Break even analysis & response of longer span frames with or without post-tensioned beams in multipurpose hall

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Abstract-In this paper analyzed the RC and PT Beam against variation in the clear span length of the beam. This work includes the design and estimate of Cost/Beam from 5m span up to 15m span length of the beam. Also, The response of the frame following two variation in its modelling. Initially, The primary model consists of a conventional RCC frame with all beams and columns as RCC. The secondarily model considers peripheral beams as RCC and interior beams with PT. Such as ETABS software used to designed RC beam element and ADAPT-PTRC used to designed PT beam element. However it has been note that variation of cost with respect to the span of beam where the break-even point between RCC and PT technique is approx 7m Span. Also the control on deflection of beam by restrict the depth of beam by using unbonded Post-tensioned prestress concrete beam method. There is very good understand all aspects PT beam better than as compared with RC beam in deflection against longer span length of beams. This paper gives suggestion about to reach a decidedly conclusion regarding which technique is superior over one another.

Index Terms- Break-even point, PT beam element, RC beam element, Cost/Beam, Reinforced cement concrete, Post-tensioned prestress concrete
1. Introduction

1.1 Importance and necessity

Reinforced cement concrete technology is widely available and is well understood. Post-tensioned prestressed is an advancement in reinforced concrete technique. A many years back there was a big problem of skilled labours for pre-stressing work. Currently there are so many private infrastructure companies for implementation of the same work. In reinforced cement concrete Beams, depth of beam increases with expansion in Span, because of deflection limitation. Depth of beam can be restrict in Post-tensioning method. In conventional concrete construction, the beam will tend to deflects downwards. This deflection will cause the bottom of the beam to elongate minimal down-ward direction. Even a minimum elongation is usually enough to cause cracking. Steel reinforcing bars are typically introduced in the concrete as tensile reinforcement to restrict the crack widths. Reinforcing steel is what is called “passive” reinforcement however; it doesn’t take any force until the concrete has already deflected adequate to crack. Post-tensioning tendons, on the other side, are considered “active” reinforcing. Post-tensioned structures can be intended to have minimum deflection and cracking, significantly under full load.

1.2 Scope

This work cover the analysis and designed of multipurpose hall with variation in the plan dimensions. Material utilization depends on dimension effect. Here cost comparison between of a RCC framed structure with interior RC beams and RCC framed structure with interior PT beams of an various plan dimensions. The first model consists of a conventional RC frame with all beams and columns as reinforced cement concrete. The second model considers peripheral beams as Reinforced cement concrete and interior beams with Post-tensioned pre-stressed beam. And also calculate deflection of beam by restrict the depth of beam by using unbonded Post-tensioned prestress concrete beam method. This guidelines helps to the structural designer to reach a decidedly conclusion regarding which technique is superior over over one another with respect to the financial aspects and structural stability.

2. Current status

Although a very less research studies have been conducted on the cost effective analysis between RCC and Post-tensioned pre-stressed concrete beams, there is a very less work on the same. A complete literature survey give out that a little bit of work had been done in India.

Economics of Continuous R.C.C. Beams Vis-à-vis Continuous Prestressed Concrete Beams, (A.R.Mundhada,Mohammad Shahezad), 2012. The focus of this paper is to designed continual RCC beams as well as continual prestress concrete beam and then analogize final results. RCC beams was manually designed by using the LSM method which is based on IS: 456-2000. Based on the steps & formulas involved, a designed program was prepared in Excel. An indistinguishable method was followed for prestress cement beams. The manual design dependent on the LSM technique proposed by the IS: 1343-1980. The program for planning the equivalent was created by utilizing Excel and its last check by first tackling the manual problem and examine the outcomes. The beams were designed for various concrete grades between M: 30 to M: 50. Results shows continuing RCC beam is affordable than continuing pre-stressed concrete beam for shorter spans but vice versa is true for longer spans. Output shows for Span 10 up to 15m, RCC beams are preferable. Span range between 15 to 20m, the decision should be based on other factors such as size and place of the project. For spans past 20m, Pre-stressed concrete beams are better outputs as analogize to conventional RCC beams.

Cost effectiveness of Reinforced Concrete and Post Tensioning beam in multi-storied building (Dinesh Choudhary, K.Swathi, K.Padmanabham), 2017. The aim of this pa- per concludes that, Compare the outputs be- tween RCC beam and PT beam of 20m span for same preliminary data. In this paper the six storied commercial building is designed for floor plan dimension of 20mx20m. The prototype have been analyzed, designed manually and by using ETABS software. And determine the percentage cost difference between RCC & Post-tensioned pre-stressed concrete beam. Finally results come out that the
construction value of framed structure with Reinforced Concrete beam and Post-tensioning beam. Comparing the two prototype cost of construction less as 10% in Post-tensioned beam model.

The Comparison between R.C.C and Post- Tensioned Beam Economically and the Com- parison in Size of the Columns used in them, (Swathi Raj, Dr. S.K.Dubey), 2015. The focus of this paper concludes that, Analysed and designed structural elements like beam, column, T- beam in a commercial building and compare the results with a post-tensioned haunch beam. The primarily analysed the structure will be done manually for both lateral as well as vertical loads by substitute frame method and portal frame method respectively. The distinguish in both the beams are finding out and with respect to the span to cost ratio as well as the distinguish in size of the column to be used to compute the cost of construction. Result shows that the post-tensioned bonded beam is more economical compare to ordinary RCC beam. Using post-tensioned bonded beam larger column free areas can be created, were plotted and it shows that the post-tensioned haunch beam shows superior results when compared to R.C.C T-beam.

Cost Constructional Comparison Between RCC & Pre-stressed Beams Spanning 26m, (Ankit Sahu, Prof.Anubhav Rai, Prof.Y.K.Bajpai), 2014. The focus of this paper concludes that, Design and detailed estimate of RCC Beam and Post-tensioned pre-stress Beam of span 26 m and then analyze the outputs. Outcome shows that, for span 26m Post-tensioned pre-stressed concrete beam is 34% affordable than RCC beam. Also, Outcome ranges between span from 6m up to 26m and above than, Result shows that for 11.25 meter length cost of RC Beam & PT Beam are equal. Finally the conclusion of this paper RC beams are affordable for spans up to 11.25 meter and Post-tensioned pre-stressed beams are affordable for spans greater than 11.25 meter.

3. Methodology

![Research Process Flowchart](image)

Figure 1. Research Process Flowchart

This work includes the analysis, design and detail estimate of quantity of steel, concrete and shuttering requirement for beams contribute mostly to the all-inclusive cost of the beam. Material consumption
depends on size effect. Here compare the output of beam for various span length by RCC and Post-tensioned pre-stressed concrete beam techniques. And calculation of percentage cost difference between RCC and Post-tensioned pre-stressed concrete beam.

To begin with the first model consists of a conventional RC frame with all beams and columns as RCC. All RCC Frames designed by ETABS software. Concrete frame designed in ETABS to find out the required area of steel, deflection of beam and check all members should have passed or not through define load combinations.

The limit state method used to design frames based on IS:456-2000. The concrete grade maintained at M:20 for RCC. The next model considers outer peripheral beams as RCC and internal beams with PT (Post Tensioned) tendons. An identical procedure followed for un-bounded post-tensioning beams. All interior PT beams designed by ADAPT-PTRC software which is based on IS:1343-2012. Indian standard Pre-stressed concrete which is link into the program so as to directly calculate pre-stressing steel, non-prestressing steel, deflection of beam and check the member should have passed or not through define load combinations. The grade of concrete maintained at M:40 PT beams only. Designed of post-tensioning beam carried out for parabolic cable profile only, which is most popular one. Post-tensioning beams of all spans design for Type 3 only which is practice in field. There are first two types of structures are used only in special cases like water tanks, pipes, sleepers & electric poles.

The internal beams design for various spans between 5m to 15m for one and another design methods firstly Reinforced cement concrete method and secondly Post tensioning method. Only rectangular sections are considered to design RCC as well as PT internal beams. Program prepared for estimating and costing in Excel. Cost based on the latest SSR in Maharashtra. In case of pre-stressed concrete, several of the rates obtain from well known particular private infrastructure company. There are some design considerations assume such as:

3.1 Floor plan
Two dimensional drawing in that clearly mentioned all dimensions such as column-column distance, clear span length of beam, thickness of wall, Sizes of column and beam. AutoCAD software used for drafting the floor plans and same file working as a input file for further designing part.

3.2 Design loads
The design loads are takeoff as per IS 456- 2000, IS 1343-2012, IS 875-1987(part I, II and III) and IS 1893-2016 for gravity and lateral loads. The wind speed considered as 39m/s, Terrain category II with the type of structure class A. The structure located in seismic zone III with zone factor 0.16.

3.3 Soil and foundation
Foundation provide the structural safety from the ground to distribute the load of structure over large area in order to overloading the underlying soil. The foundation located on medium coarse grained soil with allowable bearing pressure 200 KN/m2 (assumed). The ground water bottom of the foundation. RC strip footing used in substructure.

3.4 Materials
M:20 is the minimum grade of concrete to be used in R.C.C., as recommended by IS 456- 2000 and Fe500 grade HYSD steel used to design of RC elements. M:40 is the minimum grade of concrete to be used in unbonded Post-tensioning beam, as recommended by IS 1343- 2012 and pre-stressing steel used low relaxation 7 wire strand class II (Grade 270) with 12.7mm nominal diameter shall verifying to the
requirements of IS 14268:1995. Medium coarse grained soil, 20mm down coarse aggregate, OPC 53 grade cement used in mix design.

3.5 Cost Comparison
Cost is important aspect for comparison of Reinforced concrete and Post-tensioning beam in longer length beam. Because costly structures generally neglected in construction if another cheaper option in front it. The configurated structural member, is evaluated for quantities of primary materials such as steel, concrete, shuttering and labour charges which is shown in detail below. This estimation is basically meant for material quantity takeoff of skeleton internal beam member of superstructure. The quantity of concrete and steel requirement for beam contribute mostly to the total cost of the beam member. The percentage of steel utilization and concrete utilization depends on size effect. The rates are taken as per MH SSR 2020-2021 and particular private infrastructure company. Variation of cost difference between both type of RC and PT beam which is shown in table.

3.6 Preliminary Basic Input Data
Live load : 3.0 kN/m2
Floor finish : 1.5 kN/m2
Location : Dhule City
Windload : As per IS: 875(Category 2, Class A)
Seismicload : As per IS:1893(Zone-III)
Storey height : 4m
Wall1 : 230 mm(Outer Wall)
Wall 2 : 115 mm (Internal Wall)

4. Results & Discussion
Table.1 below shows that Cost/Beam in rupees for various spans for both RCC beam in M:20 grade of concrete and PT beam in M:40 grade of concrete.

| Span(m) | Estimated Cost Of RC Beam | Estimated Cost Of PT Beam |
|--------|---------------------------|--------------------------|
| 5m     | Rs.10211/-                | Rs.11044/-               |
| 7.5m   | Rs.25310/-                | Rs.24005/-               |
| 10m    | Rs.55116/-                | Rs.35196/-               |
| 12.5m  | Rs.103572/-               | Rs.60063/-               |
| 15m    | Rs.141305/-               | Rs.94462/-               |

Figure.2 below shows that variation of cost with respect to the span of beam where the break-even point between RCC and PT technique is approx 7m Span.
I. Result shows that for 5m span Reinforced cement concrete beam is \(7.54\%\) cheaper than Post-Tensioned Pre-stressed concrete beam. Result shows that for 7.5m span Post- Tensioned Pre-stressed concrete beam is \(5.15\%\) cheaper than Reinforced cement concrete beam.

II. Result shows that for 10m span Post- Tensioned Pre-stressed concrete beam is \(36.144\%\) cheaper than Reinforced cement concrete beam.

III. Result shows that for 12.5m span Post- Tensioned Pre-stressed concrete beam is \(42\%\) cheaper than Reinforced cement concrete beam.

IV. Result shows that for 15m span Post- Tensioned Pre-stressed concrete beam is \(33.15\%\) cheaper than Reinforced cement concrete beam.

Table 2 below gives minimum depth of beam required for particular span of beam such as 5m, 7.5m, 10m, 12.5m and 15m for both RCC and PT beam technique.

**Table 2** Depth of RC Beam vice versa PT Beam

| Span (m) | RCC beam cross section | PT beam cross section |
|----------|------------------------|-----------------------|
| 5m       | 230 X 450              | 230 X 300             |
| 7.5m     | 230 X 600              | 230 X 380             |
| 10m      | 300 X 750              | 230 X 450             |
| 12.5m    | 380 X 900              | 230 X 530             |
| 15m      | 380 X 1050             | 300 X 600             |

Figure 3 below shows that variation of depth of beam with respect to the span of beam where the structural designer knows easily depth of beam required ranges from span 5m up to 15m.
Table 3 below gives deflection comparison between both RC and PT beam design methods for total load combination.

**Table 3** Deflection of RC Beam vice versa PT Beam

| Span (m) | Deflection of RC beam | Deflection of PT beam |
|---------|-----------------------|-----------------------|
| 5m      | 1.92mm                | 0.4mm                 |
| 7.5m    | 5.32mm                | 1.5mm                 |
| 10m     | 7.45mm                | 2.4mm                 |
| 12.5m   | 10.39mm               | 4.3mm                 |
| 15m     | 14.44mm               | 9.3mm                 |

Figure 4 below shows that deflection relative to beam ends for both RC and PT beam design methods. Final Outcome shows that Post-Tensioned pre-stressed concrete beam good in deflection control than Reinforced cement concrete beam.
5. Conclusion

Finally, the conclusion of this project cost/beam of Post-Tensioned prestress concrete beam reduces after 7m long length beam and also the outcome shows that control deflection of beam by restrict the depth of beam by using unbonded Post-Tensioned pre-stressed concrete beam method. A break-even analysis is done because importance of decision making point of view as it helps the structural designer either we go for RC beam or PT beam casting method. Also, The outcome shows that variation of cost with respect to the span of beam where the break-even point between RCC and PT technique is approx 7m Span.

6. References

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