Experimental Study of High Temperature Performance of Steel Suspension Bridge Wires

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1 Abstract

The performance of suspension bridges exposed to fire hazards is severely under-studied – so much so that no experimental data exists to quantify the safety of a suspension bridge during or after a major fire event. Bridge performance and safety rely on the integrity of the main cable and its constituent high-strength steel wires. Due to the current lack of experimental high temperature data for wires, the theoretical models use properties and coefficients from data for other types of structural steel. No other structural steel undergoes the amount of cold-working that bridge wire does, and plastic strains from cold-working can be relieved at high temperature, drastically weakening the steel. As such, this work determines the elastic modulus, ultimate strength, and general thermo-mechanical profile of the high-strength steel wires in a range of elevated temperature environments. Specifically, these tests are conducted on a bundle of 61-wires (transient), and at the single wire level (steady-state) at a temperature range of approximately 20-700°C. The test results show an alarmingly high reduction in the elastic modulus and ultimate strength with increased temperature. The degradation shown by experiments is higher than predicted by current theoretical models, indicating that use of high-temperature properties of other types of steel is not sufficient. The test results also show scaling agreement between the single wire and the 61-wire bundle, implying that a full material work up at the single-wire level will accurately inform the failure characterization of the full cable.

Keywords: Suspension bridge, cable, strand, wire, high temperature, thermo-mechanical

2 Introduction

Many of the suspension bridges currently in service are well past their design life, giving rise to a surge in interest in the safety of these structures. Still, fire resistance is a severely under-studied aspect of the safety of these bridges. The life of the bridge relies completely on the strength of the main cables; if a main cable fails, the bridge fails. Given the reduction in main cable safety factor due to corrosion and other damaging effects, and the volume of highly flammable materials transported across suspension bridges every day, analysis of the susceptibility of old bridges to fire threats is paramount to a holistic safety assessment.

Corrosion damage of main cables was examined experimentally by Sloane et al., who found that the interior of the cable is highly susceptible to moisture intrusion and therefore corrosion damage [1]. Though clamping at cable bands can cause damaged wires to return to service in other parts of the cable, work by Brügger et al. in 2017 [2] showed

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