This dissertation investigates the bending fatigue response of high-strength steel monostrands and multistrand stay cables to cyclic transverse deformations. Increasing bridge stock numbers and a push for longer cable-supported span lengths have led to an increased number of reported incidents of damage and replacement of bridge stay cables due to wind and traffic-induced fatigue. The understanding of fatigue mechanisms in most steel structures is well established. However, in the case of cables composed of steel strands, many important aspects related with bending fatigue remain to be clarified. The thesis starts with a literature review of the state-of-the-art in the fields of stay cable fatigue testing and cable fatigue resistance. The study helped to systemize the understanding of the fatigue characteristics of bridge cables subjected to cyclic transverse displacements, failure mechanisms associated with variable loading, and different testing procedures.

As most of the contemporary stay cables are comprised of a number of individual high-strength steel monostrands, the research study started with an extensive experimental work on the fatigue response of a single monostrand to cyclic flexural loading. Initial analysis of the deformations showed that, depending on the anchorage type, the bending fatigue behavior of the monostrand may be controlled either by local bending deformations or by the interwire movement (fretting) of the helically wound wires. The experimental study involved a detailed description of the observed failure mechanisms. For this purpose, a digital image correlation (DIC) technique was employed as an efficient tool for quantifying the interwire movement and measurement of individual wire strains along the length of the strand. The novel application of the DIC technique for the measurement of local cable deformations provided relevant data on the internal state of displacement of the strand specimen under axial and transverse loading and led to a more in-depth understanding of the underlying fatigue mechanisms. The experimental data show that the interwire movement due to transverse deformations is the highest at the neutral axis of the monostrand. Moreover, the results indicate that the midspan and the anchorage of the monostrand are the two locations where the combination of tensile strains and the interwire movement is the most unfavorable. It was also shown that, in the absence of a guide, the high localized curvatures due to bending may cause yielding of the monostrand. From the conducted series of dynamic tests, the fretting and the localized bending fatigue spectra have been derived for the estimation of the monostrand fatigue life. Further analysis of mechanical aspects of monostrand wires under bending load provided information on the failure mode-dependent cross sectional stress distribution and aimed to explain differences in the observed fatigue models.

Finally, once the bending fatigue behavior of a single monostrand was described in detail, the experimental study focused on the response of a full-scale multistrand stay cable to transverse deformations. The experimental investigation performed on the parallel monostrand stay cable had three objectives. Firstly, a correlation between the bending fatigue behavior of the single monostrand and that of the multistrand stay cable was established through full-scale testing and data obtained from the DIC measurement. Secondly, it was studied whether the fatigue life of a multistrand cable can be predicted based on the fatigue spectra derived from the tests on single monostrands. Thirdly, the relationship between the transversal stiffness and the tensile force variations (hysteresis) of a monostrand and that of a multistrand specimen was investigated. The results from the full-scale tests led to a better understanding of the structural response of a modern stay cable to cyclic transverse loading and resulted in significant insight in the flexural behavior of a multistrand assembly in critical locations with respect to bending fatigue, i.e. guide deviator and exit of the socket. The thesis ends with an example of how the outcome of the research work can be used in the estimation of the life-cycle performance of a cable stayed bridge. Characterization of a bridge monitoring data is shown and a generic method for the analysis of a cable fatigue in cable supported bridge structure is proposed.

With this research, one of the most basic oversights in the lifetime assessment of cablesupported structures, namely the bending fatigue resistance of parallel monostrand stay cables, is addressed.