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Analysis and Design of Prestressed Concrete Beam with Different Proportions

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ABSTRACT: Prestressed concrete is basically concrete in which internal stress of a suitable magnitude and distribution are deliberately introduced so that the stresses resulting from external loads are counter acted to a desired degree. Prestressed concrete beams are very suitable for heavy loads and longer spans. Pre-stressing is generally a way to overcome concrete weakness in tension. Pre-stressing removes a number of design limitations conventional concrete faces on span and load and also permits the building of roofs, floors, bridges, and walls with longer unsupported spans. With the use of high strength concrete in prestressed concrete structures reduced to Shrinkage cracks are low as compared to low strength concrete.

In the prestressed concrete beam the entire section is effectively used and beams are light weight by providing the curved tendons and the pre-compression, a considerable part of the shear is resisted. High strength steel is needed to transfer large prestressing force. Cracks do not occur under working loads. Even if a minute crack occurs when overloaded, such crack gets closed when the overload is removed. The deflections of the prestressed concrete beams are small. In prestressed concrete beams, testing of steel and concrete can be made while prestressing.

Prestressed concrete sections are thinner and lighter than RCC sections, since high strength concrete and steel are used. Thinner sections in prestressed concrete results in less self weight and hence overall economy. Post-tensioning is an economical way of achieving these larger spans. In the project the analysis and design of PSC beam with different proportions is made and the result is reported.

KEYWORDS: Prestressed Concrete, Post-tensioning, Beam design, Self weight, Heavy loads, Economy, Deflection, Reinforced cement concrete.

I. INTRODUCTION

Prestressed concrete is basically concrete in which internal stress of a suitable magnitude and distribution are deliberately introduced so that the stresses resulting from external loads are counteracted to a desired degree. Pre-stressing is generally a way to overcome concrete weakness in tension. Generally, the concrete undergoes compression on top flange and tension at bottom flange. In pre-stressing the tendons are stretched along the axis and cement is poured, later when the tendons are released the compression is generated at the bottom which tries to counter-balance the compression due to loading at the top part of the beam. The upward force along the length of the beam counteracts the service loads applied to the member.

Pre-stressing removes a number of design limitations conventional concrete faces on span and load and also permits the building of roofs, floors, bridges, and walls with longer unsupported spans. This allows architects and engineers to design and build lighter and shallower concrete structures without sacrificing strength. This also helps in the construction of longer spans thereby reducing the intermediate pier construction and making bridge construction economical.

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In ordinary reinforced cement concrete, compressive stresses are taken up by concrete and tensile stresses by steel alone. The concrete below the neutral axis is ignored since it is weak in tension. Although steel takes up the tensile stresses, the concrete in the tensile zone develops minute cracks. The load carrying capacity of such concrete sections can be increased if steel and concrete both are stressed before the applications of external loads. This is the concept of prestressed concrete. As per ACI committee prestressed concrete is that concrete in which internal stresses of suitable magnitude are introduced so that the stresses resulting from the external loadings can be counteracted to a desired degree.

III. LITERATURE REVIEW

1. Miller and Juarez (1978):

The design decisions about cross-sectional dimensions made during preliminary design can have a substantial influence on the final cost of the bridge. To help the designer obtain an economical starting point for a final design, a program was written to determine section dimensions and mid span and pier prestressing steel areas to give minimum cost. The optimization algorithm used was the generalized reduced gradient technique. Since a preliminary design is obtained, the analysis techniques and design criteria have been simplified to reduce computation. Because of simplifications made in the analysis and design the resulting design is intended to be used as a starting point from which detailed design can be carried out.

2. Tadros M K et al. (1979):

Discusses the long term deflections of segmental bridges. A step by step computer method was proposed for determining the deflections and stress distribution due to creep, relaxation of prestressed steel. The computer program accounts for the presence of the non prestressed steel, difference in ages of the concrete segments, the multiple stages in which the external loads and prestressing are applied, and the changes in geometry and support condition as construction progresses. Deflection of a particular node with and without considering creep, shrinkage and relaxation was evaluated. Graphs are plotted for the vertical deflection of bridge at various construction stages considering the effects of long term deflections.

3. Abdel-Karim and Tadros (1995):

Most prestressed concrete slab-on-girder bridges are simply supported with precast, pretensioned girders and a cast-in-place (CIP) deck. Spans are limited to about 150 ft due to weight and length restrictions on transporting the precast girder units from the prestressing plant to the bridge site. Such bridge construction, while economical from an initial cost point-of-view, may become somewhat limiting when longer spans are needed. According to the available literature, a variety of methods have been used to extend the span range of concrete slab-on-girder bridges. These include the use of high performance materials and modified girder sections. However, to significantly increase the span length, it is necessary to modify the layout and provide continuity connections between the spans.

4. Castrodale and White (2004):

For these longer spans, continuity between the girder segments has the advantage of eliminating bridge deck joints, which leads to reduced maintenance costs and improved durability. The performance and cost-effectiveness of a spliced girder system depends on the design and construction details. This involves a combination of the different design enhancements instead of applying them individually.

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5. Peter Beaumont Morice – illustrates some of the results of recent research on the behaviour of prestressed concrete structures. A simple set of expressions is developed for the elastic design and ultimate load carrying capacity of prestressed members in both statically determined and statically indeterminate structures. The use of these expressions in the analysis of continuous beams, portal frames and bridge decks is discussed.

6. Adekunle Philips Adewuyi and Shodolapo Oluyemi Franklin- analytically assesses the behaviour and criteria for optimal performance of prestressed concrete structures under the combined actions of post-tensioning and post-compression. Magnel type diagrams are also developed to show the feasible solution regions for different loading conditions. The findings revealed that the prestressing forces in the post-tensioned tendons are independent of the eccentricity ratio, but increases perfectly curvilinearly up to prestressing ratio of 0.7 beyond which the technique becomes impracticable.

IV. MATERIALS

Cement

The cement used shall be any of the following, with the prior approval of the engineer-in-charge:

- Ordinary Portland cement conforming to IS:269-1976
- Portland slag cement conforming to IS:455-1976, but with not more than 50 percent slag content
- Rapid-hardening Portland cement conforming to IS:8041-1978
- High strength ordinary Portland cement conforming to IS : 8112-1976

Aggregates

All aggregates shall comply with the requirements of IS:383-1970.

The nominal maximum size of coarse aggregate shall be as large as possible subject to the following:

- In no case greater than one-fourth the minimum thickness of the member, provided that the concrete can be placed without difficulty so as to surround all prestressing tendons and reinforcements and fill the corners of the form.
- It shall be 5mm less than the spacing between the cables, strands or sheathings where provided.
- Not more than 40mm; aggregates having a maximum nominal size of 20mm or smaller are generally considered satisfactory.

Water

The requirements of water used for mixing and curing shall conform to the requirements given in IS: 456-1978. However, use of sea water is prohibited.

Admixtures

Admixtures may be used with the approval of the engineer-in-charge. However use of any admixture containing chlorides in any form is prohibited.

Prestressing Steel

The prestressing steel shall be any one of the following:

- Plain hard-drawn steel wire conforming to IS:1785 (Part I)-1966 and IS:1785 (Part II)-1967
- Cold-drawn indented wire conforming to IS:6003-1970
- High tensile steel bar conforming to IS:2090-1962, and
- Uncoated stress relieved strand conforming to IS:6006-1970.

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High strength Concrete

Since high tensile steel is used in prestressed concrete, the concrete used should also be of good quality and high strength. Therefore, the code recommends a minimum mix of M 40 for pre-tensioned system and M 30 for post tensioned system. These mixes have high strength and a high value of modulus of elasticity of concrete which results in less deflection.

V. RESULTS & DISCUSSION

Mix Proportions:

The mix proportions of cement, sand and coarse aggregate are calculated by mix design method given by IS code of 10262. In this project, three grades of concrete are designed i.e, M30, M35 and M40. The following table shows the mix proportions of the above mentioned grades of concrete.

Mix	Proportion
M30	1:1.85:3.24
M35	1:1.75:3.12
M40	1:1.63:2.95

Compressive strength:

Concrete cubes are prepared by test specimens of size 150×150×150 mm. Cubes are to be cured for 28 days by any of the curing methods, generally preferable is water curing method. Cubes are to be surface dried before testing in compression testing machine. Load is applied at the rate of 14tonne/min. The value of load at the first crack is noted down and the compressive strength value is to be determined. Compressive strength test results at curing ages of 3 days, 7 days and 28 days for design mix are shown in the Table. For testing in compression, no cushioning material was placed between the specimen and the plates of the machine. The load was applied axially without shock till the specimen was crushed. I prepared nine specimens for each grade of mix design was tested.

Mix	3 days	7days	28 days
M30	17.6 N/mm ²	24.65N/mm ²	38.78N/mm ²
M35	18.3N/mm ²	24.70N/mm ²	41.67N/mm ²
M40	18.15N/mm ²	31.75N/mm ²	44.48N/mm ²

Comparison of PSC and RCC beam :

In the structures for site conditions , load calculations results and economical purpose I chose PSC beam design because for heavy load condition. RCC structure is uneconomical, less strength so I go for design of structures by PSC concept.

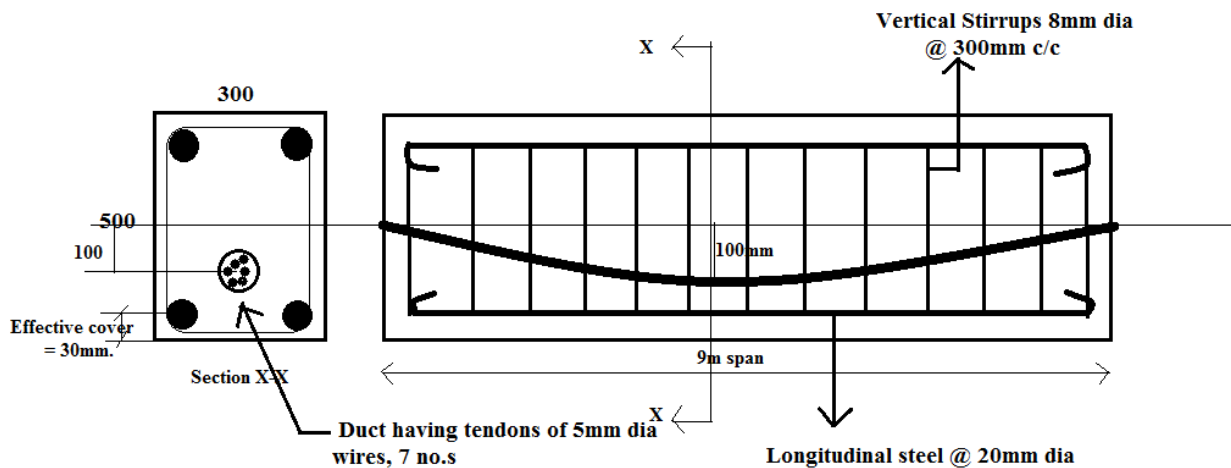
In the below fig prestressed concrete beam design and clear representation of detailed reinforcement is given and reinforced cement concrete beam design details are explained.

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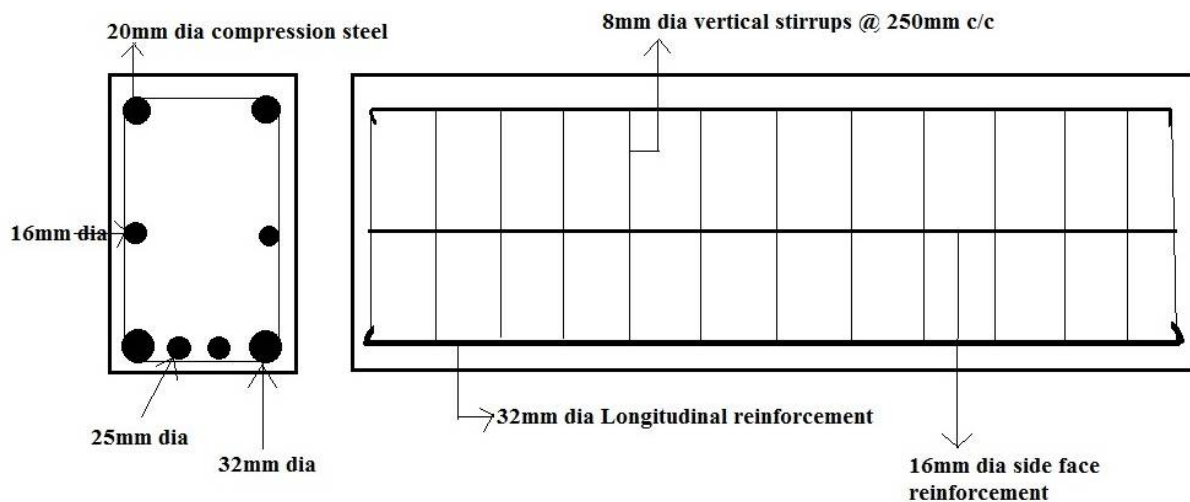
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The beam is designed for residential (high rised) building construction purpose. The detailing is given in fig. In the beam duct provide having tendons of 5mm dia wires with 7 numbers. Main reinforcement is provided 20mm dia at bottom, 20mm dia at top and vertical stirrups 8mm dia with spacing of 300mm c/c.



In RCC beam design detailing is given in fig. The main reinforcement is provided 32mm dia 2 numbers and 25mm dia 2 numbers at bottom and 25mm dia 2 numbers provided at top reinforcement with vertical and side reinforcement also provided in RCC beam for given loads.

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S.NO	TYPE	PSC	RCC
1	Main bars	2 bars @20mm dia at top and bottom	4 bars at bottom such 2 bars 32mm dia and 2 bars 25mm dia . 2 bars 25mm dia at top
2	Ducts	It having tendons of 5mm dia each have 7 members	No need
3	Vertical stirrups	8mm dia 300mm c/c	8mm dia 250mm c/c
4	Side reinforcement	No need	16mm dia along the length of beam

VI.CONCLUSION

The use of high strength concrete results in a reduction in the cross sectional dimensions of prestressed concrete structural elements, with reduced dead weight of the materials, large spans become technically practicable. As shown in the above figs reinforcement details as given in RCC requirement of reinforcement is more than 3times of PSC and depth also very high in RCC than PSC so in economical point of view in this condition PSC is better than RCC.

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