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Unusual structural effects in a variable-depth box girder bridge: The Pujayo viaduct

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ABSTRACT

The new Spanish highway bridge, the Pujayo Viaduct, has a single-cell box girder. Owing to the large width of 26.1 m, the box girder had to be stiffened by transverse upper and lower ribs, by haunches in the connection web-flange and by inclined webs. Together with the variable girder depth, a relatively complicated geometry was created that was analysed by means of finite-shell-element calculation. Several unusual secondary structural effects are identified and explained. The longitudinal axial force resulting from global bending causes deviation forces in the curved bottom slab, which are responsible for transverse bending in the bottom slab and axial forces in the webs. Shear lag deformation of the box section causes moderate horizontal bending of the transverse ribs. Global deflection of the bridge girder causes out-of-plane bending of inclined webs. Global bending of box girders causes local bending moment output in finite shell elements. A further conclusion is that three-dimensional finite-shell-element models are an exact and appropriate complement to the common beam-element calculation models.

1. Introduction

Prestressed concrete box girders are frequently used for medium and large span bridges, as they provide a bending and torsional stiff deck with reasonably small self-weight. Their structural response is known and documented in the literature [1,2]. Usually, a good structural performance is obtained with single-cell box girders for a deck width of up to 13 m and with multi-cell box girders for wider decks [3]. The 420 m Spanish highway bridge, the Pujayo Viaduct (Fig. 1), has a total width of 26.1 m but only one single-cell box girder. In order to increase the bridge girder's resistance against distortion, special design measures have been found necessary.

Transverse strengthening has been realised by transverse upper and lower ribs inside the box and underneath the lateral cantilevers, at a 5 m spacing. Furthermore, the webs have a strong inclination, decreasing their distance towards the bottom slab, and the connection of the web and bottom slab is strengthened with haunches (Fig. 2). This cross section is combined with a variable girder depth in the longitudinal direction, leading to a variable width of the bottom slab.

The result is a quite unusual bridge geometry, whose effects on the structural behaviour of the box girder have been studied extensively during the elaboration of the construction project by means of a detailed finite-shell-element analysis in ABAQUS/Standard software. A great variety of secondary structural effects have been detected that in most instances have not been found documented in the literature. Some of the most interesting and important are presented and evaluated in the following:

- Transverse axial forces in the webs.
- Transverse bending in the bottom slab.
- Longitudinal bending in the webs.
- Horizontal bending from shear lag.
- Global versus local bending.

This paper provides a detailed description of these structural effects and general explanations of their concepts. An analytical calculation method for the determination of local bending moments resulting from global bending is suggested. Furthermore, the paper evaluates the influence of these structural effects on the design assessment of concrete box girder bridges in general.

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