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Cost effectiveness of Reinforced Concrete and Post Tensioning beam in multi-storied building

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Abstract - *In present century conventional RC frame buildings are commonly used. In multi storied construction large column free areas receive maximum service utility of the building. Few guidelines are available to the designer for economic consideration. Hence this study aims to compare the results of Reinforced Concrete (RC) Vs Post tensioning (PT) beam of 20m span for same configuration. The six storied commercial building is designed for plot area of 20mx20m. The models have been analyzed, designed manually and by using Etabs software. The quantities of concrete and reinforcing steel required for the slab, beam, column and footing are calculated and compare the cost effectiveness of both models.*

Key Words*: *RC beam, PT beam, Etabs software,Geometric configuration, Economic cost.

1. INTRODUCTION

RCC Structures are commonly used for Residential as well as commercial Buildings. In RCC Beams, depth of beam increases with increase in Span, because of deflection limitation. Depth of beam can be reduced in Pre-stressed section, for longer span prestressed beams are cheaper. This paper is focused to know the percentage cost difference between both techniques with respect to span. Design considerations are given for gravity, wind, seismic loads and analyzed by ETABS software. The models considered is located in seismic zone II -Visakhapatnam city, Andhra Pradesh, India. The analysis for both the model are done to know Max Sagging Moment in Beams, Max Shear force in Beams, Base Reactions of column, Storey Displacement, Inter Storey Drift and cost comparison. Ankit et.al [1] shows Cost Comparison Between RCC & Post-Tensioned Prestressed beams spanning 26m. R.K. Makode et.al,2014 [2] discussed about the flat slab buildings in which slab is directly rested on columns, have been adopted in many buildings constructed recently due to the advantage of reduced floor to floor heights to meet the economical and architectural demands. Rahman1,2013 et.al [3] work on design of R.C.C. as well as pre-stressed concrete flat slabs for various spans and then compare the results. A.A. Sathawane et al,2011, [4] the aim of the project is to determine the most economical slab between flat slab with drop, Flat slab without drop and grid slab. Snigdha A. et al 2008 [5] stated that seismic performance of a building will benefit greatly due to it's configuration. Vyas and Raisinghani, 2007 [6] conducted a study on optimum spacing of columns and it's economic viability. Watts S et al 2007 [7] described about the economic aspects of tall towers in relation with other geometric aspects of the structure.

2. SCOPE

This work includes the analysis, design and estimate of quantity of steel, concrete and shuttering requirement for footings, beams, columns and slabs contribute mostly to the overall cost of the structure. Material consumption depends on size effect. Here compare the effect of beam for Span 20 m, by R.C.C. and Post-tensioned prestressed concrete techniques. And calculation of percentage cost comparison between RCC & Post-tensioned prestressed concrete beam.

3.DESIGN CONSIDERATIONS

3.1 Floor Plan

The Plan of Floor system considered is shown in Fig.4.1 and Six Storeyed RC Frame system is shown in Fig.4.2

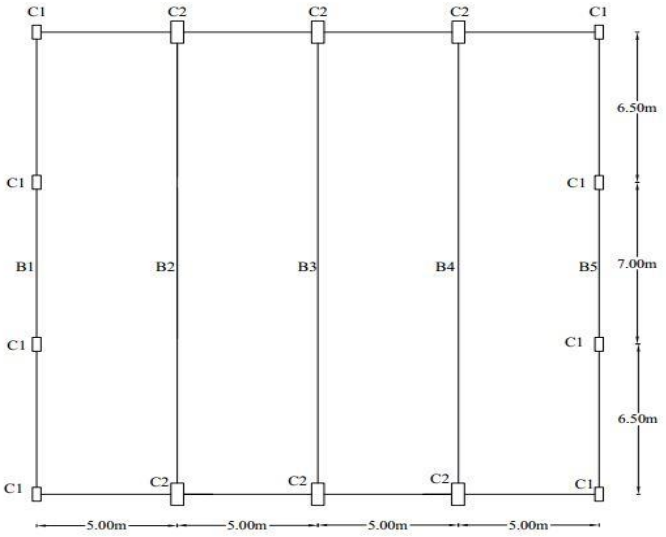

Fig.3.1 Geometrical plan of floor system

Fig.3.2 Six Storeyed RC Frame System

Floor Dimension : (20x20)m
Column Cross section C1 : (300x600)m
Column Cross section C2 : (450x960)m
Beam Span : 20m
Beam Cross section B (RCC) :(300x730)m & from 2m either of support is (300x1230)m
Beam Cross section B (PT) :(900x650)m

3.2 Design loads:

The design loads are considered as per IS 456-2000, IS875-1987(part I,II and III) and IS 1893-2000 for gravity and lateral loads. The wind speed considered as 50m/s, terrain category II with the type of structure class B. The Structure located in sesimic zone II with zone factor 0.16.Limit state method used in the design of RC structure.

3.3 Soil and foundation:

The foundation located on medium coarse grained soil with allowable bearing pressure 200 kN/m² (assumed). The ground water located below the foundation. RC Strip footing used in sub structure.

3.4 Materials:

M_{20} grade concrete, Fe415 grade HYSD steel used in the design of RC elements. M_{30} grade concrete for PT beam. The RC mix design done by using OPC 53grade cement, medium coarse grained soil and 20mm down coarse aggregate.

4. ANALYSIS RESULT

4.1 Data for Preliminary Analysis

G+5 storey building for a commercial complex

Live load : 4.0 kN/m² at typical floor 1.5 kN/m² on terrace
Floor finish : 1.0 kN/m²
Location : Visakhapatnam City
Wind load [9] : As per IS: 875(Category 2, Class B)
Seismic load [10] : As per IS: 1893(Zone-II)
Type of soil : Type II, Medium as per IS:1893
Storey height : Typical floor: 3.6m, GF: 3.3 m
Floors : G+5 floors.
Walls 1 : 230 mm thick brick masonry walls only at periphery.
Wall 2 : 115 mm thick brick masonry walls interior.

4.2 Max Sagging Moment in Beams

The Maximum Sagging Moment obtained for 20m span (B3) of both RC and PT beam is shown in Fig.5.2

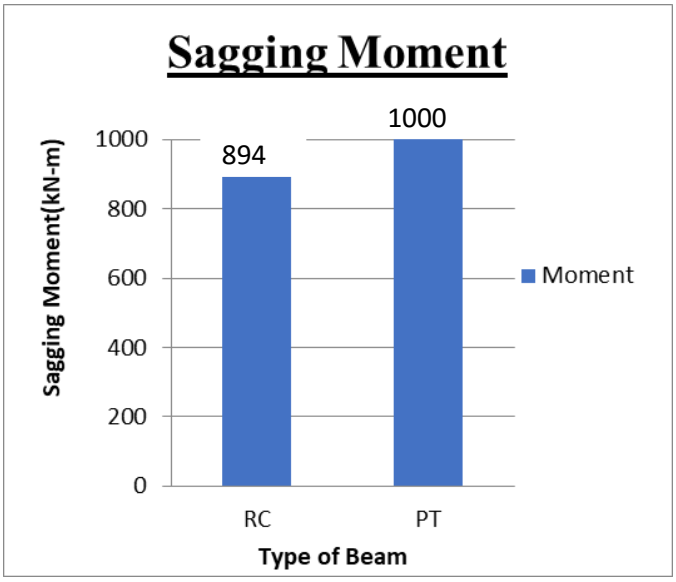

Fig.4.2 Max Sagging Moment

4.3 Base Reactions of column

The Base Reactions of column (C2) obtain in both type of RC and PT beam is shown in Fig.5.3

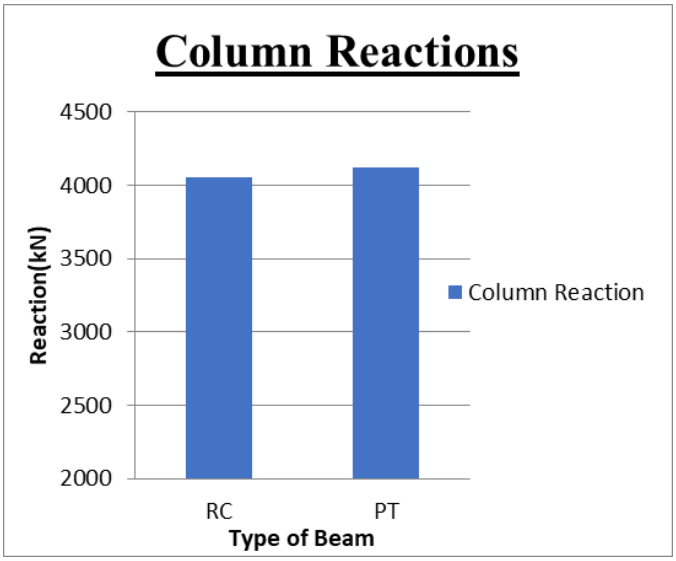

Fig.4.3 Base Reactions of column

4.4 Storey Displacement

Under the application of various loads the displacement of nodes can occur. Less lateral displacement indicates safe structure. This paper concluded that node displacement in RC is more as compared to PT. This is because the RC structure is more flexible as compared to PT structure. The storey Displacement obtain in both type of RC and PT beam is shown in Fig.4.4

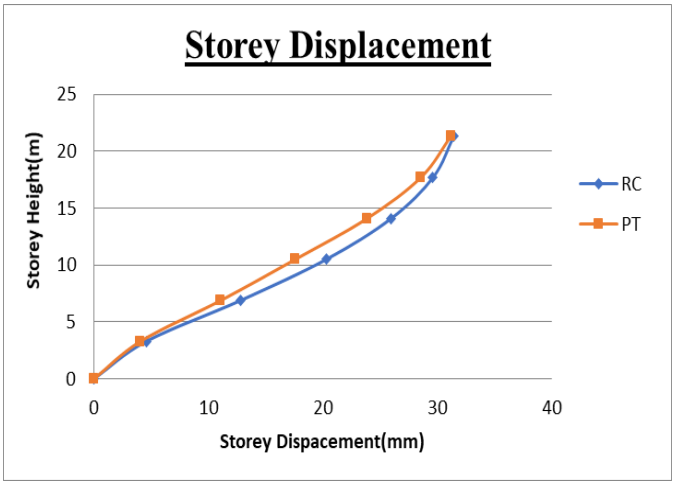

Fig.4.4 Storey Displacement

4.5 Inter Storey Drift

Storey sway and Inter storey drift
Controlling storey sway or inter-storey drift of a building is an important aspect because

1. It prevents pounding of adjacent buildings in urban areas.
2. It controls plastic deformation of coupling beams within the values that can be met.
3. It prevents shear (brittle) failure.
4. It restricts damage to fragile non-structural elements, which can be costlier than the building.
5. Drift limitation provide stability of individual columns as well as the structure as a whole.
6. Limited drift also provide comfort to occupant of such buildings.

As per clause 7.11.1 of IS 1893 (part-I):2002, the storey drift in any storey due to specified designed lateral force with partial load factor of 1.0, shall not exceed 0.004 times the storey height.
The Storey drift obtain in both type of RC and PT beam is shown in Fig.5.5

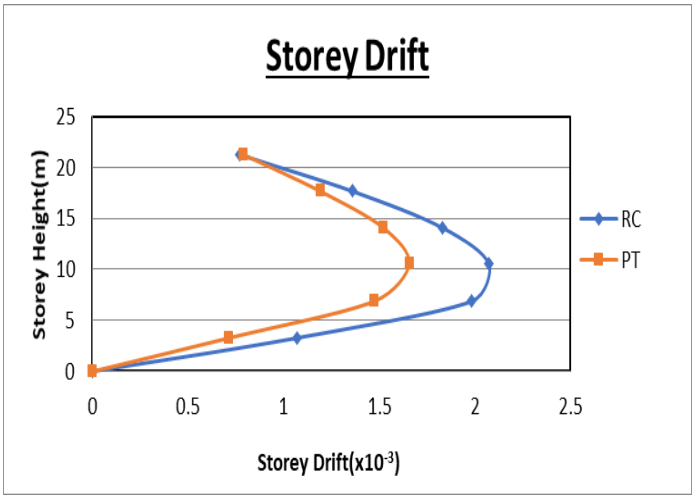

Fig.4.5 Storey drift

5. Cost Comparison

Cost is major aspect for comparison of Reinforced Concrete and Post Tensioning beam in multi-storied building. Because costly structures are generally neglected in construction if another cheaper option is available in front of it. The configurated structural models of six storied structure, is evaluated for quantities of basic materials such as steel , concrete and shuttering and cost involved .This estimation is basically meant for material takeoff of skeleton frame work of sub structure and super structure.

The quantity of steel and concrete requirement for footings, beams, columns and slabs contribute mostly to the overall cost of the structure. The percentage of steel consumption and concrete consumption depends on size effect. The rates are taken as per AP SSR 2016-2017 Schedule such that concrete Rs 6,500/m^3, reinforcing steel Rs 60,000/ton, pre stressing steel Rs 750,000/ton, Shuttering cost 250/m^2. including labor. Variation of Cost obtain in both type of RC and PT beam is shown in Fig.6

Table-1 Quantities of 20m Span beam of RC and PT

	BEAM (Length-20m)	
	RC Beam	**PT Beam**
Size	0.3x0.73x20	0.950x0.650x20
Concrete	4.38 (m^3)	12.35(m^3)
Pre stressing steel	-	611.52kg
Non-Pre stressing Steel	854.47kg	188kg
Anchorage Steel	-	0.71kg/m
Stirrups	0.58kg/m	0.58kg/m
Shuttering	35.2(m^2)	45(m^2)

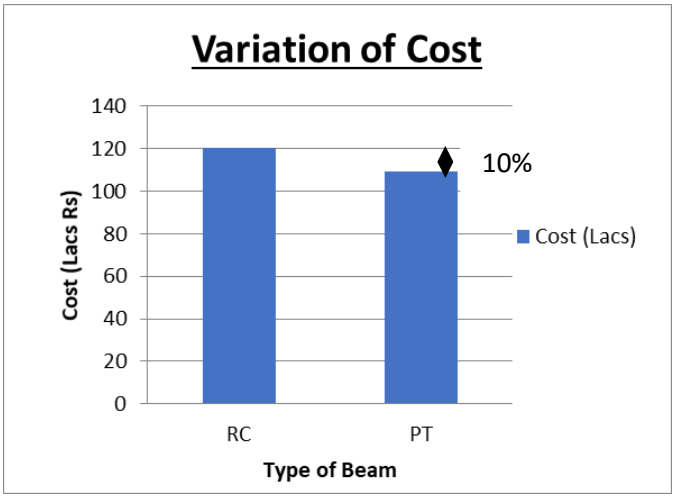

Fig.5 Variation of Cost

6. CONCLUSION

By considering the effect of gravity and lateral loads (wind/seismic), the global and local performance of the six storey structure located at Visakhapatnam city, evaluated for RC Frame, PT Frame and is verified as per Indian standard code of practice. The parameter considered to evaluate the global performance of the structure are lateral displacement, inter storey drift. The parameters evaluated for local performance of the structural elements such as sagging moment of beams and base reactions in columns.

1) Maximum sagging moment gives PT beam. The value is 1000kN-m
2) Maximum Column reaction in PT frame structure. The percentage variation is not too high 1.6% increases. It's identified as approximately same.
3) The storey displacement in model-1 is more as compared to model-1 structure. This is because the Model -1 is more flexible as compared to Model-2.
4) Model-2 has the lowest value of storey drift because of its high stiffness, which indicates that as the value of stiffness increases, storey drift values decreases with it.
5) For two models considered drift values follow a parabolic path along storey height with maximum value lying somewhere near the middle storey.
6) The construction cost of framed structure for Model-1 is Rs120.4 /- Lacs Model-2 is Rs 109.5/- Lacs. Comparing the two models cost of construction decreased as 10% in model-2.

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