Simulation of Low-cycle Fatigue in Integral Abutment Piles

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Summary

Integral abutment bridges are bridges without any expansion joints, and their largest benefits are the lower construction- and maintenance costs. In order to build longer integral bridges it might be necessary to allow plastic hinges to be developed in the piles. Lateral thermal movements are the major reason to plastic deformations, and since temperature variations are cyclic it has to be proved that low-cycle fatigue will not occur. A simulation of the pile strain spectra should be able to take into account the strains caused by temperature variations and traffic loads. Such a model has been created from real temperature data and traffic loads measured by Bridge-Weigh-In-Motion technology. Monte Carlo simulations have been performed in order to simulate daily and annual temperature changes as well as the varying traffic loads. Piles strains have been calculated, and their fatigue effect has been evaluated.

Keywords: Integral abutments, jointless bridges, low cycle fatigue, Monte Carlo simulation.

1. Introduction

Integral abutment bridges are bridges without any expansion joints, and their largest benefits are the lower construction- and maintenance costs. This paper deals with a type of integral abutment shown in Fig. 1 with concrete end walls supported by steel piles. The top of the piles will experience lateral displacements as well as rotations, as a result of thermal movements, temperature gradients, and traffic loads. In order to build longer integral bridges, it is necessary to allow the development of plastic strains in the piles. Lateral thermal displacements are the major reason to plastic strains, and since the temperature variations are cyclic it must be proved that low-cycle fatigue failure will not occur.

A calculation method called the Equivalent Cantilever Method (see 2.2) has been used in order to create a model of the abutment-pile-soil interaction. The pile strains were expressed as a function of varying parameters such as effective bridge temperature, traffic load, and temperature gradient. The effective bridge temperature was simulated by using a mathematical temperature model which had been adapted to real temperature measurements. Daily maximum and minimum temperatures are generated for every single day during the bridge service lifetime, giving daily- as well as annual strain cycles. Traffic loads are simulated by using a traffic load model based on the gross weight distribution of the lorries that crosses the bridge. Data from measurements of traffic intensity and lorry gross weights, at two Swedish roads, have been used to create the traffic simulation model.

2. Low-cycle Fatigue Simulation Model

Thermal expansion and contraction of bridge decks are normally handled by expansion joints. In an integral abutment bridge the abutments will be pushed towards the backfill or pulled away, as a result of the bridge longitudinal expansion. Variations in bridge temperature will appear both daily and seasonally and lead to a cyclic loading procedure of the piles. The piles will deflect under the

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