

Structural Evaluation and Maintenance of Brooks Aqueduct, a Canadian Historic Site

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ABSTRACT

Brooks Aqueduct is a national historic site built in 1914 in Alberta, Canada, being one of the largest and most sophisticated reinforced concrete aqueducts in the world. The large elevated flume was built by the Canadian Pacific Railway (CPR) to irrigate 50,000 hectares of land in the southern parts of Alberta near the city of Brooks. Therefore, the aqueduct had a significant effect on the economy of that region for a long time. The concrete in the aqueduct was subject to significant damage and deterioration from the early stages of operation. The damage was mostly because of the poor quality of the concrete with respect to durability issues, poor design and lack of proper workmanship. These deficiencies have to be recognized in the context of the knowledge of reinforced concrete at the time of construction. While the aqueduct has deteriorated due to some obvious environmental factors there is also some cracking that cannot be obviously attributed to material deterioration. To address the problems and issues of the Aqueduct, and to maintain the structure in a safe condition, several assessments have been performed on the structure, and remediation measures implemented on the more critical locations. Results of field and laboratory tests (such as concrete cover measurements, carbonation depths, corrosion potentials, areas of delamination, concrete and rebar strength, air void analysis and petrographic analysis) were used to develop a 3-D finite element model of the aqueduct using Abaqus software. Both the concrete and steel reinforcement were modeled in the software and the results of the model were validated by comparing to values derived from other theoretical approaches at some check points. The main objective of the analyses was to evaluate the structural condition of the aqueduct and determine possible causes of overstress and the unexplained damage observed at certain locations in the structure.

The finite element model was subjected to several possible load and settlement conditions and the amount of possible overstress, damage and deterioration under each case was obtained. No structural reasons were found for some of the cracking. Thus, based on the results of the analyses, the most probable causes of damage and deterioration in Brooks Aqueduct were thought to be as follows:

- Severe freeze-thaw damage, concrete carbonation and corrosion of the steel reinforcement
- Poor quality of concrete mainly because of the lack of knowledge about the effect of factors such as water-cement ratio, aggregate selection, curing, vibration, etc. on the quality and performance of the concrete at the time of construction of Aqueduct.
- Poor workmanship in the placing of rebars and concrete.
- Lack of proper understanding of the behavior of the concrete of the flume in compression and detailing of the rebars in different areas (adequate splice length, concrete cover, etc.)
- Lack of appropriate design of expansion joints to prevent water infiltration.

Ways to prioritize and perform the strengthening and maintenance required to conserve the Aqueduct were suggested based on this assessment.