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Comprehensive Design Example for Prestressed Concrete (PSC) Girder Super Structure 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.

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 EugèneFreyssinet 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, oftenbeing 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.

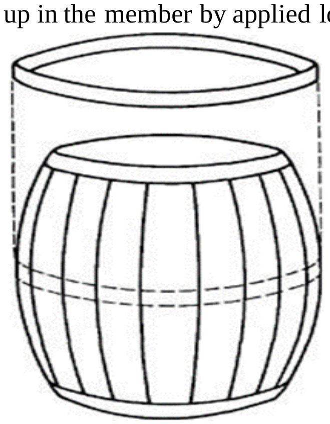

Figure 1.1 Barrel staves compressed with hoops.

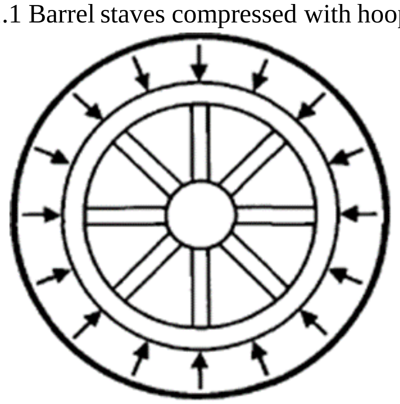

Figure 1.2 Cartwheel compressed by contracting tyre.

Within the field of building structures, most prestressed concrete applications are in the form of simply supported precast floor and roof beams (Fig. 1.3). These are usually factory-made, where the advantages of controlled mass production can be realized. Where large spans are required, in situ prestressed concrete beams are sometimes used, and in situ prestressed concrete flat slab construction is increasingly being employed. This last technique is often associated with that of the lift slab, whereby whole floor slabs are cast and tensioned at ground level, and then jacked up into their final position. In the field of bridge engineering, the introduction of prestressed concrete has aided the construction of long-span concrete bridges. These often comprise precast units, lifted into position and then tensioned against theunits already in place, the process being continued until the span is complete. For smaller bridges, the use of simply supported precast prestressed concrete beams has proved an economical form of construction, particularly where there is restricted access beneath the bridge for construction. The introduction of ranges of standard beam sections has simplified the design and construction of these bridges (Fig. 1.4).

Some further examples of the many applications of prestressed concrete are shownin Fig 1.5–1.8.

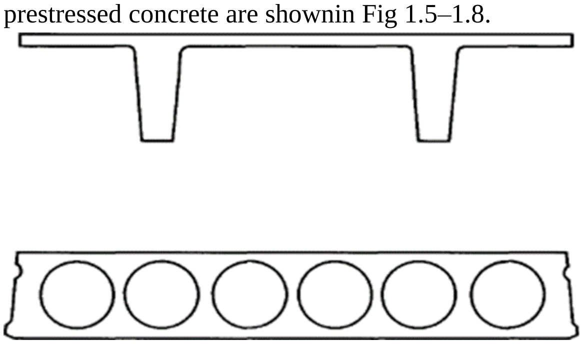

Figure 1.3 Examples of precast beams

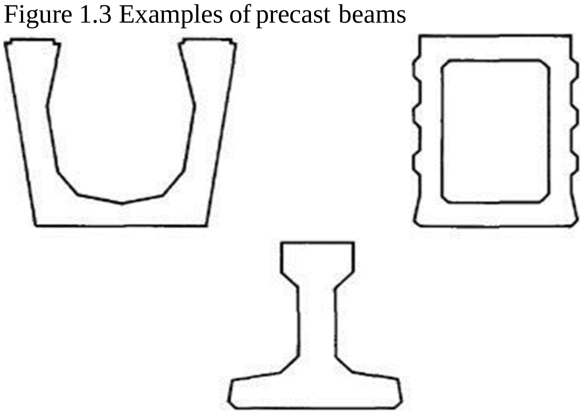

Figure 1.4 Examples of standard bridge beams.

Figure 1.8 Prestressed double-tee roof beams.

One of the main advantages of prestressed over reinforced concrete is that, for a given span and loading, a smaller prestressed concrete member is required. This saving of the dead load of the structure is particularly important in long-span structures such as bridges, where the dead load is a large proportion of the total load. As well as a saving in concrete material for members, there is also a saving in foundation costs, and this can be a significant factor in areas of poor foundation material. Another important advantage of prestressed concrete is that by suitable prestressing the structure can be rendered crack-free, which has important implications for durability, especially for liquid-retaining structures.

A third advantage is that prestressing offers a means of controlling deflections. Aprestress force eccentric to the centroid of a member will cause a vertical deflection, usuallyin the opposite direction to that caused by the applied load. By suitable choice of prestress force, the deflections under applied load can be reduced or eliminated entirely.

Against the advantages listed above must be listed some disadvantages of using prestressed concrete. The fact that most, if not all, of the concrete cross-section is in compression under all load conditions means that any inherent problems due to long-term creep movements are increased. From the point of view of construction, a high level of quality control is required, both for material production and for locating the tendons within the structure.

The technology required for prestressing concrete may not be available in many developing countries, and, if specified, may prove to be uneconomical since all equipment and personnel would have to be imported.

METHODS OF PRESTRESSING

Methods of prestressing concrete fall into two main categories:

Pretensioning and post-tensioning.

A.Pretensioning

In this method steel tendons, in the form of wires or strands, are tensioned between end-anchorages and the concrete members cast around the tendons. Once the concrete has hardened sufficiently, the end-anchorages are released and the prestress force is transferred tothe concrete through the bond between the steel and concrete. The protruding ends of the tendons are then cut away to produce the finished concrete member. Pretensioned members usually have a large number of wires or strands to provide the prestress force, since the force in them is developed by bond to the surrounding concrete, and as large an area of surface contact as possible is desirable. This method is ideally suited to factory production since largeanchorages are required to anchor all the tendons, and several members can be cast along the same set of tendons (Fig. 1.9). It is important to ensure that the members are free to move along the prestressing bed; otherwise undesirable tensile stresses may be set up in them when the end-anchorages are released. It is interesting to note the use of in situ prestressing in cable-stayed and suspension bridge construction. In the former, the stays are tensioned in order to reduce the deflections of the bridge and also to optimize the deck cross-section. Pretensioning of suspension bridge cables has also been employed to ensure that the grout used to protect them from corrosion remains in compression, and therefore crack-free, under all load conditions. Some examples of pretensioned members, other than beams, which are commonly produced, are shown in Fig. 1.10.