COMPREHENSIVE DESIGN EXAMPLE FOR PRESTRESSED CONCRETE (PSC) GIRDER SUPERSTRUCTURE BRIDGE WITH COMMENTARY

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ABSTRACT

A study of I-girder with same cross-section, same number of support and same number of intermediate diaphragm with support configurations is done. Commercial available software STAAD PRO has been used to carry out linear analysis of these I-girder bridges. Grillage method of analysis has been used to analyse the bridges. The linear analysis has been carried out for the dead load (self-weight) and live load of Indian Road Congress (IRC) class 70R LOADING, CLASS A TWO LANE AND CLASS A FOUR LANE for eccentricity loading as per IRC is done. The paper presents a parametric study for deflection, bending and shear for different support configuration. The benefit of pre-stressing is reflected in significant decrease in longitudinal bending moment and transverse moment and longitudinal stresses.

1. INTRODUCTION

Prestressed concrete is the most recent of the major forms of construction to be introduced into structural engineering. Although several patents were taken out in the last century for various prestressing schemes, they were unsuccessful because low strength steel was used, with the result that long-term effects of creep and shrinkage of the concrete reduced the prestress force so much that any advantage was lost. It was only in the early part of the twentieth century that the French engineer Eugène Freyssinet approached the problem in a systematic way and, using high-strength steel, first applied the technique of prestressing concrete successfully. Since then prestressed concrete has become a well-established method of construction, and the technology is available in most developed, and in many developing, countries. An account of some of the early developments in prestressed concrete is given in Walley (1984).

The idea of prestressing, or preloading, a structure is not new. Barrels were, and still are, made from separate wooden staves, kept in place by metal hoops. These are slightly smaller in diameter than the diameter of the barrel, and are forced into place over the staves, so tightening them together and forming a watertight barrel (Fig 1.1). Cartwheels were similarly prestressed by passing a heated iron type around the wooden rim of the wheel. On cooling, the tyre would contract and be held firmly in place on the rim (Fig. 1.2), thus strengthening the joints between the spokes and the rim by putting them into compression. The technique of prestressing has several different applications within civil engineering, often being used to keep cables taut when subjected to compressive forces. However, by far the most common application is in prestressed concrete where a prestress force is applied to a concrete member, and this induces an axial compression that counteracts all, or part of, the tensile stresses set up in the member by applied loading.

Fig-1.1: Barrel staves compressed with hoops.
1.2 METHODS OF PRESTRESSING

Prestressed concrete is basically concrete in which internal stresses of a suitable magnitude and distribution are introduced so that the stresses resulting from external loads are counteracted to desired degree. In reinforced concrete members, the prestress is commonly introduced by tensioning the steel reinforcement. The earliest example of wooden barrel construction by free force-fitting of metal bands and shrink-fitting of metal tyres on wooden wheels indicate that the art of prestressing has been practised from ancient times. The tensile strength of plain concrete is only a fraction of its compressive strength and the problem of it being deficient in tensile strength appears to have been the driving factor in the development of the composite material known as “reinforced concrete”.

The development of early cracks in reinforced concrete due to incompatibility in the strains of steel and concrete was perhaps the starting point in the development of the a new material like “Prestressed concrete”. The application of permanent compressive stress to a material like concrete, which is strong in compression but weak in tension, increases the apparent tensile strength of that material, because the subsequent application of tensile stress must first nullify the compressive prestress. In 1904, Freyssinet attempted to introduce permanently acting forces in concrete to resist the elastic forces developed under loads and this idea was later developed under the name of “prestressing”.

1.3 ADVANTAGES AND DISADVANTAGES OF PRESTRESSED CONCRETE:

The use of high strength concrete and steel in prestressed members results in lighter and slender members than is possible with RC members.

2. In fully prestressed members the member is free from tensile stresses under working loads, thus whole of the section is effective.

3. In prestressed members, dead loads may be counter-balanced by eccentric prestressing

1.3.2 Disadvantages Of Prestressed Concrete

1. The availability of experienced builders is scanty.
2. Initial equipment cost is very high.
3. Availability of experienced engineers is scanty.
4. Prestressed sections are brittle
5. Prestressed concrete sections are less fire resistant

1.4 AIM AND OBJECTIVE

2. Design of the Prestressed I-Girder as per IRC 112:2011.
4. To prepare a model of I-Girder and analyse it in Staad pro software.

2. REVIEW OF LITERATURE

The finite element method of analysis is generally the most powerful, versatile and accurate analytical method of all the available methods and
has rapidly become a very popular technique for the computer solution of complex problems in engineering. It is very effective in the analysis of complicated structures such as that of a box girder bridge with complex geometry, material properties and support conditions and subjected to a variety of loading conditions. Canadian Highway Bridge Design Code has recommended the finite element method for all type of bridges.

A large number of elements have been developed for use in the finite element technique that includes one-dimensional beam-type elements, two dimensional plate or shell elements or even three-dimensional solid elements. Since the structure is composed of several finite elements interconnected at nodal points, the individual element stiffness matrix, which approximates the behaviour in the continuum, is assembled based on assumed displacement or stress patterns. Then, the nodal displacements and hence the internal stresses in the finite element are obtained by the overall equilibrium equations. By using adequate mesh refinement, results obtained from finite element model usually satisfy compatibility and equilibrium.

Zienkiewicz (1977), Sisodiya,et.al (1970) presented finite element analyses for single box girder skew bridges that were curved in plan. The bridge that could be analyzed by this method may be of varying width, curved in any shape, not just a circular shape and with any support conditions. They used rectangular elements for the webs and parallelogram or triangular elements for top and bottom flanges. This approximation would require a large number of elements to achieve a satisfactory solution. Such an approach is impractical, especially for highly curved box bridges.

Chapman, et al (1971) conducted a finite element analysis on steel and concrete box girder bridges with different cross section shapes to investigate the effect of intermediate diaphragms on the warping and distortional stresses. They showed that curved steel boxes even with symmetrical load components gave rise to distortional stresses, and showed that the use of sloping webs resulted in an increase in distortional stresses.

Lim, et al. (1971) developed an element that has a beam-like-in-plane displacement field which is trapezoidal in shape, and hence, can be used to analyze right, skew, or curved box-girder bridges with constant depth and width.

Fam and Turkstra (1975) developed a finite element scheme for static and free vibration analysis of box girders with orthogonal boundaries and arbitrary combination of straight and horizontally curved sections. Four-node plate bending annular elements with two straight radial boundaries, for the top and bottom flanges, and conical elements for the inclined web members were used. The importance of warping and distortional stresses in single-cell curved bridges was established in relation to the longitudinal normal bending stresses, using the finite element method.

Dezi (1985) examined the influence of some parameters including transverse and longitudinal locations of external loads, span-to-radius ratio, width-to-depth of the cell, and number of cross diaphragms on the deformation of the cross section in curved single-cell box beams over those in straight single-cell box beams.

3 METHODOLOGY

3.1 Design Philosophy for PSC I Girder

The design of the super structure done for the 2 lane loading with footpath & 3 lane loading without footpath loading, critical design values are considered.

a) Structure Type : Major Bridge
b) Chainage : 209+435
c) Span arrangement : 1 x 45.5 m
d) Span lengths, L (c/c of bearing) :44.3 m

3.1 Geometry

a) Carriageway Width 9.50m
b) Overall width 12.6 m
c) Width of Crash Barrier 0.50m
d) Cross slope 2.50%
e) Thickness of wearing course 75mm
f) C/C of the Girder 3.1m
3.2 Dead Load (DL):
Unit weight for Dead loads calculation shall be considered as per IRC: 6-2014

3.3 Carriageway & Footpath Live Load (LL):
1 Lane of Class 70R/2 lane of Class A
- 3 Lanes of Class A/1 lane of 70R in combination with 1 lane of class A on third lane

Conforming to IRC 6-2014 shall be considered in analysis and whichever producing severe effect shall be considered in design. Reduction in longitudinal effect for three lane loading shall be considered as per clause 208 of IRC: 6. Pedestrian live load in conformity with clause 209.4 shall be considered over the footpath

3.4 Prestressing Effects
- It is proposed to use 19T15 cables conforming to Class 2 of IS : 14268 (Low relaxation strands) with Uncoated galvanized Sheathing for prestressing.
- Values of friction and wobble coefficient (μ and k) for prestressing strands shall be considered as μ = 0.2 and k = 0.0030. (Ref Table 7.1 of IRC 112:2011)
- Relaxation losses shall be computed considering relaxation loss of 2.5% at 0.75 UTS. (Ref Table 6.2 ; IRC:112-2011)
- Ultimate resistance of the T-Girder in flexure shall be checked against yielding of steel and against crushing of concrete as of IRC: 112-2011.
- Maximum jack pressure shall be considered as 75% of ultimate force.
- Duct diameter (Internal) is considered as 100mm. Clear cover protecting cable from the nearest concrete surface is kept as 75mm as per IRC: 112-2011.

4. MODELING AND ANALYSIS OF RCC GIRDER
4.1 GIRDER DETAILS
4.2 Section Dimensions of PSC I-Girder

4.5 SIDL:

5. ANALYSIS RESULTS

5.1 Bending Moment for External Girder (t-m):
5.2 Shear Force for External Girder (t):

5.3 Bending Moment for Internal Girder (t-m):

5.4 Shear Force for Internal Girder (t):

5.5 Transverse Moment for External Cross Girder (t):

5.6 Transverse Moment for Internal Cross Girder (t-m):

5.7 Summary of Prestress Calculations:
CONCLUSION

Torsion moment of inertia effect on the PSC I-girder Bridge with different skew angels i.e. 0o, were studied in this research.

- Depending upon the bending moment diagram obtained from Staad Pro software a parabolic cable profile is provided.
- Bending moment, shear force and torsion moments are getting from the STAAD grillage analysis results.
- The values obtained by manual computation and that of Staad Pro software are found to be in good agreement.
- The results tables show that bending moment, shear force and torsion moment at different sections of each girder.
- For straight girder bridge no torsion moment is observed.

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