Effect of Climate Change on the Deterioration of Steel Bridges

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Summary

Corrosion, which is associated with material loss over time, is a widespread cause of deterioration in metallic bridges. If left untreated, increasing corrosion damage may lead to reduced safety, premature in-service failures as well as altered structural behaviour and failure modes. The exposure conditions of the structure, which are determined by environmental and atmospheric parameters, i.e. relative humidity (RH), temperature (T), atmospheric pollution, etc, have a significant influence on the deterioration process due to corrosion. Hence, changes on the exposure conditions of the structure are likely to be responsible for changes on the deterioration process, including the rate of corrosion. In this paper, a reliability based procedure – using Monte Carlo simulation – is developed for the time-dependent risk assessment of corroding metallic bridges, considering explicitly the influence of environmental and atmospheric parameters. Several variables associated with the deterioration process (e.g. RH, T, SO_2, Cl) as well as the resistance of the bridge are treated as random using suitable distributions. The potential effect of climate change on bridge risk and reliability is quantified by considering changes in the statistical properties of these variables based on the emissions scenarios of UKCP09. A case study is presented in which a steel railway bridge is used to demonstrate the proposed procedure. Results are presented for the moment capacity limit state for a number of exposure scenarios. The results indicate that for the examined bridge type and location, climate change is shown to have a beneficial (but relatively small) effect on the long term reliability and risk. The parameters with highest adverse influence on deterioration performance of the examined bridge are shown to be the concentrations of SO_2 and airborne salinity.

Keywords: Steel corrosion; bridge reliability; moment capacity; climate change; atmospheric pollution; risk assessment.

1. Introduction

Corrosion, which is associated with time-dependent material loss, is a widespread cause of deterioration in metallic bridges. If left untreated, increasing corrosion damage may lead to reduced safety, premature in-service failures as well as altered structural behaviour and failure modes. The exposure conditions of the structure, which are determined by environmental and atmospheric parameters, i.e. relative humidity (RH), temperature (T), atmospheric pollution, etc, have a significant influence on the deterioration process due to corrosion. Hence, changes on the exposure conditions are likely to be responsible for changes on the deterioration process, including the rate of corrosion. Assessing the long-term performance of corroding bridges is associated with significant uncertainty due to variability of parameters related to bridge resistance (i.e. material and geometrical properties) as well as the deterioration process itself (i.e. environmental and atmospheric variables). Time-dependent reliability analysis has been widely proposed for the rational assessment of deteriorating structures due to its ability to consider the variability of the different parameters which affect structural performance. Furthermore, risk assessment, which considers the consequences of bridge failure, is a useful tool within a decisions-making/planning framework. A number of previous studies exist on the long-term reliability of corroding

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steel/composite highway bridges, e.g. [1-3]. These studies, however, considered indirectly the influence of exposure conditions on the rate of corrosion and the influence of the different exposure parameters on the rate of corrosion was not examined. Furthermore, the potential effects of altered exposure conditions of the structure due to climate change were not examined in these studies. In this paper, a reliability based procedure – using Monte Carlo simulation – is developed for the time-dependent risk assessment of corroding metallic bridges, considering explicitly the influence of environmental and atmospheric parameters. Several variables associated with the deterioration process (e.g. RH, T, SO_2, Cl) as well as the resistance of the bridge are treated as random suitable distributions. The potential effect of climate change on bridge risk and reliability is quantified by considering changes in the statistical properties of these variables based on the emissions scenarios of UKCP09. A case study is presented in which a steel railway bridge is used to demonstrate the proposed procedure. Results are presented for the moment capacity limit state for a number of exposure scenarios.

2. Findings & conclusions

In this paper, a procedure is presented for the risk assessment of corroding steel bridges, considering explicitly the influence of exposure conditions on the rate of corrosion. A case study is presented in which the moment capacity of a typical half-through railway bridge is examined considering a number of exposure scenarios. The following conclusions can be made based on the results presented in this paper:

1) For the assumed location of the structure, climate change is likely to cause a decrease of relative humidity accompanied by a temperature increase. The degree of these changes, however, depends on the assumed emissions scenario in UKCP.

2) The results indicate that climate change - in terms of relative humidity (RH) and temperature (T) - has a beneficial effect on the risk and reliability of the bridge. The high emissions scenario, which is associated with the highest increase and decrease of T and RH, respectively, was found to predict the lowest probabilities of failure and corresponding risk for the bridge, compared to the low emissions scenario. In all cases, however, the effect of changing T and RH is relatively small.

3) The results indicate that the atmospheric parameters (i.e. SO_2 and salinity) have a much higher influence on the risk and reliability of the bridge examined, compared to T and RH.

3. References

[1] CZARNECKI A.A., and NOWAKM A.S., “Time-variant reliability profiles for steel girder bridges”, *Structural Safety*, Vol. 30, 2008, pp. 49-64.

[2] SHARIFI Y., and PAIL J.K., “Ultimate strength reliability analysis of corroded steel-box girder bridges”, *Thin-Walled Structures*, Vol. 49, 2011, pp. 157-166.

[3] DECO A., and FRANGOPOL D.M., “Risk assessment of highway bridges under multiple hazards”, *Journal of Risk Research*, Vol. 14, pp.1-33.