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Advanced Composite Stay Cables

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Summary

The paper summarizes the ongoing research at the University of California in San Diego about the performance of composite stay cables available on the world market. Research emphasis is placed on investigating the long term behavior of such cable systems, in particular of their anchorages. Five cable systems offered on the world market were selected for the testing; three were composed of unidirectional carbon and two of aramid fiber reinforced polymer. The selected cable systems were subjected to short- and long-term testing.

Introduction

The infrastructure industry is in the search for more durable materials for key structural elements. Advanced composite materials like carbon or aramid fiber reinforced plastics stand out for their light weight, excellent performance, durability and chemical resistance and seem to be a good addition to conventional construction materials. Stay cables made of these advanced composites are promising, and an increasing number of products is appearing on the world market. However, a lot of investigation, in particular of the long term behavior, has to be done to gain the necessary confidence into the structural reliability of these new cable systems. In a research program at the University of California in San Diego, available cable systems from the world market were subject to long and short term tests to investigate the behavior of such systems. The results provide short term characteristics and lead to an estimate of their long term behavior. The program is not completed yet. Initial and preliminary results and trends are discussed in the following chapters.

Cable systems

Scanning the world market for commercially available cable systems, most of the systems are found in Japan and Europe. Only a few companies offer cables with appropriate anchorage systems which could fulfill the requirements for stay cables.

Two different types of anchorages can be identified. The first one has tendons potted in polymer matrix and the load is introduced by bond forces between the matrix and the composite tendons. The second type is similar to conventional high strength steel tendon anchorages and anchors the tendons mechanically by wedges and the force is introduced by friction. There are also systems using a combination of mechanical and bonded anchors.

Short Term Test

Three specimen of each of the cable systems were subject to short term load tests. The procedure of the test was similar to those recommended by the Post-Tensioning Institute (PTI) and the Federation Internationale de la Precontrainte (FIP) for steel tendons. However, the recommendations were adjusted for composite cables.

Even though only three specimen per tendon type were tested, the repeatability of the test results was very satisfactory. Cable systems which failed due to slippage in the anchorage had a deviation of 8 % of the average failure load and the other systems only 4 %. The deviation is hereby defined as the difference between the highest and smallest failure load. However, the tested failure load was sometimes significantly higher than the manufacturers specified guaranteed breaking load.

Performance of the bond anchorages

Strain gages at the outer shell of the bond anchors allowed the estimation of the tendon force transfer within the anchorages. The bond stresses between the strand and the matrix were roughly estimated by evaluating the strains at the surface of the sleeve. During cyclic loading, high bond stresses of up to 20 MPa were developed. With each cycle, the peak stress was moving slightly towards the back of the anchorage, and the bond stress concentration at the front of the anchorage was decreasing. During loading to failure, the peak of the bond stress distribution was moving to the back of the anchorage, developing up to 44 MPa of maximum average bond stress before tendon failure. This observation was independent of the failure mode in the cable systems.

Long Term Test

Two specimens of each of the selected cable systems were mounted in separate steel frames for long time monitoring. The tendons were tensioned and then anchored at their specified maximum service load of 65 % and 55 % of their nominal breaking load for carbon and aramid based systems, respectively. This was the same load level as of the upper load during cyclic loading in the previous tests. After about 1000 hours, they were restressed to the service load. The observed initial relaxation is generally high. The bond anchors reveal a similar behavior as during cyclic loading. The peak average bond stresses tend to move more to the back of the anchors.

Conclusions

All cable systems showed a very good performance during the short term tests with a high repeatability. The behavior of the cable systems is different for the two load cases in short term and long term tests. Therefore, the long term behavior cannot be predicted satisfactorily by short term testing. This is true in particular for the bond anchor systems, because of the viscous behavior of the matrix. As a third test for the estimation of the long term behavior of composite cables it is recommended to perform accelerated aging tests of the anchors under sustained load.