Extreme action effects in reinforced concrete bridges from monitoring

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Summary

The need to maximise the lifetime of existing road bridges necessitates clear and efficient tools for engineers to perform structural safety verifications based on monitored data. This study develops methodologies for ultimate limit safety (ULS) verification of reinforced concrete elements using directly measured action effects. The paper incorporates results from a prestressed concrete highway bridge in Switzerland equipped with a structural health monitoring (SHM) system. The design considerations for the monitoring regime are presented. Estimates of the extreme traffic action effects for a given return period are obtained from daily block maxima results using a generalised extreme value approach. A number of factors are found to have a significant effect on the observed results, most notably the duration of monitoring.

Keywords: Bridge loading, box-girder bridges, monitoring, structural safety verification

1. Introduction

Heavy road freight transport volumes have increased dramatically in Europe in recent decades. For example there was an average annual increase in road freight transport (tonnes-km) of 31.2% in the EU-27 zone between 1995 and 2009 [1] and the same trends are present in many other countries. Such figures are alarming at first sight. But what does this mean for today's existing road bridges regarding structural and fatigue safety? The real answer lies in the action effects arriving in the structural elements, rather than the heavy vehicles causing them. Safety verification techniques incorporating measured action effects (e.g. strain, displacement, crack opening, acceleration, etc) as opposed to updated load models applied in structural analyses can lead to less conservative decisions being taken, which could otherwise result in costly interventions. In addition to removing uncertainty regarding traffic loading, direct monitoring of the bridge reduces further uncertainties regarding dynamic and environmental effects, in particular temperature effects, as they are inherently included in the measurements.

This paper presents results from an on-going research study of a prestressed box-girder bridge in Switzerland to understand the long term performance of the deck slab under traffic and environmental effects with the aid of monitoring. The focus is on the upper flange or deck slab of the girder which experiences the localised effects of all heavy axles at an elemental level, in this case steel reinforcing bars (rebars). The paper firstly describes some of the considerations in developing the monitoring system. The work then examines the nature of extreme traffic loading events in a number of rebars within the deck slab which are instrumented with strain gauges. Codified verification approaches require characteristic load effect values for a certain return period for ULS verification so techniques for extrapolation of measured action effect data, in this case strain, for the estimation of extreme behaviour are tested and the influence of monitoring duration is studied.

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