Assessment of the Suspension Cables of the Severn Bridge, UK

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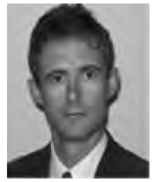

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Summary

The Severn Bridge in the United Kingdom was completed in 1966 and was the first suspension bridge to adopt a streamlined box girder deck that reduced the dead weight and improved aerodynamic performance. The 988m (3249 ft) span bridge crosses the estuary of the River Severn and is an important asset within the UK's highway network. The UK's Highways Agency, through the concessionaire Severn River Crossing plc, commissioned a programme of internal intrusive examination of the main suspension cables of the Severn Bridge in 2006 with Faber-Maunsell/Weidlinger acting as consultant for the inspection. The information obtained during these investigations provided the basic data for use in a formal strength assessment of the suspension cables that has been undertaken by Mott MacDonald. Analytical techniques developed over the past two years have enabled the adoption of limit state principles for the assessment in line with UK practice. In addition deterioration modelling has been developed to improve understanding of the current condition of the cables and also to assist in the future management of the bridge.

Keywords: Suspension bridge; suspension cables; limit state assessment; deterioration modelling.

1. Introduction

Fig. 1: The Severn Bridge

Modern suspension bridges with cables constructed by aerial spinning were introduced relatively late in the UK with the Forth and Severn Bridges being constructed in the 1960s. The cables of several older suspension bridges in the US have suffered internal corrosion. Hence, precautionary intrusive inspections have recently been undertaken on the Severn Bridge. This paper describes the assessment that has been undertaken at the Severn Bridge.

Whilst there is considerable experience of assessing suspension cables in the US it is only recently in 2004 that the Transport Research Board published their guidelines for inspection and strength evaluation of parallel wire suspension cables. The strength evaluation guidelines provide comprehensive advice but are not directly applicable to the limit state assessment principles adopted in the UK.

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2. Assessment of the Strength of the Suspension Cables

Tests confirmed that as the suspension cable wire deteriorates the Ultimate Tensile Strength (UTS) and ductility reduce whereas the Proof Stress remains largely unaffected. Hence, assessment of the Severn Bridge suspension cables has been based on the UTS of the wire. The suspension cable wire as-manufactured had a characteristic tensile strength and 0.2% proof stress values of 1585 N/mm^2 and 1255 N/mm^2 respectively. The assessment of the tensile strength of the suspension cable, which comprises 8322 No. individual 5mm diameter wires of varying states of deterioration, is problematic because the mechanism of failure of a cable under load is a complex process with the individual wires interacting with one another in sharing load and deformation. Further uncertainty arises from the variability in strength and ductility-limit of the individual wires.

2.1 Strength determination according to NCHRP Report 534

The NCHRP Report 534 identifies three load models that can be applied for the evaluation of cable strength. Where a significant number of reduced ductility wires with 'crack like' defects are found in the cable, the brittle wire model is directed as the most the appropriate model. Intrusive inspections had shown a significant level of deterioration within the Severn Bridge's cables with wire sample testing confirming reduced tensile strengths and ductility of the most severely affected wires. The tensile strengths of the cables calculated by the method set out in the NCHRP Report 534 showed significant strength reductions.

2.2 Strength determination for Limit State assessment

Limit state assessment criteria were developed for the Severn Bridge with defined confidence limits consistent with UK standards. The two main issues that required considerable statistical evaluation were the determination of the ultimate limit state cable capacities at the positions where the cable had been inspected and the extrapolation of this assessment to the remaining parts of the cable that had not been inspected. To achieve this, the wire condition data and associated tensile properties both with a 95% confidence limit were derived from the inspection and test data for defined lengths of the cables and used in conjunction with the brittle wire model to determine the tensile strengths of the cable. This value was compared to the ultimate limit state forces generated in the cable. It has therefore been possible to assess the suspension cables to limit state principles over their full length; thereby taking account of the statistical variation of both the various loadings contributing to the cable forces and the variable strength of the cables over their length.

3. Future Condition and Strength of the Suspension Cables

The development of an analytical tool for the modelling of the cable deterioration is crucially important to the ongoing management of the Severn Bridge. This is well advanced and predictions are being evaluated. This tool will be used to predict the future strength of the cable and expected condition of the cable at the next intrusive inspection taking into account the effects of the dehumidification system being installed on the bridge.

4. Conclusions

The UK and European limit state design philosophy provides a rational means of expressing the safety margins provided against defined structural states. An Overall Factor of Safety can be derived, for comparison purposes..

Methods have been developed to enable the full length of the cables to be assessed in their current condition, to limit state principles based on a 95% confidence limit consistent with UK limit state principles. Deterioration modelling has been developed to enable predictions of future cable condition and strength to be made, including the mitigating affects of a dehumidification system that is being installed on the cables. This tool will be an important asset in the management of the bridge.

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