Whole-Life Reliability Assessment of Deteriorating RC Structures

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Abstract

If a client has a large number of structures that are deteriorating at different rates and with different structural properties, then a method of prioritising the repair and strengthening works is required to ensure their overall structural integrity is maintained. The work described is one part of an extensive research programme, undertaken by Maunsell, to develop procedures for the risk-based management of a large number of deteriorating structures.

Maunsell have developed a methodology for predicting the residual strength of deteriorating reinforced concrete beams with time using both code-based (deterministic) and reliability based (probabilistic) methods of assessment . If an acceptable safe level of strength is defined, then the strength-time profile can be used to determine the latest time that repairs can be carried out on the structures without compromising safety.

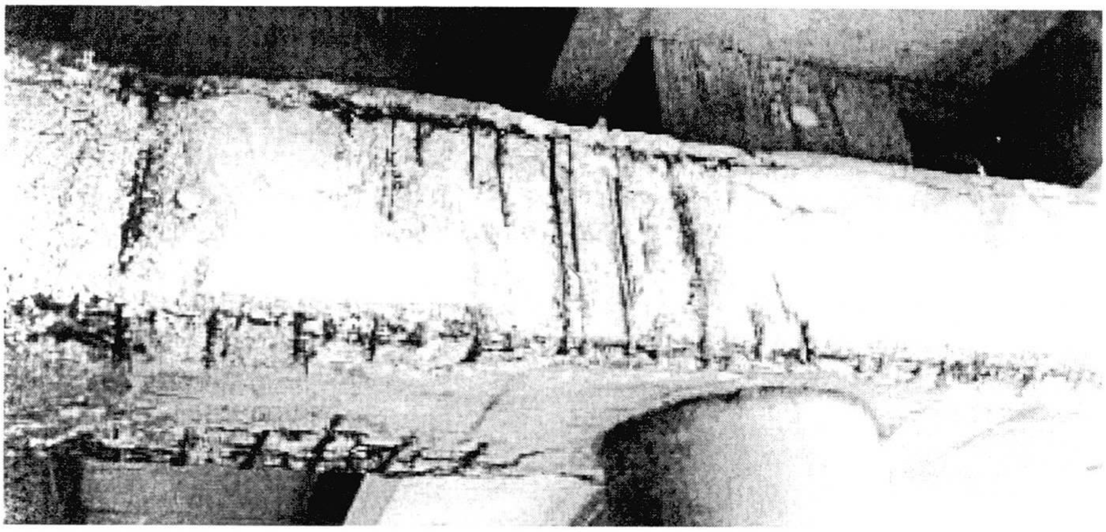

Fig. 1 An Example of a Deteriorated Crossbeam

The principal cause of deterioration of reinforced concrete highway structures in the United Kingdom is that of chloride induced corrosion of the reinforcement. An example of a deteriorated beam from the present work is shown in Fig. 1. In this specific case the source of chloride ions was from salt laden carriageway run-off leaking through defective deck joints onto the substructures.

A deterioration model has been developed to predict the time of arrival of chlorides at the beam surface, the time of corrosion initiation, the local rate of corrosion and whether the corrosion process has advanced sufficiently to cause delamination of the cover concrete. Corrosion is a stochastic process, therefore, the variability associated with each stage in the deterioration process and site measurement techniques were considered.

Due to the low sensitivity of the values used in the corrosion initiation process, combined with a lack of suitable data on corrosion thresholds, these values were treated as deterministic, although it was recognised that there may be significant variability in these values. The variability in the predicted corrosion rates and the half-cell monitoring technique were assessed. The variability found in the prediction of delamination was also assessed and found to be due primarily to the variability associated with the corrosion rate.

All the load components were considered as random variables. The probability distributions and statistical parameters were obtained from available literature. The deteriorated beam was assessed for: bending moment; shear force; and combined moment and shear. The calculation of moment resistance and shear capacity was based on existing code guidance. The section shear resistance was considered to be governed by the shear link contribution, the tension reinforcement via dowel action, and the aggregate interlock of the concrete. The reduction in capacity due to delamination of the tension reinforcement was taken into account by using the effective residual area of corroded steel bars. The resistance model for the combined moment and shear was based on reducing the bond strength between the steel and the concrete to incorporate concrete delamination. The model assumes that the bars may fail due to either insufficient bond strength or yielding as a result of reduced cross-sectional area.

A reinforced concrete beam, which supports a bridge deck that carries three lanes of traffic in each direction, was first analysed deterministically including predicted deterioration to identify the critical sections along the span. A critical section was defined as the section with the lowest capacity ratio (the ratio of strength to applied load). A capacity ratio of less than 1.0 implies that the margin of safety is less than that required by the code. The results of deterministic analysis indicated that the moment resistance was not at all critical for the beam considered.

The critical sections were then analysed probabilistically using First Order Reliability Method to determine the reliability profiles for shear and bond failure modes. An acceptable level of reliability was defined and the latest time at which repairs must be undertaken, such that structural integrity is not compromised, was determined.

The authors have demonstrated, using a sample beam, that reliability analysis is a powerful method of evaluating the long-term structural performance of deteriorating structures. These techniques have been used successfully in the development of a risk-based maintenance strategy to prioritise the repairs to the substructures on 21 kilometres of motorway viaducts in the UK.