Fatigue analysis of a railway bridge deck slab considering the influence of simultaneous train crossings

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Summary

Fatigue analyses play an important role in the context of railway bridge decks assessment. This type of structure is usually subjected to important cyclic loads due to railway traffic, and consequently, the fatigue phenomenon has to be taken into account. In this paper, a recently developed numerical methodology for fatigue analyses is applied to the study of a typical bridge deck configuration, which consists of a double track structure made with precast U-shaped girders connected by a thin cast-in-place slab. The study focuses on the fatigue behaviour of the deck slab and girder webs, considering the influence of crossings of trains travelling in opposite directions. The developed numerical methodology takes into account the statistical properties of the location of the point where the trains cross. The most critical points in terms of fatigue verifications and the practical implications of train crossings are shown by means of a parametric analysis.

Keywords: bridge, railway, fatigue, train crossing

1 Introduction

Railway viaducts are subjected to important cyclic loads, which may limit the structure service life, particularly at points where cracking occurs. Therefore, fatigue analyses play an important role, either at the design stage of new structures, or during the assessment of the structural condition of existing constructions. The dynamic enhancement of internal forces and bending moments, due to dynamic impact, track and vehicle imperfections or resonance effects, has to be taken into account in such fatigue analyses.

In the case of box-girder railway bridge decks, the fatigue performance of transverse reinforcements (transverse reinforcements in the deck slab and web stirrups) is essentially determined by two load effects: in-plane shear forces and transverse bending. Note that, on the one hand, both the deck slab and the webs are subjected to important cyclic bending moments caused by the passage of trains. On the other hand, the structural elements are also subjected to important in-plane shear forces (in the case of the slab, in-plane shear is mainly due to transfer of shear forces from the web to the girder flanges). Detailed fatigue analyses can be carried out by applying the damage accumulation method (DAM), including the effects of in-plane shear stresses and transverse bending moments.

In the case of double track railway bridges, the influence of simultaneous train crossings (usually travelling in opposite directions) has also to be taken into account. In this work, a new methodology for the calculation of such effects is applied in the analysis of a case study, which consists of a double track railway bridge decks made with precast U-shaped girders and a cast-in-place slab. Although this study focuses on fatigue effects, the results of ultimate limit state (ULS) calculations are also presented, so that one can evaluate which limit state (ULS or fatigue) is the most onerous.

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2 Case Study

The structure under analysis is composed of five continuous spans, with interior and end spans of 40 m and 32 m, respectively. This structure carries a double railway ballasted track. The bridge cross section is composed of two U-shaped precast girders and a cast-in-place slab, forming a box-girder deck (Fig. 1).

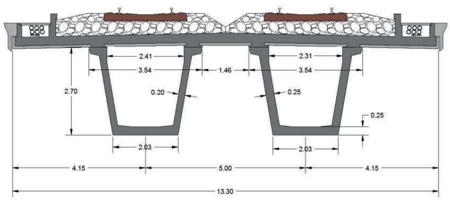

Fig. 1: Cross-section geometry

3 Methodology

The fatigue analysis is performed by employing the damage accumulation method which makes possible the calculation of the fatigue effects of a variable-amplitude stress history. The stress calculations (considering the effects of in-plane shear and transverse bending) are carried out considering the following resistance mechanisms: (i) truss action, to calculate the stresses due to in-plane shear (i.e., the shear force parallel to the web or to the slab plane, depending on the element under analysis); (ii) lateral translation of the plane where the shear force is applied; (iii) symmetric variation of the forces applied to the web chords. Transverse bending is resisted by mechanisms (ii) and (iii). The influence of simultaneous train crossings is analysed by assuming a uniform distribution of probability for the coordinate of the point where the first axles of each train meet.

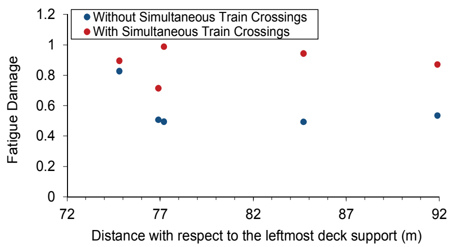

Fig. 2: Fatigue damage for point P3, in the slab

4 Fatigue Analysis

Relevant results of fatigue calculations are presented for some critical points. In order to assess the relevance of simultaneous train crossings, the calculated fatigue damage for a service life of 100 years is compared with the computed fatigue life considering isolated train passages in both tracks (Fig. 2). It was concluded that the fatigue damage increases if simultaneous train crossings are taken into account, both for girder webs and slab deck. In some cases, the accumulated fatigue damage considering simultaneous train crossings is almost the double of the one for isolated passages.

5 Conclusions

The methodology applied to a case study shows the relevance of simultaneous train crossings in the context of fatigue analyses. It was demonstrated that these events give rise to higher fatigue damage than isolated train passages in both tracks.

In the structure under analysis, it was shown that, in most locations, ULS verifications are more detrimental than fatigue checks. However, in some locations fatigue verifications are more determinant than ULS ones.

The influence of the crossing coordinate was also analysed. It was observed that, generally, simultaneous train crossings give rise to higher fatigue damage than isolated train passages. It was also clearly shown that the crossing coordinate is relevant for the fatigue analysis, because the calculated fatigue damage significantly depends on this coordinate. The proposed methodology takes this effect into account by assuming a uniform distribution of probability for the coordinate of the crossing point.