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Evaluation of Failed Nipigon River Bridge West Abutment Bolts

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National Research Council Canada
Conseil national de recherches Canada

Canada

1. Executive Summary

The new Nipigon River Bridge was put into service on November 29, 2015. On January 10, 2016, the connection between the bridge girder and the northwest bearing failed, causing that corner of the bridge to separate from the bearing shoeplate and rise 600 mm into the air. Examination showed that all forty of the bolts holding the bridge girder to the bearing shoeplate had fractured. The Ministry of Transportation of Ontario (MTO) subsequently requested the National Research Council Canada (NRC) and the University of Western Ontario (UWO) to carry out independent investigations of the bolts' performance and the mode of their failure.

MTO delivered 14 failed bolts from the northwest bearing shoeplate and 10 intact bolts from the west-central bearing shoeplate to NRC for testing and analysis. Tests included determination of the elemental composition of the bolts by glow discharge mass spectrometry and wavelength dispersive x-ray fluorescence mass spectrometry; tensile tests on bolt coupons and intact bolts; Charpy v-notch impact tests for fracture toughness; Rockwell C hardness; and Vicker's microhardness. The microstructure of the bolts was examined using optical and scanning electron microscopy (OM and SEM), while the fracture surfaces of the failed bolts were examined visually and using SEM.

The analysis of the bolts showed that they met the chemical composition and mechanical performance requirements found in the relevant standard, ASTM A490. Additional tests to examine non-standard specified properties such as low temperature performance of the steel also showed results that would be expected of steel made to ASTM A490 specifications. Cracks were found in the crests and flanks of both the intact and failed bolts, but no evidence was found that those cracks contributed to the bolt failure. The protective coating specified for the bolts, washers and nuts was found to be present. Neither bolt composition, bolt mechanical performance nor the coating appeared to be responsible for the bolt failures.

Analysis of the fracture surfaces showed that the bolts had failed due to low-cycle fatigue, with between 50 and 140 cycles occurring between crack initiation and final fracture. Low-cycle fatigue occurs when plastic behaviour predominates during fatigue and is controlled by changing strain levels, rather than the changing stress levels of the more common high-cycle fatigue. A comparison to published data for steels with similar composition to the failed bolts suggested that the cyclic range of strain experienced by the bolts was at least 2%, indicating that the bolts undergone high cyclic loads that were responsible for their failure.

Recommendations were provided for next stages in the failure investigation, as well safety and performance of bolting on the bridge and obtaining information on critical A325 and A490 bolt properties that is currently unavailable.