Application of Spatial Grid Model in Structural Analysis of Concrete Box Girder Bridges

Dong XU
Professor, Ph.D.
Tongji University
Shanghai, China
xu_dong@tongji.edu.cn

Dong XU, born 1966, received his PhD in bridge engineering from Tongji University. He is a member of Working Group 3 of IABSE.

Yu ZHAO
Ph.D.
Tongji University
Shanghai, China
06zhaoyu@tongji.edu.cn

Yu ZHAO, born 1981, received his PhD in bridge engineering from Tongji University. His research interest includes reinforced concrete bridges.

Summary

For concrete box girder with wide transverse edge cantilevers, different analysis method (single beam model, plane grillage analogy, three-dimensional finite element model) has its merits and limited applicability. Therefore a need exists for a simple method of elastic analysis of thin-walled concrete box girders, while retaining sufficient accuracy for reinforcement design. A new method-spatial grid model-is proposed, which can consider out-of-plane bending and in-plane membrane effect. Clear analysis of spatial behaviour (including shear lag effect, statically indeterminate shear flow distribution and local flexural effect) can be obtained from the proposed model. Application of the proposed model in a single-span concrete box girder bridge is shown in this paper. The method is shown to give excellent agreement when compared to an elaborate three-dimensional shell finite element model.

Keywords: Concrete box girder; thin-walled effect; beam bending effect; plate effect; shear lag effect.

1. Introduction

Thin-walled concrete box-girder bridges are widely used throughout the world because of their high structural efficiency as well as better aesthetics compared to open-web type sections. Up to now, a significant amount of work has been conducted to better understand the behaviour of all types of box-girder bridges, and several methods have been proposed for their analysis [1, 2, 3]. However, different kinds of simplifications also exist in current structural analysis methods, i.e., concept of effective flange width [4], amplified factor to account for warping effect [5].

While shear lag and thin-walled effect (warping and distortional effects) are essential for box girder bridges, the use of single beam model and plane grillage method is approximate at best and does not address the loading effect clearly. Compared to other analytical techniques, the main advantage of three-dimensional FE models is its generality. It can describe the geometry of highly complex structures very accurately and automatically allows for shear lag effect, thin-walled effect and local loading effect. But the analytical results mix global loading and local loading effects, which is not convenient to design reinforcement directly using the current code items. Usually, the sectional forces at the different locations for different loading cases are determined by integrating the stresses obtained from elastic analysis. So it is frequently used to study stress distribution in parts of structure while simpler methods are used to investigate the load distribution behaviour of the structure as a whole.

Every method has its merits and limitations and some of them even have limited applicability. Therefore a need exists for a simple method of elastic analysis of thin-walled box girders to determine the combined effects of bending, shear and torque, while retaining sufficient accuracy for reinforcement design. In this paper, a 3D extension of plane grillage analysis - Spatial Grid Model - is proposed. The basic element is three-dimensional beam element. Such model can analyze all spatial behaviour clearly (including shear lag, statically indeterminate shear flow distribution, thin-walled effect and local bending) for structures subjected to combined loading actions, without

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