Probabilistic Modeling and Risk Assessment of Cable Icing

This dissertation addresses the issues related to icing of structures with special emphasis on bridge cables. Cable supported bridges in cold climate suffers for ice accreting on the cables, this poses three different undesirable situations. Firstly the changed shape of the cable due to ice accretion can lead to large amplitude vibrations, which might reduce the fatigue life of the cables significantly. Secondly ice shedding from the cables pose a safety issue for the users of the bridge, which leads to the third issue. The third issue is regarding the consequences of the ice shedding from the bridge cables, which can cause socioeconomically expensive closures of bridges and traffic disruptions.

The objective is to develop a simple model that can be used to assess the occurrence probability of ice accretion on bridge cables from readily available meteorological variables. This model is used both in relation to ice induced vibrations to assess the fatigue life and in relation to decision making in risk management of bridges exposed to icing.

First a basic and preliminary framework for the assessment of cumulative bridge cable fatigue damage due to wind-induced vibrations is presented. The damage assessment is performed using a probabilistic approach, based on a Bayesian Probabilistic Network, where the wind environment, traffic loading, bridge specific parameters and the mechanisms that induce significant cable vibrations are the main input parameters. It is outlined how information with respect to meteorological and site-specific conditions can be utilized to assess the probability of occurrence of ice induced vibrations. Furthermore it is shown how the fatigue stress in the cable bending mode is evaluated together with the corresponding fatigue lifetime.

Secondly the developed preliminary framework is modified for assessing the probability of occurrence of in-cloud and precipitation icing and its duration. Different probabilistic models are utilized for the representation of the meteorological variables and their appropriateness is evaluated both through goodness-of-fit tests and by means of qualitative considerations. The Bayesian Probabilistic Network model used for the estimation of the occurrence and duration probabilities is studied and it is found to be robust with respect to changes in the choice of distribution types used to model the meteorological variables which are influencing the two icing mechanisms and their duration. The model is found to be more sensitive to changes in the discretization levels of the input variables.

Thirdly the developed operational probabilistic framework for the assessment of the expected number of occurrences of ice/snow accretion on bridge cables is used as a tool to support engineering decision making and risk management of cable structures with respect to icing events. These events may lead to human life safety issues, functional disruptions and associated economic consequences. Here emphasis is placed on the value of early warning of icing events, which is based on the monitoring of environmental conditions and short term forecasting. Decision problems in risk management can be supported by quantifying the value of structural health monitoring (SHM). The approach for the assessment of the value of SHM takes basis in structural risk assessments together with the Bayesian pre-posterior decision analysis and builds upon the quantification of Value of Information (VoI). The consequences are evaluated for different outputs of the probabilistic model to provide a basis for prioritizing risk management decision alternatives.

Each step of the developed framework is illustrated with a case study of either the Great Belt Bridge or the Øresund Bridge.