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Abstract

A novel is presented methodology for probabilistic fatigue life prediction of welded joints in orthotropic bridge steel decks. Monitoring data were used to specify time-series model parameters for the main drivers of fatigue damage in such structures, namely pavement temperatures and heavy traffic intensities, which influence the stress range distributions at critical locations. Polynomial regression models were developed to quantify the relationship between fatigue loading, derived using S-N principles from strain measurements at welded joints, with pavement temperatures and heavy traffic counts. The different models were integrated within a fatigue reliability framework, in which the uncertainties arising from material properties and fatigue damage at failure were modelled via random variables. A Monte Carlo scheme was then deployed to predict S-N fatigue damage using the fatigue loading regression models and simulated time-series of heavy traffic and pavement temperatures. Thus, fatigue reliability profiles were generated, which account for different scenarios in terms of future changes in traffic and pavement temperature. The proposed methodology was illustrated considering actual monitoring outcomes from the Great Belt Bridge (Denmark) with reliability profiles developed for both 'baseline' and 'adverse' scenarios in the context of asset integrity management. The combined effect of higher temperature and heavy traffic levels was shown to result in considerable reductions in fatigue reliability, with a commonly used threshold being reached up to 40 years earlier compared to the baseline 'no change' scenario. However, this reduction was not uniform for all the fatigue details considered, emphasizing the importance of monitoring different locations, based on a thorough understanding of the fatigue behaviour of the orthotropic steel deck.

Keywords: Fatigue, steel bridges, orthotropic steel decks, Structural Health Monitoring, regression analysis, time-series models, structural reliability, asset management.