BEF Analogy for Concrete Box Girder Analysis of Bridges

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Summary

Box girder, due to its high torsional stiffness, is very appropriate for railway and highway long-medium span bridges. This type of cross section, subjected to transversely non-uniform loads, present warping and distortion phenomena. Accurate but time-consuming numerical procedures are available for determination of further strains and stresses caused by cross-section deformation. In this paper warping and distortion of box girders is evaluated through BEF analogy, by writing a 4th order differential equation. The problem is solved for practical cases of box girders by considering internal diaphragms stiffness. Graphs are supplied to designers and main design parameters affecting cross section deformation are underlined. The proposed methodology is shown through the use of graphs by developing numerical examples on actual bridge girders.

Keywords: box-girder, bridges, warping, distortion, Winkler foundation, BEF analogy.

1. Introduction

Concrete box girders are common in beam bridges for their efficient cross section with high torsional stiffness. They can be built by cantilever method, by incremental launching or through gantries but in all these cases deck presents internal diaphragms in order to transversely stiffen the box section. These diaphragms are generally placed on piers and abutments, to drive the flow of forces in support regions. But they have also the function of reducing cross section deformability, so they can be placed also into the span, between two supports. In every cases each section of girder, resting between two stiffened sections by diaphragms, can be considered as a deformable frame in its plane. For current widths of served roads, the tendency is to have deck composed of unicellular hollow boxes; they are much higher for railway bridges and less for road bridges. Multi-cellular boxes are used in the case of very large decks or for particular purposes, because in this case formworks and casting are much more complicated.
Classical beam theory does not consider the deformation of box section but as a matter of fact cross sections do not remain stiff in their plane. In addition they present warping phenomena, i.e. deformation of slabs and webs in longitudinal direction (section does not maintain itself into the plane in the deformed configuration). When warping is prevented, normal stresses born in addition to those associated with bending, already found with the classical beam theory. Moreover for transversely eccentric loads, cross section distortion born. These phenomena have been studied by different authors [1-8]. Theory of non-uniform torsion faces the problem by maintaining the stiffness of section in its plane, with the addition of normal longitudinal stresses depending on prevented warping. A classical way to study box distortion, instead, is to consider girders as tubular frames composed of walls as membrane elements [8]; in this case, due to eccentricity of loads, slabs and webs do not maintain a rigid angle between themselves and a relative rotation between elements occurs, with the result of cross section distortion. A more complete theory that takes into account globally these phenomena is that of folded plates, in which box is considered and calculated as a deformable frame with symmetric and anti-symmetric loads. This approach is more

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