Probabilistic approach to fatigue assessment for stay cables

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Summary

Many parameters used for predicting times to failure of structure due to fatigue are uncertain and their variations have a big influence on the real lifetime. This paper focus on a global methodology to take main sources of variability in fatigue prediction for stay cables into account. The first step of this methodology is to model the variability of each parameter. Loading is one of the most important sources of variability. Another important source of variability is the strength of the stay cable. Finally, the reliability is assessed using Monte Carlo simulations.

Keywords: reliability; fatigue; cable; bridge; corrosion; traffic load.

1. Methodology

Stay cables are important structural components of cable stayed bridge. These cables are subjected to a combined action of fatigue load and corrosion. These two processes must be taken into account to assess reliability. A cable consists of many wires and must be modeled as a parallel system. A global methodology is needed to assess reliability.

The first step is to determine loads induce by the traffic flow on the bridge. The quantification of the traffic load in both normal and extreme conditions is a crucial part of the structural analysis of bridges. The traffic load is computed using WIM data for measured traffic flow and a finite element model to determine the load in the cable. The distribution of load amplitude is presented in Figure 1. The effect of extreme load is also studied in this work. The 100 largest peak loads are shown in Figure 2.

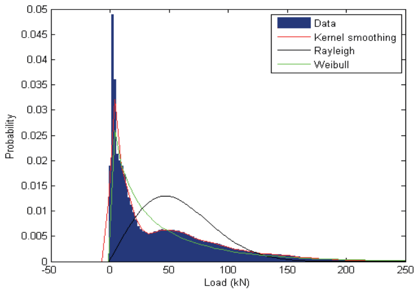

Figure 1: Distribution of load amplitude

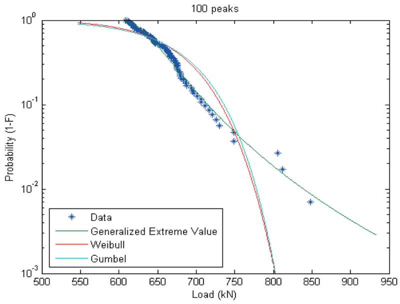

Figure 2: Distribution of peaks load

The second step is to assess the cable strength. The influences of the number of wires, the cable length and the corrosion process must be taken into account. For a cable, there are two common types of corrosion, uniform corrosion that is presumed to be uniform on a wide zone and pitting corrosion that may be locally concentrated. A corrosion depth is computed for each wire section and each time step. An example of corrosion depth for a five wire cable is presented in Figure 3. The fatigue behavior of the high strength steel is not deterministic. If different fatigue tests are performed at the same stress level, number of cycles to failure would be different for each test. This

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strength variability has to be considered to assess an accurate life prediction. A probabilistic bilinear S-N curve is used in this study, see Figure 4.
The third step is to combined load and strength previously defined in order to obtain the cable reliability. The reliability is assessed using Monte Carlo simulation.

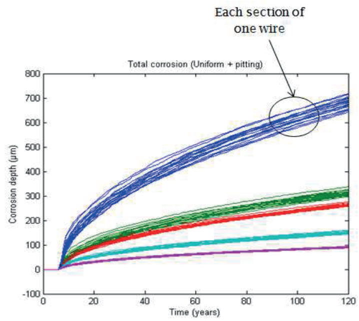

Figure 3: Evolution of corrosion depth

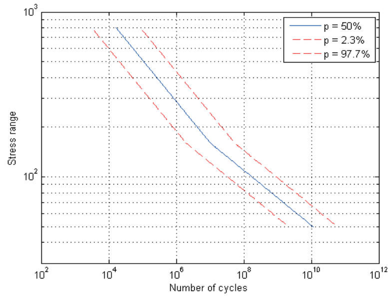

Figure 4: Probabilistic bilinear S-N curve

2. Results

The times to failure distribution is given in Figure 5. This distribution is fitted by the Log-normal and the Weibull distributions using the maximum likelihood method. Any of them fit very well. The cumulative reliability index evolution is given in Figure 6.

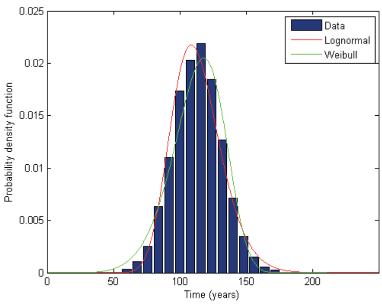

Figure 5: Time to failure distribution

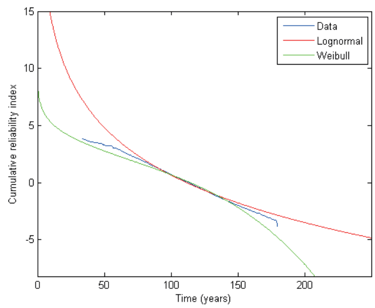

Figure 6: Cumulative reliability index

3. Conclusions

In this paper, a global methodology to assess reliability for cables of cable stayed bridges is presented. First, the traffic load in cables has been determined from measurements and using a finite element model of the bridge. Then, the cable strength is defined taking into account the effect of corrosion, the number and the length of wires and using a probabilistic bilinear S-N curve. The reliability assessment is performed using Monte Carlo simulation.
It is possible to assess the reliability of a cable with this methodology, but all assumptions must be verified by means of test like for the S-N curve or the corrosion process.

4. Acknowledgements

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