Project Summary

Texas Department of Transportation

0-1401: Determination of Fatigue Damage in Cable Stays

Background

Large-amplitude vibrations have been observed on numerous cable-stayed bridges around the world. Both long-span, cable-stayed bridges in Texas – the Veterans Memorial Bridge and the Fred Hartman Bridge – have experienced large-amplitude, wind and rain-induced vibrations, as well as vibrations caused by vortex shedding, deck vibrations, and other sources. A major concern resulting from these vibrations is possible fatigue damage on the parallel strands in the cables and the safety of the bridges.

What the Researchers Did

A series of large-scale bending fatigue tests was performed in the laboratory. The specimen geometry replicated the smallest diameter stay cables used in the Fred Hartman Bridge. The anchorage geometry, tension ring configuration, and the type of wedges matched those in the prototype cables. The influence of grouting, construction defects (grout voids and inadvertently crossed strands), displacement amplitude, and stay geometry on the bending fatigue response of the stays was investigated. Acoustic sensors were attached to the test specimens to determine if they can be used to detect and locate wire breaks during the fatigue tests.

What They Found

The results of this study show that the stays are susceptible to fatigue damage from the bending of the cable when they are excited by transverse vibrations. The fatigue failures of the wires in the prestressing strand were localized. The majority of the failures occurred at the location of the attachment of the specimen to the loading actuator. The remaining failures occurred near the anchorage. The maximum bending stress in the strands occurs at these locations. No failures occurred along the free length of the stay, even when the strands were intentionally crossed. The fatigue failures occur one wire at a time. The interval between individual wire failures is initially large and decreases as the number of wire fractures increases. There is considerable fatigue life after the first wire fracture and before significant loss of stay strength.

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The transverse stiffness and natural frequencies of the specimens were not reliable indicators of the number of wire fractures. Within a short distance from a wire fracture, the fractured wires become fully active due to the helical form of the strand and the bond with the grout.

The locations of wire breaks detected by the acoustic sensors were compared with the actual locations determined during an autopsy of the specimen at the conclusion of the fatigue test. The agreement between the number and location of the wire breaks predicted by the acoustic systems and the actual breaks was very good. Based upon the results of the laboratory evaluation of the acoustic monitoring system, the system was installed to monitor all the stays in both the Veterans Memorial Bridge and the Fred Hartman Bridge.

What This Means

The fatigue failures can occur at the anchorages or at locations where the lateral movement of the stay is restrained. In the bridge, failures could also occur at the damper attachments to the stay or at the cable restrainer attachment points since the cable deformation is constrained at these locations. The currently employed vibration mitigation system of cable restrainers and dampers should be maintained to reduce the accumulation of fatigue damage in the stays. These vibration mitigation methods along with the continued acoustic monitoring of the stays will increase the life of the stays and ensure the safety of the bridge

The accuracy of the acoustic system to determine the location of the wire break is approximately 3 feet. Any wire breaks within 3 feet of each other should be considered as occurring at the same location. The fracture of the wires is a slow process occurring one wire at a time. Many wire fractures can be tolerated before there is a significant loss in stay strength due to the large number of wires in the stay. The number of wire breaks at a location should not exceed 10% of the total number of wires in the stay before that area is examined. The sheathing and grout should be removed to expose the strand and the number of wire breaks verified. The cause of the failures should also be ascertained so remedial action can be taken to prevent further wire failures.

The axial and bending stiffness of the cables is not affected until a large percentage of the wires has fractured in the stay. Monitoring the cable health by measuring its stiffness by a pluck test or other means is not a viable method to determine the extent of fatigue damage in the stay.

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