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Effect of Beam Span Variation on Partially Prestressed and Reinforced Concrete Buildings: A Comparative Study

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Abstract

Partially prestressed concrete (PPC) buildings are gaining popularity in modern engineering world due to their improved strength and durability compared to the reinforced concrete (RC) building. PPC structure combine both reinforcement and prestressing elements, integrating the advantages of RC and prestressed structures. However, research on PPC buildings remains limited in Nepal, despite rapid infrastructure and urbanization growth. This study focus on the comparing the performance of PPC and RC buildings by analyzing six models each with varying beam spans ranging from 6m to 16m in an eight-storey building structure using SAP2000 v20 tool. The primary parameters analyzed include maximum bending moment, shear force, stress distribution, deflection and span to depth ratio. The analysis of the PPC buildings showed lower bending moments, lower bending stresses and smaller beam sections compare to RC buildings. This leads to a higher span to depth ratio, for PPC building increasing from 16.67 (for a 6m beam span) to 35.55 (for a 16m beam span) and for RC buildings from 15 (for a 6m span) to 20 (for a 16m beam span) while staying within prescribed limits. Additionally, prestressing enhances material efficiency, making PPC buildings more suitable for longer beam spans. This study highlights the advantages of PPC structures in optimizing structural performance and provides useful insights for engineers and architects in designing efficient and resilient buildings.

Keywords: *Partially prestressed concrete, Reinforced concrete, Structural analysis, Beam span, SAP2000*

1. Introduction

Materials used in the construction of buildings have significantly impacted the strength, durability and even cost. Advancement in construction industry has been rapid over the past century, due to the need for more efficient, highly durable, cost effective and safe building. Different researcher has conducted research in the field of challenge of modern architecture and structure for better engineering world. Among the advanced and critical innovations in this field are Reinforced Concrete (RC) and Prestressed Concrete (PC). PC, which emerged in the 1930s and was first used for vaults and silos, is gaining popularity in structural engineering (Marrey & Grote, 2003). Prestressed concrete is widely used in both developed and developing countries for buildings and bridges due to its advantages in size and long spans over 30m. It allows the construction of low to high-rise structures with larger spaces while reducing the size of beams, columns, slabs, material usage, and overall construction costs, making it a modern architectural trend (Mahure & Dhore, 2017).

Reinforced concrete (RC), partially prestressed concrete (PPC), and fully prestressed concrete are three different design and construction methods of building structures in which each have their own pros and cons. Concrete is extensively and cost-effective material that is used in the civil construction industry (Ahmad et al., 2021; Barrios-Fontalvo et al., 2020). RC is a traditional heterogeneous material that is cost effective and commonly used in construction making it available globally (Nahida Nisar & Javed Ahmed Bhat, 2021; Nahida Nisar & Javed Ahmad Bhat, 2021; Okeniyi et al., 2016). RC has certain limitations such as heavy loads that produce cracks and bending in the structure. In RC structures, the tension is carried solely by the steel reinforcement (A.Yee, 2001). Ultimately the performance of the RC building structure is affected in the long run. In course of time, fully PC was developed in such a way that it does not crack under normal conditions by eliminating the tensile stress in the structure. This was a great achievement in the construction industry providing a highly durable and capable PC to handle heavy loads. But the cost of construction is high and it has complex design and construction requirements which are challenging tasks. So the PPC serves as a balance between RC and PC. This PPC improved the structure's flexibility, resilience and overall performance keeping the costs of design and construction more manageable and logical in comparison to PC structures, while providing service and ultimate strength requirements, and ultimately, engineering judgment (Karayannis & Chalioris, 2013). PPC is a moderate design and construction approach that provides a good combination of strength, durability and cost efficiency. PPC has become a popular and efficient construction method for building structures by reducing yielding and damage (Hafezolghorani et al., 2022; Trivana et al., 2021). PPC is best suited for areas with seismically active zones, as it provides structures with better ductility for earthquake resistance. PPC behaves well under normal service loads, so it is a versatile and sustainable modern construction solution. PPC effectively bridges the gap between traditional RC and fully PC, offering a middle ground that combines the affordability of RC with the enhanced performance of fully prestressed systems (Au & Du, 2004). This makes PPC an attractive option for engineers and builders looking for a balanced, efficient, and resilient approach to structural design in today's construction industry (Marianos, 2000).

PPC structures enhance structural performance for longer spans by improving cracking and deflection control compared to fully reinforced concrete structures (Milad Hafezolghorani, 2022). The incorporation of PPC allows for the construction of low to high-rise buildings with greater spaciousness, thereby minimizing the dimensions of structural components like beams, columns, and slabs. This not only reduceds the overall volume of concrete and steel reinforcement required but also contributes to cost-effectiveness in construction projects (Roy, 2019). Many developed countries have already adopted PPC methods in multi storey buildings and this technology has enhanced the field of structural engineering for the construction of aesthetic civil engineering structures (Raka et al., 2014). However, despite PPC global advancement and application in concrete technology, Nepal has yet to develop it in the construction sector. The lack of research in Nepal about PPC is the primary cause of the lack of technical expertise, material unavailability, and lack of sufficient construction equipment. For the recent ongoing urbanization trend in Nepal, there is a great opportunity to integrate PPC in multi storey buildings and mega structures.

There are no specific provisions that exist for span-to-depth ratios in PC structures, including PPC buildings, due to the limited research conducted in this area (Hafezolghorani et al., 2022). This study primarily focuses on the analysis of PPC buildings with varying beam spans and comparing their span-to-depth ratios with regular RC buildings. In Nepal's context, this research aims to aid in selecting appropriate span-to-depth ratios, promoting economic design, and facilitating the practical application of PPC structures in multi storey buildings.

2. Material and Method

2.1 Introduction to Methodology

A systematic methodology exists for analysing building structures through performance evaluation (Figure 1). The approach starts by reviewing literature to create the research concept together with analysing existing studies. The analysis phase begins after modelling 8-storey rectangular building of both regular RC building and PPC building with different beam spans in SAP2000. Models are created through defining materials together with sections and loading parameters for diverse beam dimensions. Load were calculated (DL-Dead load, LL-live load, EQx – Earthquake force in the X-direction, EQy – Earthquake force in the Y-direction, FF – Floor Finish, PW – Partition Wall) and assigned according to the building type. Both building types were examined under the same loading conditions for the analysis of the overall performance for varying beam sizes. The moment developed in each beam was determined, and the global response of the buildings was analysed individually for different beam spans. This helped in understanding the structural behaviour of RC and PPC buildings under varying conditions.

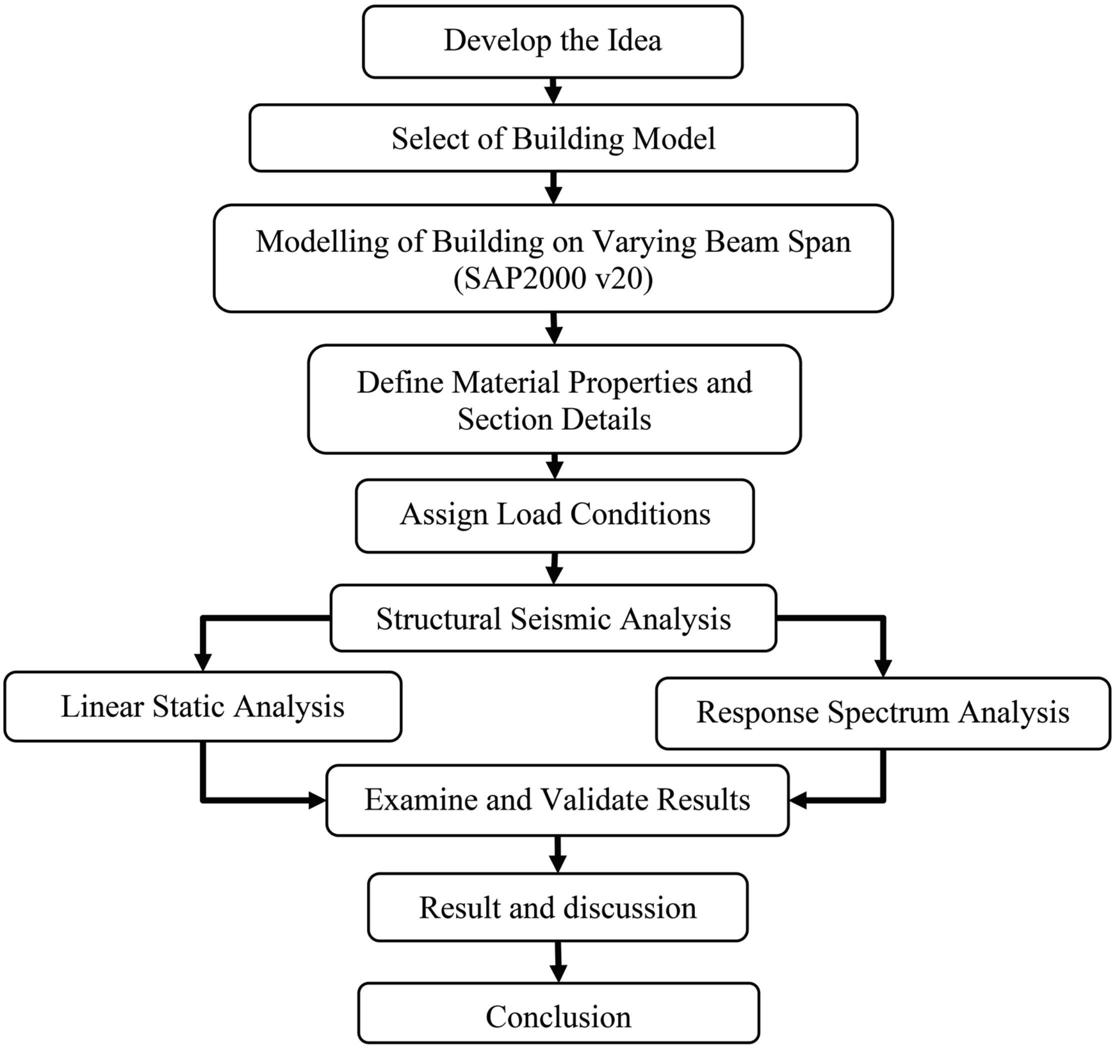


Figure 1: Flow Chart of the study for methodology

The models undergo two types of analysis: the equivalent static method (static analysis) and the response spectrum method (dynamic analysis). A total of 6 RC and 6 PPC buildings with beam spans ranging from 6m to 16m are analysed. The study analysed each model as an 8-storey building having a total height of 30m to evaluate the performance of structural elements, specifically beams and slabs. After assigning loads, the models are tested for safety based on maximum deflection, base shear, and drift parameters. Once these parameters meet the permissible limits, other factors like moment, stress, and fundamental time periods are compared. Finally, the global response of the buildings is analysed to achieve the study's main objective to examine the depth ratio concerning span variations.

After the analysis phase, the results are compared within the two types of analysis: static and dynamic, to determine which method provides better results with varying beam spans. The comparison is also made between the two types of buildings: RC and PPC, both with different beam spans, and within each type of analysis. Microsoft Excel is used to create graphs and bar charts to visually represent the comparative results. Finally, the findings are discussed and interpreted to draw meaningful conclusions.

2.2 Equivalent static method

Equivalent static methods are widely used by different researchers in seismic design and analysis of various civil engineering structures (Al Agha & Umamaheswari, 2021; Faiz & Kumar, 2023; Xu et al., 2019). Equivalent static analysis, or direct static analysis, is a common method that requires less computation, using formulas based on established practices. It calculates base shear (Vb) for the entire structure, distributes it across various levels, and applies lateral forces statically. However, this approach is not suitable for irregular or complex structures.

The design base shear Vb along the lateral direction of the structure shall be determined by:

$Vb= A_h W$

Where,

Ah = Design horizontal seismic coefficient for structure.

W = Seismic weight of the structure.

The horizontal seismic coefficient of the structure can be calculated by:

$A_h = (Z/2) *(S_a/g) *(I/R)$

Where,

Z = Seismic zone factor

I = Importance factor

R = Response reduction factor

S_a/g = Design acceleration coefficient.

As per IS 1893 (Part 1): 2016, the approximate fundamental period of vibration T_a, is determined as:

$T_a= 0.075\ h^{0.75}$

The design seismic base shear calculated above shall be distributed along the height of the structure as per the following expression:

$$Q_i = V_b * \frac{W_i h_i^2}{\sum W_i h_i^2}$$

Where,

Q_i= Lateral force at floor ith,

W_i= Seismic weight of the ith floor,

h_i= Height of floor I measured from the base,

n = Number of stories in the building is the number of levels at which masses are located.

2.3 Response spectrum analysis

The response spectrum analysis method is commonly employed to enhance the accuracy of building assessments (Al Agha & Umamaheswari, 2021; Faiz & Kumar, 2023). The IS code recommends linear static analysis for structures up to 15m in seismic zone II. For larger structures, dynamic analysis is performed using response spectrum or time history analysis. Response spectrum analysis, used for evaluating structural response to dynamic events, considers at least 90% of seismic mass in its modes. The building model was analysed using IS 1893 (Part 1): 2016, with a fixed base on medium soil, in zone V with an importance factor of 1.2 and a response reduction factor of 5, and the peak responses were combined using the complete quadratic combination method.

2.4 Code used for analysis

The analysis of an 8-storey RC high-rise building is conducted using specific codes to ensure structural accuracy and compliance. IS 1893:2016 (Part 1) is followed for earthquake-resistant design, including seismic loads and design load combinations. Dead loads are determined based on IS 875:1987 (Part 1, Second Revision), while live loads are considered according to IS 875:1987 (Part 2, Second Revision). The design and analysis of concrete sections, as well as load combinations, adhere to IS 456:2000. Similarly, for the analysis of PPC in conventional RC structures of the same height, IS 1343-2012, an updated version of IS 1343-1980, is used. This code provides guidelines for prestressed load combinations, material properties, and prestress losses. Furthermore, as per IS 1343-2012, the structural analysis follows IS 456:2000, maintaining consistency in the analysis methodology.

The load combination used for the analysis of PPC in the Limit State was as follows, as per the Indian Standard Code 1343-2012 (Clause 21.4.2):

- Limit the State of Collapse
  1.5 DL+1.5 LL +1.0 PL
  1.5 DL + (-)1.5 EL + 1.0 PL
  1.2 DL + (-) 1.2 EL + 1.2 LL +1.0 PL
- Limit State of Serviceability
  1.0 DL+ 1.0 LL + 1.05 PL
  1.0 DL + (-) 1.0 EL + 1.05 PL
  DL + (-) 0.8 EL + 0.8 LL + 1.05 PL

2.5 Numerical tools

This research adopts SAP2000 v20 which represents a well-known tool among structural engineers for performing Finite Element Method (FEM) of analysis on building models and has already been used by different researchers (Ghozi et al., 2011; Lallotra & Singhal, 2017; Manjunath, 2015; Massumi & Tabatabaiefar, 2007; Pasticier et al., 2008; Poluraju & Rao, 2011). The analytical tools available in SAP2000 provide linear and nonlinear capabilities, which qualify the software to study normal RC and PPC buildings. The software offers capabilities to assess behavioural differences between prestressed elements through effective analysis systems.

For the comparative analysis of RC and PPC buildings with varying beam spans, SAP2000 v20 is used as a primary tool for the modelling and analysis. At first, models are created for the reinforced concrete buildings are designed and then models for PPC buildings were designed with tendons in beam and slabs. As per Table 1, different material properties were assigned for all. Then after, beam and column section properties were assigned for both models. Next, the same load case was assigned for both the model, and loads were applied. Both static and dynamic analyses for each model were run, evaluating the structural response such as displacements, forces, and moments. Finally, the results were compared, focusing on the differences in beam behaviour, structural performance, and overall efficiency between the RC and PPC buildings.

Table 1: Building features and seismic parameters of both type of building (IS:1343:2012.; IS:1893(Part-1):2016.)

S.N.	a. Material Properties used on Structure	
1	Concrete Grade	M25 for Beam, Column and Slab (for RC) M40 for Beam, Column and Slab (for PPC)
2	Steel Grade	Fe500 (for RC)
3	Tendon Diameter	7 stranded wire with 21.6mm diameter
4	Tensile strength of Tendon	1860 N/mm²
5	RC Unit weight	25kN/m3
	b. Building Structure Data for Both (RC and PPC)type Building	
1	Building Type	Multi storey Building
2	Structure Type	Special Moment Resisting Frame
3	Soil Type	Medium Soil
4	Beam Section	As per beam span
5	Column Section	As per beam span
6	Slab Section	150mm (RC) and 125mm (PPC)
	c. Architectural Data of structure	
1	Model with varying Beam Span	6m, 8m,10m, 12m, 14m and 16m
2	Floor Height	3.3528m
3	Total height of building	30m (8 Storey)
4	Building Shape	Rectangular
5	Bay in X-direction	4 bay with varying beam span
6	Bay in Y-direction	3 bay with varying beam span
	d. Seismic Data of structure	
1	Seismic Zone	V
2	Zone Factor	0.36
3	Soil Type	Type II
4	Response Reduction	5
5	Importance Factor	1.2
	e. Loading on building	
1	Live Load	4 kN/M² (As per IS 875 Part II)
2	Floor Finish Load	2 kN/M² (As per IS 875 Part II)
3	Brick wall Load	15.4 kN for 230 mm wall
4	Parapet wall Load	2.2 kN
5	Staircase Load	7.95 kN/m² for Dead Load and Live Load

2.6 Building types with features and seismic parameters

An Eight storey building with storey height 3.3528m (11feet.) and of rectangular shape was used in the analysis. The first type was a regular RC building, while the second was a PPC building with tendons and reinforcement applied to beams and slabs. RC and PPC buildings were assumed to use concrete grade of M25 and M40 respectively. The material properties used, along with the architectural data and building structure data for both building types, as well as the loading data and seismic data are shown in Table 1.

2.6.1 RC Building without tendon and with tendon (PPC building) on structural element

RC buildings with different beam lengths are first designed using SAP2000 v20 software, and then analysed using both static and dynamic methods without tendons on the beam and slab. The Table 2 shows the beam and column sizes for an RC building with different beam lengths. For both static and dynamic analysis, the beam and column sizes remain the same.

Table 2: Beam and column dimensions of normal RC building and of PPC building

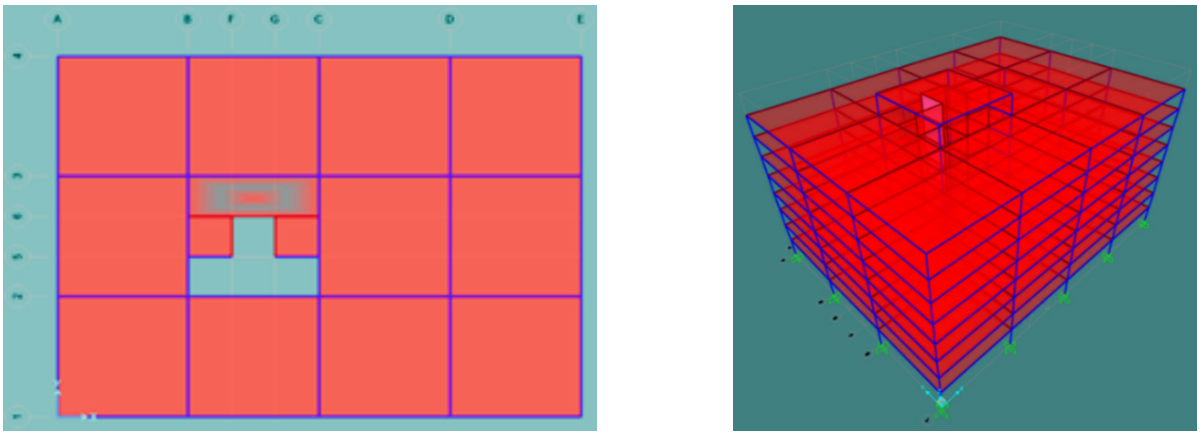
S.N.	Beam Span (m)	Normal RC building		PPC building	
		Beam Dimension (mm)	Column Dimension (mm)	Beam Dimension (mm)	Column Dimension (mm)
1	6	400 X 300	500 X 500	360 X 240	400 X 400
2	8	450 X 400	600 X 500	360 X 240	400 X 400
3	10	550 X 400	700 X 550	380 X 280	500 X 500
4	12	600 X 500	700 X 700	400 X 300	500 X 500
5	14	700 X 600	1000 X 800	450 X 350	600 X 600
6	16	800 X 600	1500 X 900	450 X 350	600 X 600

After analysing the RC building without tendons, the same building with tendons in beams and slabs (prestressed) is analysed using both static and dynamic methods. Necessary values are taken from IS 1343:2012. The values of the Table 2 are redesigned with the analysis of the PPC model and checked with depth ratio with respect to the beam span. The necessary sizes of columns, and beams are tabulated in Table 2.

Tendons were assigned to beams and slabs, with the process for slabs mirroring that of beams. The slab was divided into four parts to create wide beams, with hidden beams assigned to the divisions. Tendons were applied using the load-balancing method, adopting a parabolic profile due to fixed beam-column joints. The tendon's eccentricity was 140 mm at the ends and mid-centre, reducing to 70 mm near the centre point.

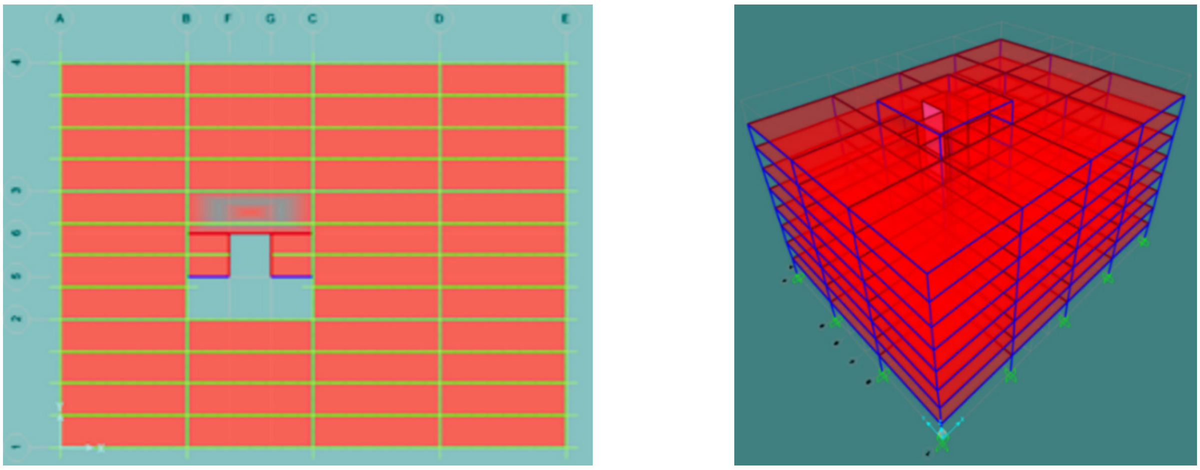
2.7 Model preparation

Before the model preparation in SAP2000 v20, the plan of a Normal RC building without tendons, with 6m, 8m, 10m, 12m, 14m and 16m beam span is done (a sample figure is shown in Figure 2 (a)). Then only 3D models are prepared for each respective beam span with appropriate units along with the grid system as shown in Figure 2 (b). Similarly, the plan and model for the prestressed building are prepared in a similar manner as shown in figure 3.



(a) (b)

Figure 2: (a) Plan of normal RC building without tendon on structural elements and (b) 3-D view of normal RC building



(a) (b)

Figure 3: (a) Plan of prestressed RC building with tendon on structural elements and (b) 3-D view of PPC building

3. Result and Discussion

3.1 Displacement and drift check

According to IS Code provisions, the permissible drift is limited to 0.004 times the story height. As shown in Figures 4 and 5, the RC building model exhibited maximum story displacement and drift values within these prescribed limits. This indicates that the structure maintains satisfactory lateral stiffness and conforms to safety standards under seismic loading conditions. However, when the model was adapted to a partially prestressed configuration, the displacement and drift values were found to be significantly lower, with negligible values in some cases (Priestley & Tao, 1993). This behavior can be attributed to the presence of pinned tendon joints in PPC buildings, which introduce a self-centering mechanism. This mechanism effectively counteracts lateral movement, leading to minimal residual displacement after loading. The improved performance in PPC buildings, compared to RC models, is consistent with prior discussed by Handana & Karolina, Sephanie et al., Sultan & Mohammed, and Zaker Esteghamati et al., which also highlighted the role of prestressing in enhancing structural control and seismic resistance (Handana & Karolina, 2018; Sephanie et al., 2025; Sultan & Mohammed, 2023; Zaker Esteghamati et al., 2018).

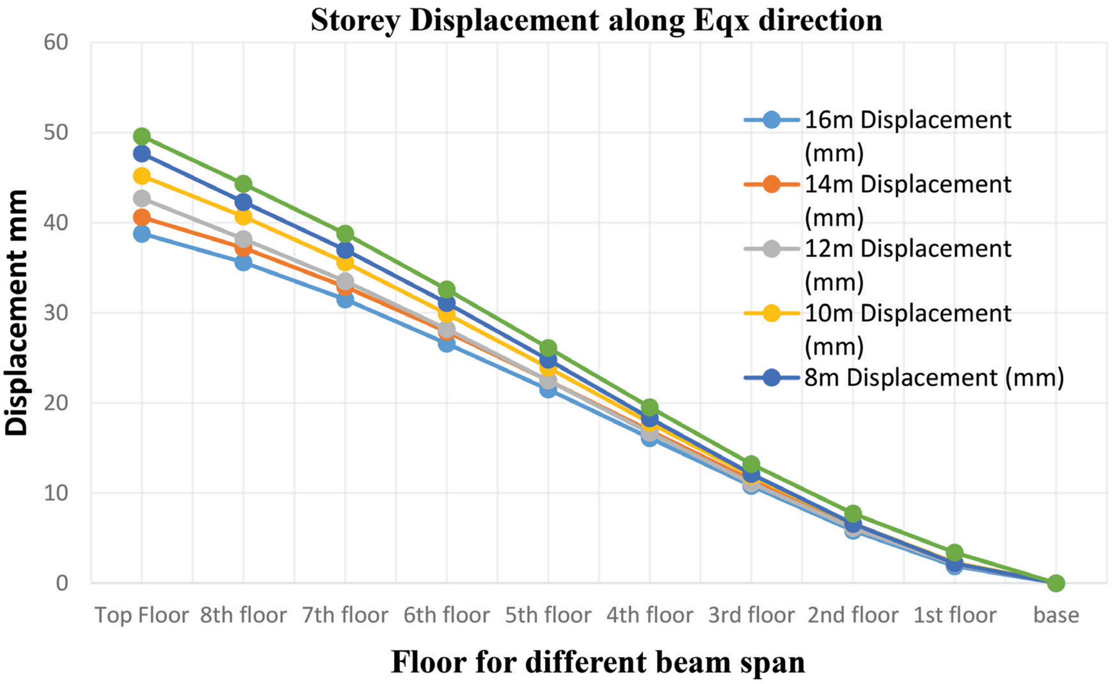


Figure 4: Storey displacement of regular RC building on varying beam span

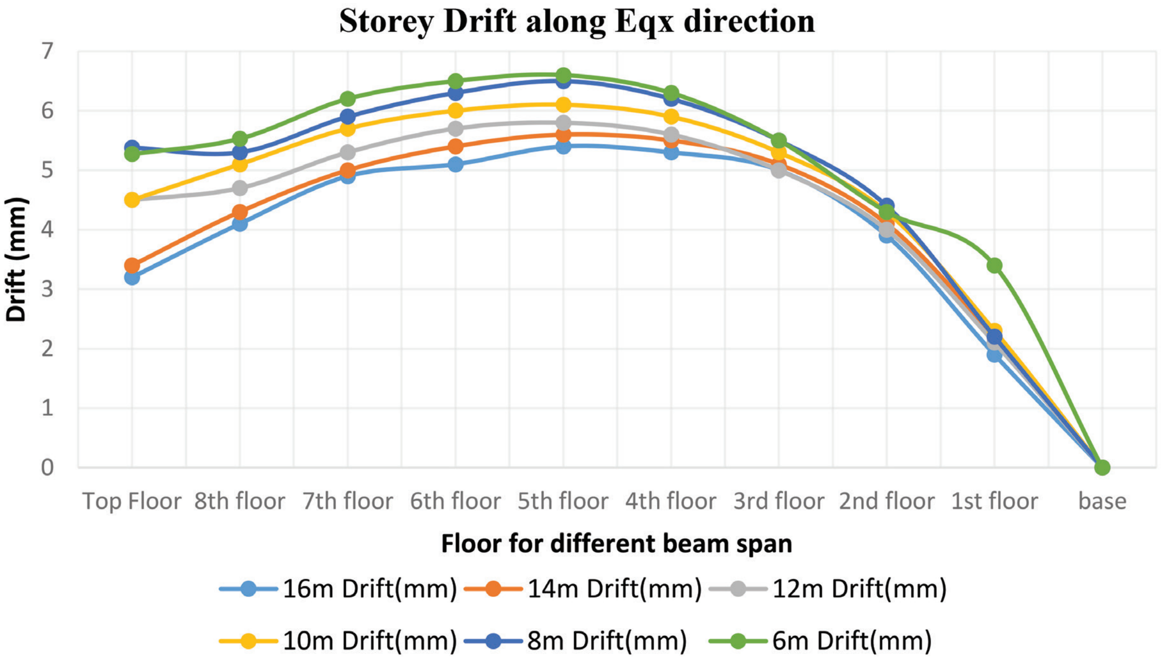


Figure 5: Storey drift of regular RC building on varying beam span

3.2 Maximum bending moment developed on the building

Figures 6 and 7 illustrate the maximum bending moments for both RC and PPC buildings under Linear Static and Response Spectrum Methods across varying beam spans (6 m, 8 m, 10 m, 12 m, 14 m, and 16 m). The results clearly show that the overall bending moment in RC buildings is consistently higher than in PPC buildings for all span lengths and in both analysis methods. This pattern aligns with the discussion of Khattab & Oukaili, Nour et al., and Turkeli & Ozturk, which emphasize the contribution of prestressing in reducing internal force demands (Khattab & Oukaili, 2019; Nour et al., 2021; Turkeli & Ozturk, 2017).

An increasing trend in bending moment is observed with the increase in beam span for both RC and PPC structures. This is expected, as longer spans naturally result in higher bending moments due to the increased lever arm and distributed load effect. In RC buildings analyzed with the Response Spectrum Method, a notable fluctuation in bending moment is observed between the 6 m to 10 m spans, which can be attributed to dynamic response sensitivity in shorter spans where mass and stiffness distribution play a more pronounced role. Beyond 12 m, the trend becomes strongly upward, indicating a direct relationship between span and moment due to greater flexural demand in longer beams. A similar pattern is observed in the Linear Static Method.

In contrast, PPC buildings show relatively stable bending moment values with only slight fluctuations across the same spans. This smoother trend reflects the influence of prestressing, which effectively redistributes internal stresses and reduces peak moments by applying a counteractive force. As noted by Priestley et al. (Priestley et al., 1999), prestressed systems are designed to minimize tensile stresses and delay cracking, which justifies the lower and more consistent bending moment observed across varying spans in PPC models.

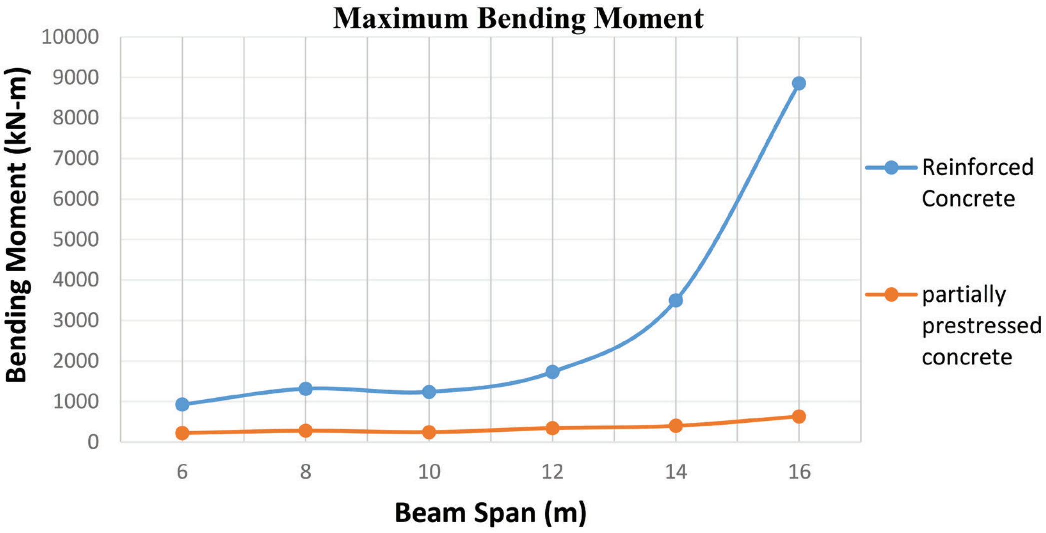


Figure 6: Maximum bending moment on varying beam span in linear static analysis

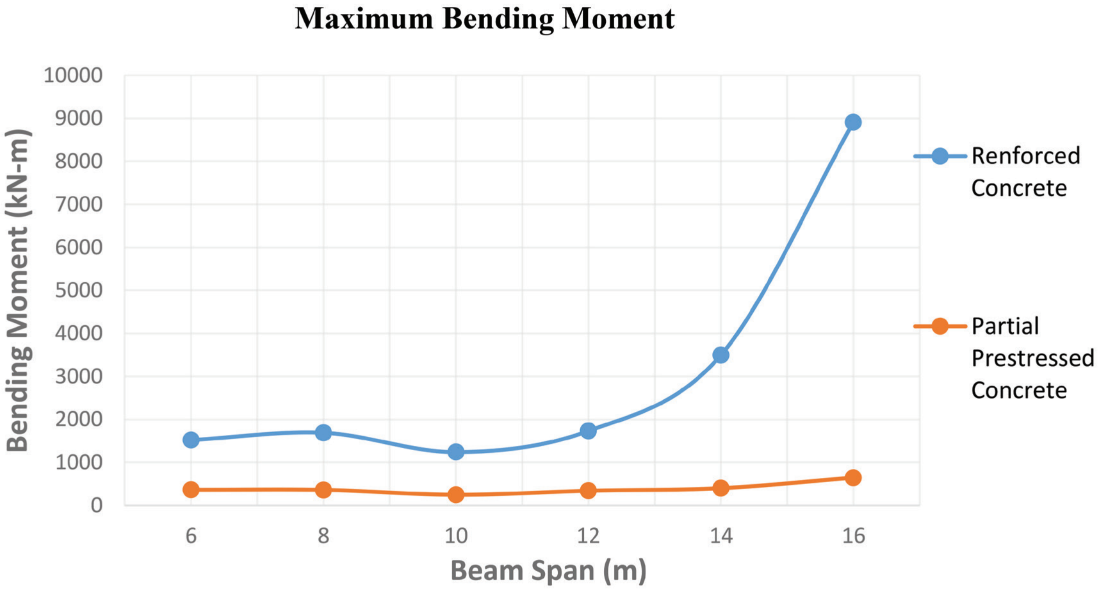


Figure 7: Maximum bending moment on varying beam span in response spectrum analysis

3.3 Maximum shear force developed on the building.

Figures 8 and 9 show that shear forces in PPC buildings are consistently lower than in RC buildings across all beam spans in both Response Spectrum and Linear Static Methods (Turkeli & Ozturk, 2017). In RC buildings, shear force increases with span due to greater lateral load demands. In contrast, PPC buildings display relatively stable or slightly decreasing shear trends up to 12 m spans, which can be attributed to the counteracting effect of prestressing. This pattern indicates that prestressing effectively reduces shear demand, enhancing structural efficiency.

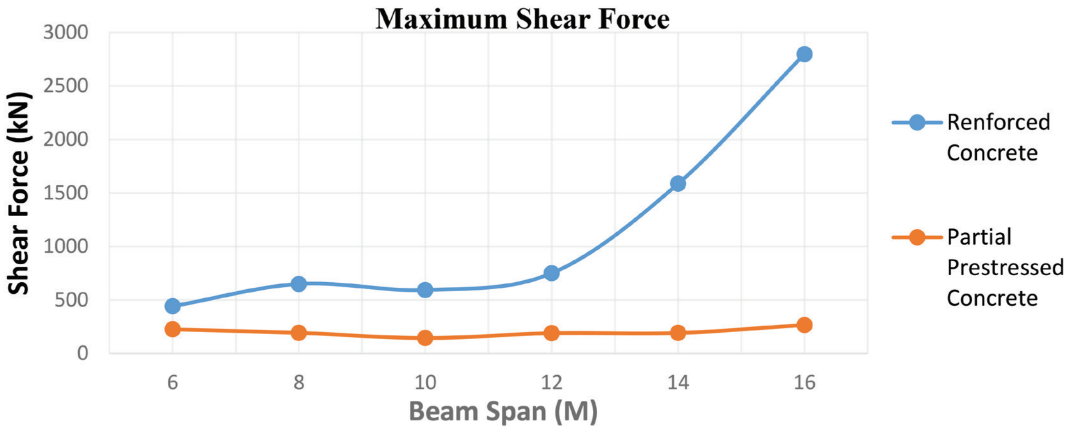


Figure 8: Maximum shear force on varying beam span in linear static analysis

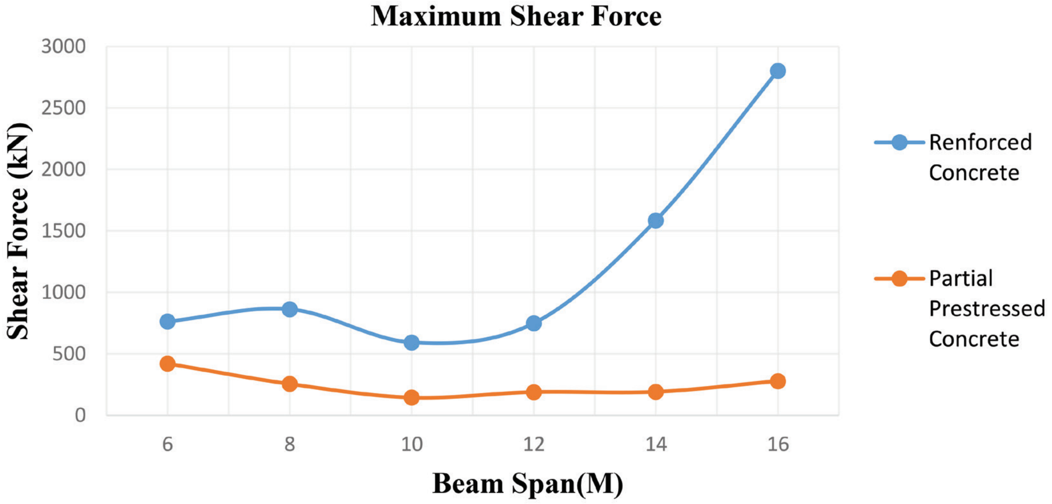


Figure 9: Maximum shear force on varying beam span in response spectrum analysis

3.4 Size of beam and column

Both structural models satisfied the structural performance criteria for beams and columns, confirming their ability to effectively carry the applied loads within the specified design dimensions (Table 2). This ensures adequate stability and safety under operational conditions. The PPC building demonstrated reduced maximum bending moments (Figures 6 and 7) and shear forces (Figures 8 and 9) due to the presence of prestressing tendons in the slab and beam. The reduced internal forces allowed for smaller cross-sectional dimensions of beams and columns compared to the reinforced concrete (RC) building. A parabolic tendon profile was implemented in the PPC system, with an eccentricity of 140 mm at the supports and 70 mm at mid-span, contributing to load balancing. Although the columns were not prestressed, M40-grade concrete was used to maintain a “strong column, weak beam” structural hierarchy.

Post-analysis, beam dimensions were modified based on performance results. According to Table 3, in a 6 m span, the PPC building's beam size and depth were reduced by 0.28 and 0.1 times respectively compared to the RC building. This trend of reduction became more pronounced with increasing span lengths; for a 16 m span, the beam size and depth reductions reached 0.67 and 0.43 times, respectively. This increasing trend can be attributed to the effectiveness of prestressing in counteracting larger bending moments over longer spans, reducing the need for additional concrete mass. As a result, prestressed systems become more material-efficient and cost-effective at larger spans.

While beam and column cross-sections were kept identical for analytical consistency, only the response spectrum method was employed for comparing the PPC building's seismic response. Table 4 presents column size variations for both structural systems across span lengths. Column dimension reductions in the PPC system ranged from 0.20 to 0.73 times compared to the RC building, with greater reductions observed at longer spans. This outcome is consistent with the principle that prestressed elements transfer internal forces more efficiently, thereby allowing for smaller supporting elements.

The decreasing trend in both beam and column sizes with increasing span in the PPC system highlights the structural and economic advantages of prestressing for long-span applications (Kaur & Singh, 2017). These reductions directly translate to lower concrete volumes, thereby offering significant cost savings during construction (Kurama et al., 2018; Tejani et al., 2015; Yee & Eng, 2001). Additionally, since structural elements in conventional RC buildings must be sized larger to resist increased seismic demands, the lighter and smaller elements in PPC structures contribute to reduced seismic weight. This, in turn, results in lower base shear forces, enhancing the seismic performance of the structure (Mahure & Dhore, 2017). Thus, the PPC system demonstrates not only material efficiency but also improved seismic behavior, particularly as span lengths increase.

Table 3: Beam section with reduced value in both types of building

Beam Span (m)	RC beam Dimension (mm)	PPC Beam Dimension (mm)	Reduced Factor (In-depth only)	Reduced Factor overall (beam dimension)
6	400 X 300	360 X 240	0.10	0.28
8	450 X 400	360 X 240	0.20	0.52
10	550 X 400	380 X 280	0.30	0.51
12	600 X 500	400 X 300	0.33	0.60
14	700 X 600	450 X 350	0.35	0.62
16	800 X 600	450 X 350	0.43	0.67

Table 4: Column section with reduced value in both types of building

Beam Span (m)	RC column dimension (mm)	PPC column dimension (mm)	Reduced Factor (In-depth only)	Reduced Factor (overall beam dimension)
6	500 X 500	400 X 400	0.20	0.36
8	600 X 500	400 X 400	0.33	0.46
10	700 X 550	500 X 500	0.28	0.35
12	700 X 700	500 X 500	0.285	0.489
14	1000 X 800	600 X 600	0.40	0.55
16	1500 X 900	600 X 600	0.60	0.73

3.5 Base shear

Beam and column sizes in PPC buildings were reduced by 10% to 67.18% compared to RC buildings, resulting in lower structural weight. Since seismic base shear is proportional to structural weight, this reduction led to base shear decreases ranging from 33.20% to 37.22% across various beam spans (Table 5). This pattern aligns with the theoretical expectation that reducing structural mass leads to decreased seismic demand, thereby improving the structure's resistance to earthquake forces (Nour et al., 2021; Poudel & Adhikari, 2025; Turkeli & Ozturk, 2017). Since prestressing enhances the structural efficiency of long-span members, it allows for a greater reduction in cross-sectional dimensions without compromising strength or stiffness. As a result, the PPC system becomes more effective in reducing seismic forces as the span increases, thereby enhancing seismic performance.

Table 5: Base Shear of both types of building on varying beam span

S.N.	Beam Span (m)	RC Building Base Shear (kN)	PPC building Base Shear (kN)	Reduced (%)
1	6	2759.410	1732.20	37.22
2	8	4547.045	2907.56	36.05
3	10	6733.800	4275.86	36.50
4	12	9542.1001	6373.52	33.20
5	14	13221.890	8787.79	33.53
6	16	16901.470	11036.32	34.70

3.6 Span to depth ratio

The span-to-depth ratio of RC beams complied with IS code limits, while partially prestressed beams exhibited higher ratios due to reduced beam depth (Figure 10). This increase is attributed to the use of prestressing, which enhances the flexural capacity and stiffness of the beam, allowing longer spans with smaller depths. The reduced depth results in more slender beams that carry the same load with lower bending stress, as confirmed through comparative analysis. Prestressing, achieved through pre-tensioning or post-tensioning, minimizes deflection and increases efficiency in load distribution. As a result, partially prestressed beams demonstrated improved performance in resisting both bending and shear stresses (Nour et al., 2021; Turkeli & Ozturk, 2017).

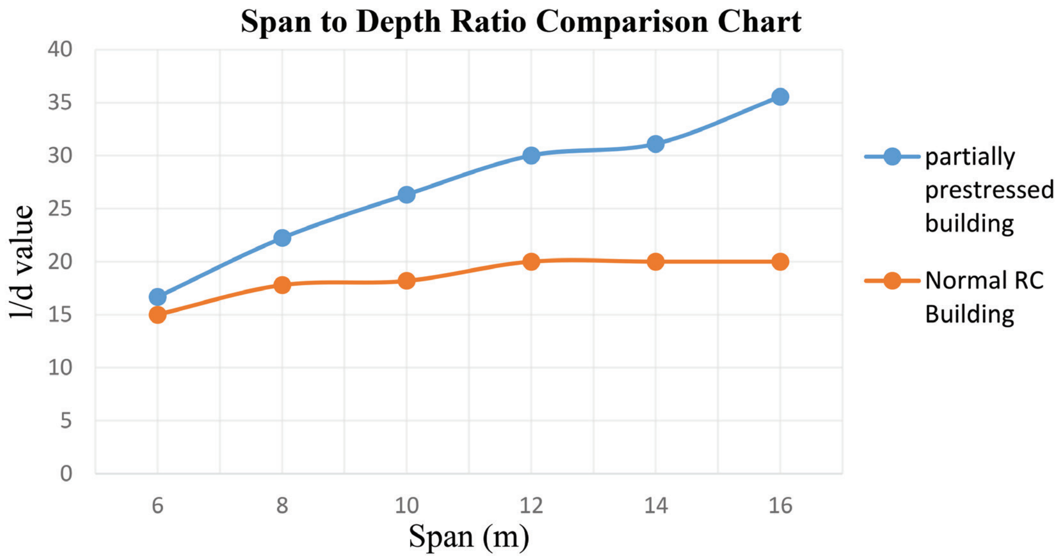


Figure 10: Span to depth ratio on varying beam span

3.7 Maximum stresses developed

The study evaluated longitudinal (S 1-1), transverse (S 1-2), and vertical (S 1-3) stresses in both PPC and RC buildings across varying beam spans. Longitudinal stress, which directly affects load-bearing capacity, was significantly higher in PPC buildings due to the use of high-strength materials such as M40-grade concrete and high-tensile prestressing wires. At a 6 m span, the RC building exhibited a longitudinal stress of 39,545.04 kN/m², while the PPC building recorded 1,067,688.8 kN/m² approximately 25.99 times higher (Figure 11). As span length increased, longitudinal stress increased in both structures, consistent with higher load demands over longer spans, but the PPC building consistently maintained higher capacity due to enhanced material properties.

Transverse stress comparisons showed a general decreasing trend in PPC buildings as span length increased. At 6 m, the RC building exhibited 7,849.51 kN/m², while the PPC building showed 1,563.64 kN/m² about 0.8 times lower. Similar reductions were observed at 8 m (0.47 times), 10 m (0.18 times), 12 m (0.14 times), and 14 m (0.15 times). The reduction is attributed to improved stress distribution and crack control in PPC members. At 16 m span, transverse stress in the PPC building increased by 0.24 times, due to the beam's increased slenderness, which makes it more susceptible to lateral deformation. Floor load values also showed a decreasing trend in PPC buildings. At 6 m, the PPC floor load was 85.78% lower than that of the RC building; at 8 m and 10 m spans, reductions were 57.1% and 40.47%, respectively (Figure 12). The decreasing trend results from the reduction in member sizes and associated dead loads in PPC buildings. At larger spans, variations in floor load reductions occur due to increased design complexity and slenderness of structural elements.

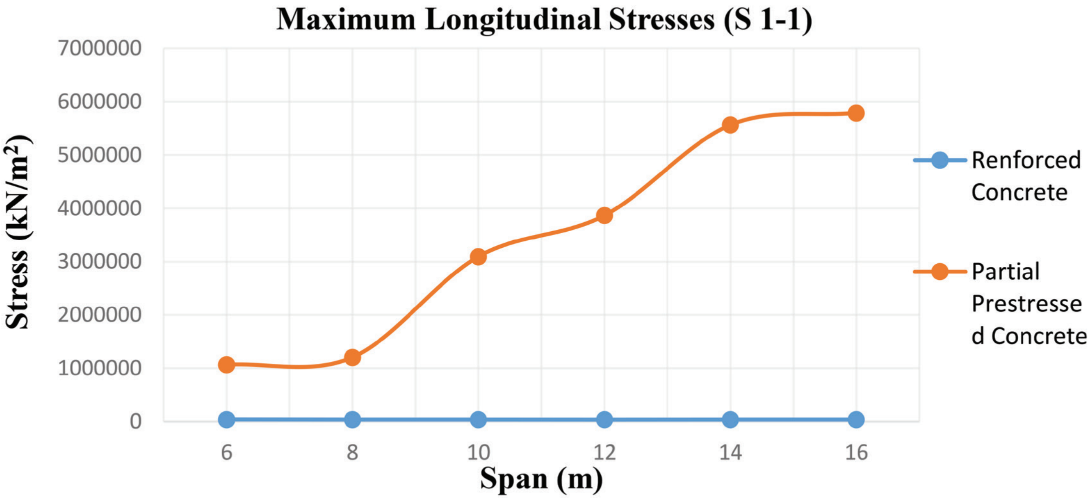


Figure 11: Maximum longitudinal stress (S 1-1) on varying beam span

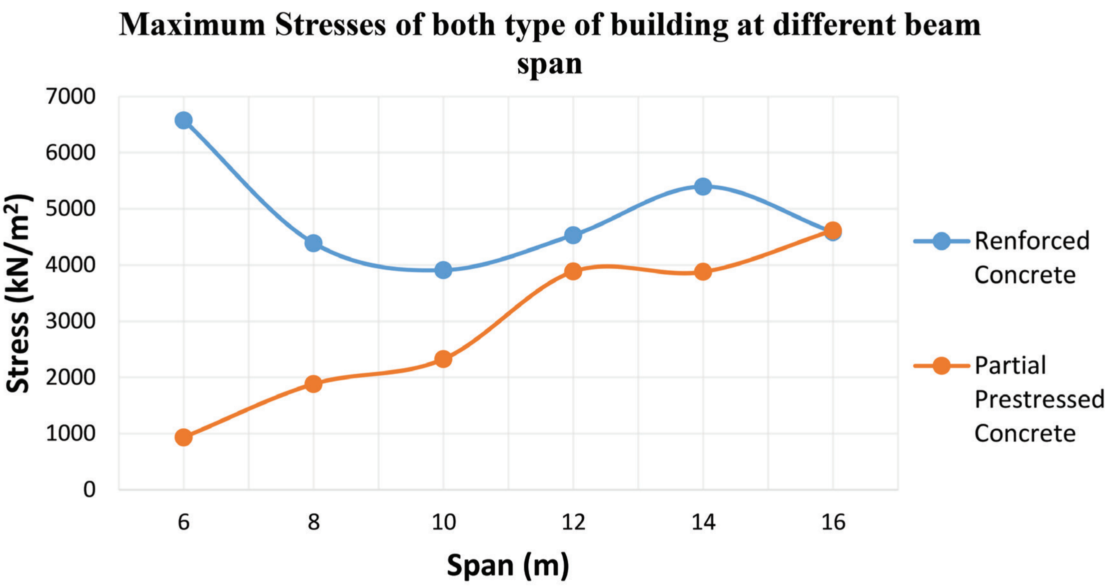


Figure 12: Maximum vertical stresses (S 1-3) on varying beam span

4. Conclusions

This study involved the structural analysis of 12 building models with varying beam spans (6 m to 16 m), using both linear static and response spectrum methods, to compare the performance of RC buildings and PPC buildings. The results demonstrated that PPC buildings consistently exhibited significantly lower bending moments and shear forces than RC buildings by as much as 45% and 80%, respectively. The span-to-depth ratio in PPC beams was higher, yet these beams effectively resisted bending and shear stresses, confirming the advantages of prestressing in optimizing material use and structural behavior. Moreover, the PPC buildings displayed better performance in longer-span applications. While higher longitudinal stresses were observed in PPC beams, they were attributed to the higher strength materials and prestressing effects, which contributed to greater load-carrying capacity. The decrease in beam sizes further reduced the seismic weight and base shear of the buildings, resulting in more efficient seismic performance. These findings highlight that PPC systems are especially beneficial in long-span structures, offering structural reliability and economic advantages over conventional RC systems.

However, it is important to consider that the design and construction of PPC elements require more sophisticated techniques, skilled labor, and careful control of prestress losses over time. Despite these challenges, the analysis performed using SAP2000 v20.2 supports the use of partially prestressed systems in modern construction, particularly in bridges, high-rise buildings, and infrastructure requiring high strength and durability. Overall, PPC buildings present a viable, efficient, and structurally sound alternative to conventional RC buildings for longer-span applications.

Conflicts of Interest Statement

The authors declare no conflicts of interest for this study.

Data Availability Statement

The data that support the findings of this study are available from the author upon reasonable request.

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