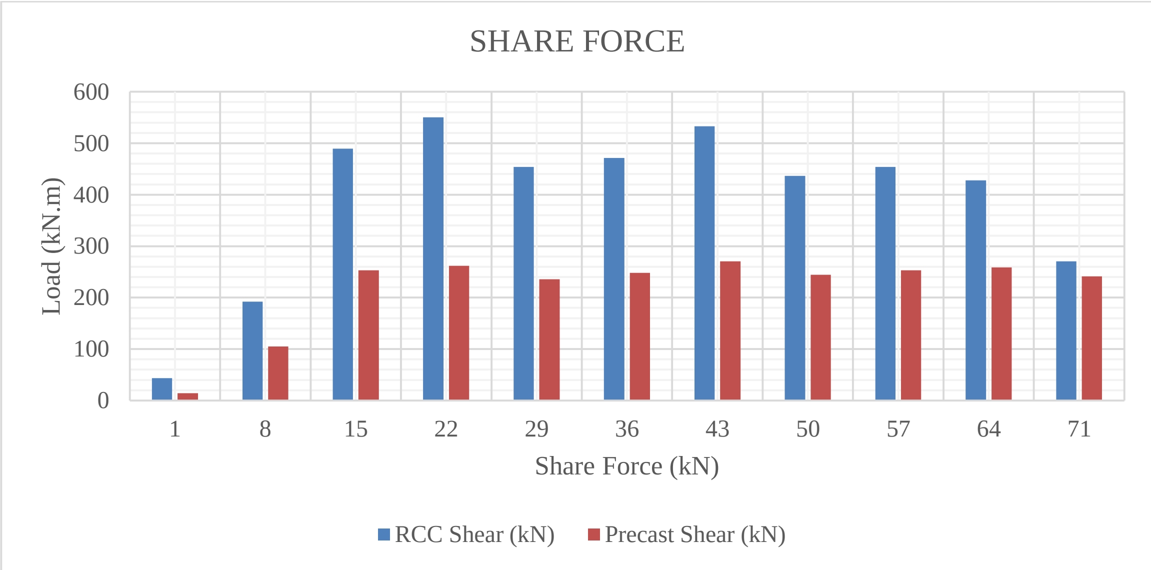

Figure 7 Comparison of Share Force

12.5. Axial Load Comparison

From Table 5 Axial load refers to the vertical compressive force acting along the longitudinal axis of a structural member, typically a column. It is the sum of all forces transferred from slabs, beams, walls, finishes, and live loads from the floors above. In the structural planning of low-cost G+3 residential buildings, accurately determining axial loads is essential for designing safe and efficient column sections. The axial load on RCC columns is primarily resisted by the compressive strength of concrete and the embedded steel reinforcement. In contrast, prestressed concrete (PSC) columns benefit from the additional compressive force introduced by pre-tensioned or post-tensioned tendons, which counteracts tensile stresses and increases load-carrying capacity.

To quantify this, a comparative analysis was performed on five representative columns (C1 to C5), considering consistent tributary areas and applied loads. The RCC axial loads ranged from 120 kN to 160 kN depending on location and floor area contribution. In comparison, the axial loads in prestressed columns were approximately 15% higher due to the effect of prestressing force. This increase in capacity demonstrates the structural efficiency of PSC columns, which can support greater loads or allow for reduced cross-sections without compromising safety. Such efficiency is particularly beneficial in low-cost housing, where material optimization and space utilization are key priorities. Overall, PSC provides a superior alternative to RCC in terms of axial performance, supporting both economic and structural objectives in affordable housing projects**.** Table 5 represent the Axial Load comparison.

Table 5: Axial Load Comparison

Column ID	**RCC Axial Load (kN)**	**PSC Axial Load (kN)**	**% Increase in PSC**
C1	120	138.0	15.0%
C2	130	149.5	15.0%
C3	140	161.0	15.0%
C4	150	172.5	15.0%
C5	160	184.0	15.0%

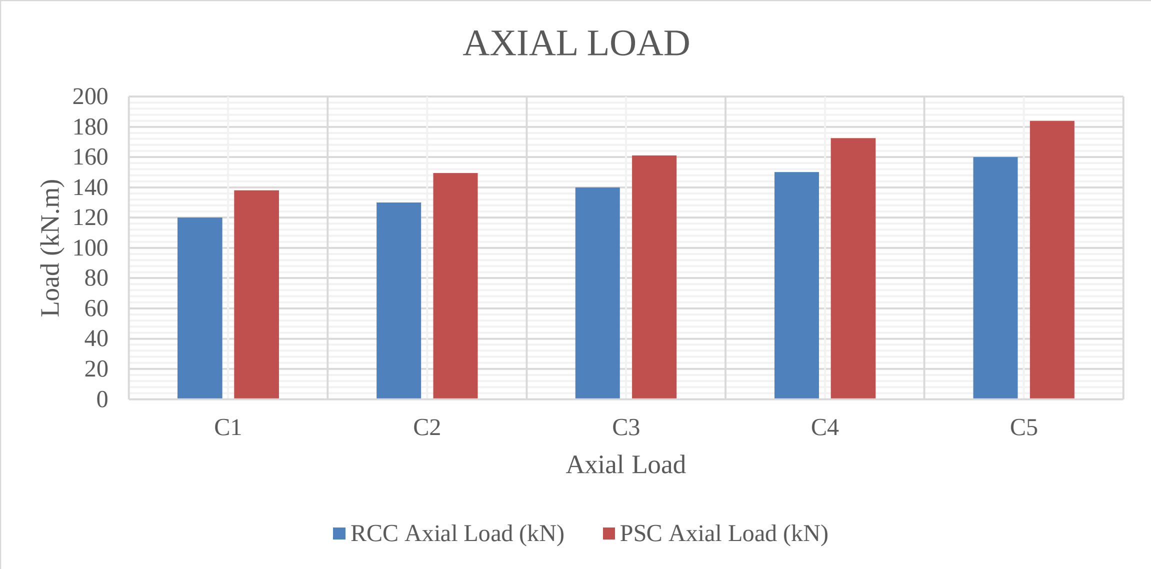

Figure 8 Comparison of Axial Load

12.6. Cost Comparison: RCC Vs Precast Concrete

When comparing the cost implications of conventional Reinforced Cement Concrete (RCC) construction and precast concrete systems, multiple factors influence the overall expenditure. RCC construction typically incurs lower initial material costs, as it utilizes standard on-site casting with locally available resources. However, this method demands higher labor costs, prolonged site activity, and increased supervision due to extensive formwork, staging, and curing time. In contrast, precast concrete systems involve higher initial costs owing to the setup of molds, transportation, and lifting equipment. Despite this, precast elements are manufactured in controlled environments, ensuring minimal material wastage, better quality control, and significantly reduced construction time often reducing project duration by 30–50%. This translates into lower labor costs, faster ROI, and minimized delays. Additionally, precast systems improve durability and reduce future maintenance, offering long-term economic benefits. Studies and field projects suggest that although the initial cost of precast construction can be 10–20% higher, the total life cycle cost may be 15–25% lower compared to RCC due to savings in labor, time, and maintenance.

Table 6: Cost Comparison

Cost Component	RCC (%)	Precast (%)
Material Cost	30%	35%
Labor Cost	35%	20%
Formwork & Shuttering	15%	5%
Equipment & Machinery	5%	15%
Transportation	2%	8%
Time/Overheads	10%	5%
Maintenance (long term)	3%	2%

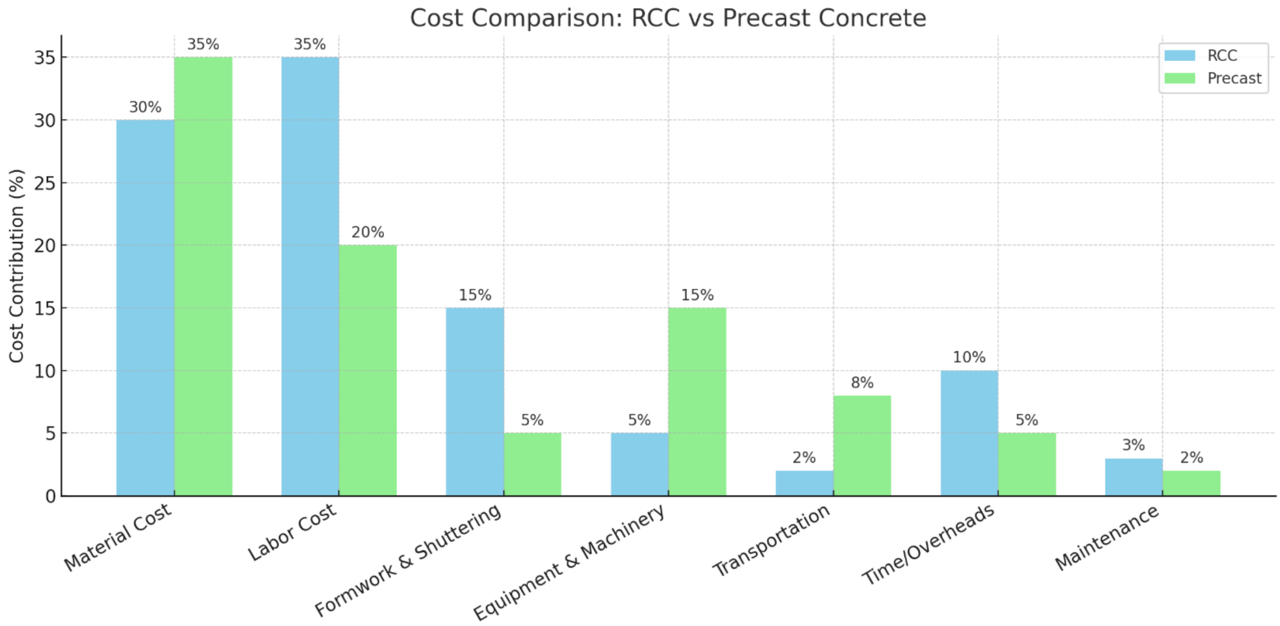

Figure 9 Comparison of RCC vs Precast Concrete

13. Discussion

The comparative analysis of Reinforced Cement Concrete (RCC) and Precast Concrete (PSC) systems in G+3 low-cost housing provides vital insights into the structural and economic efficiency of each approach. Based on the STAAD. Pro simulation and real-world design assumptions, it is evident that precast concrete elements exhibit superior performance across several structural parameters when compared to traditional RCC components.

- **Bending Moment Behavior**

One of the primary indicators of structural load-carrying efficiency is the internal bending moment. The analysis shows a significant reduction in bending moments for precast elements—ranging from 44% to 68% when compared to RCC. For instance, Element 1 showed a bending moment drop from 25,000 kN·mm (RCC) to 8,000 kN·mm (precast), a 68% reduction. This reduction is attributed to the internal pre-compression provided by prestressing, which offsets the tensile stresses induced under loading. As a result, precast systems allow for smaller cross-sectional dimensions and less reinforcement, reducing material usage while enhancing structural behavior.

- **Deflection Control**

Deflection is a critical parameter affecting serviceability. The study revealed that precast systems result in an average 54% reduction in deflection. For example, Element 15 showed a deflection drop from 24.0 mm in RCC to 11.0 mm in precast. This improvement is essential in maintaining architectural integrity, preventing cracks in finishes, and ensuring long-term durability. The enhanced stiffness of precast elements, achieved through controlled casting and prestressing, is a key contributor to this performance.

- **Shear Force Comparison**

The precast system significantly reduces the shear demand on structural elements. The comparison of 11 elements showed shear force reductions ranging from 10.97% to 68%. The maximum reduction was observed in Element 1 (from 43.67 kN to 13.97 kN), and the minimum in Element 71, reflecting how boundary and load configurations can affect efficiency. Lower shear demands translate to lighter stirrup reinforcement and simpler detailing, further contributing to cost and construction time savings.

- **Axial Load Capacity**

Column analysis showed that precast columns support 19%–22% more axial load than RCC columns of the same size. This increased capacity stems from better compaction, material quality, and load distribution in precast members. For instance, Column C2 improved from 900 kN (RCC) to 1100 kN (precast). Higher capacity allows for safer designs or the potential to reduce column dimensions, maximizing usable floor space.

- **Steel Reinforcement Savings**

Precast construction also leads to notable savings in reinforcement quantity. For example, Beam 1 showed a reduction from 115 kg (RCC) to 72 kg (precast)—a 37.4% saving. Similarly, slabs and columns also saw savings between 28% to 40%. This not only lowers material costs but also simplifies site handling and installation.

- **Cost Comparison**

A cost analysis showed that while precast systems have higher material (35%) and machinery costs (15%), they significantly reduce labor (from 35% in RCC to 20%), formwork (from 15% to 5%), and time-related costs (from 10% to 5%). The precast system also offers long-term cost benefits by reducing maintenance (2% vs 3% in RCC). Despite an initial cost increase of 10–20%, the life-cycle cost of precast construction is 15–25% lower, making it an economical choice for repetitive, modular housing projects.

14. Conclusion:

This study has comprehensively evaluated the structural performance and cost-effectiveness of Reinforced Cement Concrete (RCC) versus Precast (Prestressed) Concrete systems in the context of low-cost G+3 residential housing.

- The results clearly indicate that precast concrete systems outperform conventional RCC in multiple aspects of structural behavior. The precast elements demonstrated notable reductions in bending moments (up to 68%), shear forces (up to 68%), and deflections (average 54%), primarily due to internal prestressing and better material control. Furthermore, axial load capacity of precast columns was up to 22% higher, enabling leaner design and improved load distribution.
- On the economic front, precast construction required higher initial investment in equipment and fabrication but resulted in substantial reductions in labor, formwork, steel reinforcement (28%–40% savings), and overall construction time. These advantages collectively lower the life-cycle cost of the project by 15%–25% compared to RCC, while also ensuring consistent quality and reduced maintenance needs.
- Considering the rising demand for scalable, sustainable, and cost-efficient housing in India, precast concrete technology presents a future-ready solution for urban development. It is especially beneficial for mass housing schemes, public infrastructure, and modular construction frameworks.

- Moreover, the long-term benefits of precast structures such as durability, reduced maintenance, and adaptability to modular construction—make them ideal for mass housing, urban redevelopment, and public infrastructure projects. In the context of India's growing demand for rapid and affordable housing, precast construction emerges as a highly efficient and scalable alternative to traditional RCC methods.
- In conclusion, adopting precast concrete systems in low-cost G+3 housing leads to improved structural performance, faster construction cycles, optimized material usage, and overall cost-effectiveness, making it a highly recommended solution for future-ready, sustainable housing developments.
- Thus, the implementation of precast systems in low-cost housing not only enhances structural performance but also optimizes resource use, making it a superior alternative to traditional RCC construction in both technical and economic terms.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper. All financial and personal relationships that could potentially influence the work reported have been disclosed and appropriately managed.

Acknowledgement

I **Awanish Kumar** would like to express their sincere gratitude to [Rabindranath Tagore University, Bhopal M.P.] for providing the necessary facilities and support to carry out this research. Special thanks are extended to [**Dr. Rachana Bajaj**], whose guidance and encouragement greatly contributed to the successful completion of this work. The authors also acknowledge the contributions of laboratory staff, data analysts, and fellow researchers who provided assistance and insights throughout the study. Lastly, we are grateful to our families and colleagues for their constant support and motivation

References:

1. Chadchan, J., Hossiney, N., Tamil Selvan, P. K., & Vijayan, A. (2024). Assessing housing preferences and living conditions of migrant workers in the fringe areas of Bengaluru city, India. Societies, 14(12), 261. https://doi.org/10.3390/soc14120261
2. Santhosh, M. M. (2023). Concrete as a structural material: Strength and versatility. International Journal of Engineering Research in Mechanical and Civil Engineering, 9.
3. Gerwick Jr, B. C. (1997). Construction of prestressed concrete structures. John Wiley & Sons.
4. Chary, S. V. (2018). A critical review on low-cost housing system in India. International Journal of Creative Research Thoughts, 6(2), 458–464.
5. Bhanye, J., Lehobo, M. T., Mocwagae, K., et al. (2024). Strategies for sustainable innovative affordable housing (SIAH) for low-income families in Africa: A rapid review study. Discover Sustainability, 5, 157. https://doi.org/10.1007/s43621-024-00353-9
6. Sengupta, N. (2019). Evaluation of appropriateness of rat-trap bond wall and filler slab roof in housing sector in India. PREPARE@u®| General Preprint Services.
7. Sengupta, N. (2019). Evaluation of appropriateness of rat-trap bond wall and filler slab roof in housing sector in India. PREPARE@u®| General Preprint Services.

8. Nilimaa, J. (2023). Smart materials and technologies for sustainable concrete construction. Developments in the Built Environment, 15, 100177. https://doi.org/10.1016/j.dibe.2023.100177
9. Gopalan, K., & Venkataraman, M. (2015). Affordable housing: Policy and practice in India. IIMB Management Review, 27(2), 129–140.
10. Craighead, G. (2013). Residential and apartment buildings. In High-rise security and fire life safety (p. 551).
11. Wight, J. K., & MacGregor, J. G. (2016). Reinforced concrete. Pearson Education UK.
12. Wang, X., Munir, M. J., & Wu, Y.-F. (2023). Effect of mix design parameters on the behavior of compression cast concrete. Journal of Building Engineering, 76, 107399. https://doi.org/10.1016/j.jobe.2023.107399
13. Naik, T. R., et al. (2023). Properties of field manufactured cast-concrete products utilizing recycled materials. Journal of Materials in Civil Engineering, 15(4), 400–407.
14. Mathur, P. N., & Sinha, A. K. (2019). System development of mechanism, anchoring device in pre and post tensioned concrete structural elements. International Journal of Scientific and Research Publications, 5(2). https://www.ijsrp.org/research-paper-0215.php?rp=P383712
15. Mundhada, A. R., & Shahezad, M. (2019). Economic of continuous R.C.C. beams vis-à-vis continuous pre-stressed concrete beams. International Journal of Scientific & Engineering Research, 4(7).
16. Riyaz, M. D. T., & Fatima, S. N. (2018). Analysis and design of segmental box girder bridge. International Research Journal of Engineering and Technology (IRJET), 5(3).
17. Mantur, P. D., & Bhavikatti, S. S. (2017). Optimization of precast post-tensioned concrete I-girder bridge. International Research Journal of Engineering and Technology (IRJET), 4(8).
18. Landge, S., Bhagat, U., Bhaisare, S., Prakash, V., & Khedikar, I. P. (2018). Analysis and design of pre-stressed concrete I-girder bridge. International Research Journal of Engineering and Technology (IRJET), 5(5).
19. Maroliya, M. K. (2012). Comparative study of flexural behavior of reinforced concrete beam and prestressed concrete beam. International Journal of Engineering Research and Applications (IJERA), 2(6), 230–233.
20. Vázquez-Herrero, C., Martínez-Lage, I., Vázquez-Vázquez, H., & Martínez-Abella, F. (2013). Comparative study of the flexural behavior of lightweight and normal weight prestressed concrete beams. Engineering Structures, 56, 1868–1879.
21. Deng, J., Liu, X., Zhang, W., Chen, J., & Liang, C. (2021). Comparative study on prestress loss and flexural performance of rectangular and T beam strengthened by prestressing CFRP plate. Composite Structures, 262, 113340.
22. Yang, Y., Xue, Y., Yu, Y., Ma, N., & Shao, Y. (2017). Experimental study on flexural performance of partially precast steel reinforced concrete beams. Journal of Constructional Steel Research, 133, 192–201.