



Environmental and economical optimization of reinforced concrete overhang bridge slabs

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Abstract

The dimensioning of overhang slabs in bridge decks is usually based on simplified, thus conservative methods. The resulting over-dimensioned overhang bridge slabs can also affect the design of the girders. In this paper, an optimization procedure for the design of this structural element is presented. The aim is to minimize investment cost and global warming potential in the material production stage simultaneously while fulfilling all safety requirements. The design variables used in this study are the thicknesses of the overhang slab and the height of the edge beam. However, a complete detailed design of reinforcement is performed as well. Both a single-objective and a multi-objective formulation of the nonlinear problem are presented and handled with two well-known optimization algorithms: pattern search and genetic algorithm. The procedure is applied to a case study, which is a bridge in Sweden designed in 2013. One single solution minimizing both objective functions is found and leads to savings in investment cost and CO₂-equivalent emissions of 4.2% and 9.3%, respectively. The optimization procedure is then applied to slab free lengths between 1 and 3 m. The outcome is a graph showing the optimal slab thicknesses for each slab length to be used by designers in the early design stage.

Keywords Structural optimization · Overhang bridge slab · Edge beam · Global warming potential · Investment cost

1 Introduction

The typical cross section of a beam bridge deck can be divided into three main parts: one or more girders, one slab and two edge beams. The girders are typically made of steel or reinforced concrete (RC) and can have varying dimensions along the bridge to guarantee enough resistance in the longitudinal direction. A RC slab is placed on top of the girders or is cast together with them. In the case of concrete slabs which are wider than the girders, the two most external portions are uniquely constrained on one side each, therefore they are called overhang bridge slabs or cantilever bridge slabs. In this paper, overhang bridge slab is used to refer to

this component of the deck. Finally, the edge beams are connected to the external edges of this slab (Figure 1).

The dimensions of the overhang slab and the edge beams are usually kept constant along the bridge and chosen based on the engineer experience and rules of thumb. During the design, these elements are not considered to contribute much to the longitudinal resistance of the deck. However, they affect the deck self-weight. The reinforcement in these members is designed in order to resist the actions from groups of concentrated axle loads acting eccentrically on the slab. Such analysis can be performed on different levels of modelling sophistication (Pios et al. 2016). Simplified methods for calculating the design forces are normally used by engineers (Vegancones Muñoz 2016).

These methods permit a fast and simple analysis of the overhang slab, but they are too conservative (Pios et al. 2016 and Shu et al. 2019). Several studies have been performed to estimate the actual load bearing capacity of overhang slabs. In the work by Vaz Rodrigues et al. (2008), six specimens with thicknesses resembling those of actual overhang deck slabs of bridges have been subjected to concentrated loads to determine whether failure is

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