Load Rating Upgrade of Trout Brook Bridge Utilizing Fiber-Reinforced Polymer (FRP) Composites

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INTRODUCTION

The transportation or logistic industry is constantly looking to utilize existing routes that were not originally designed to support large commercial loads currently being carried. In order to support the full legal loads on these roads, the bridge infrastructure must be upgraded to provide sufficient capacities to support the structural demands being introduced. In October 2011, a recent bridge retrofit was completed on New Brunswick's Route 109 in Victoria County to allow truckers to haul heavier loads from Plaster Rock to Perth-Andover. In doing so, time consuming detour routes are no longer necessary as access to western New Brunswick and the United States has been provided over these upgraded structures.

The Trout Brook Bridge was originally constructed in the 1960s and consists of four reinforced concrete girders spanning twenty-one meters over a stream. In a recent analysis performed by the New Brunswick Department of Transportation, the girders were found to have inadequate shear capacity to support the required 50,000 kilogram truck load limit. The outer 5 meters of each girder was strengthened with a externally bonded unidirectional glass fiberwrap system (GFRP) to provide the required additional shear strength while minimizing the total project cost to approximately $80,000.

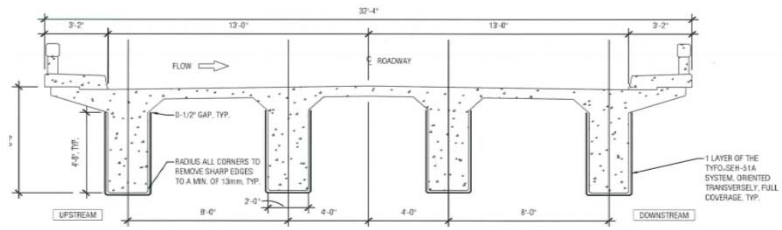
OBJECTIVES

The objective of the Trout Brook Bridge retrofit was to provide additional shear capacity to the critical shear zones of all four girders at both ends. Through analysis, the New Brunswick Department of Transportion determined that in order to increase the bridge's load carrying capacity from 43,500 kilograms to 50,000 kilograms, each girder would have to be strengthened by a minimum of 120 kN. Prior to FRP application, however, all cracking issues had to be repaired.

BENEFITS OF UTILIZING FIBRE-REINFORCED POLYMERS IN CONSTRUCTION

FRP materials are typically unidirectional tension members externally bonded to existing structural elements, designed to provide strengths comparable to those contributed by steel reinforcement. Various design codes and guidelines have been developed to address the use of composites in structures and their contribution to the strength of a member, including Chapter 16 of the Canadian Highway Bridge Design Code, CSA S6-06 Section 16.11, which covers the rehabilitation of existing concrete structures with FRP. The strength contribution of FRP's is governed by the allowable strain and modulus of the cured composite system. FRP's remain linear elastic until rupture, so added conservatism in design comes with strain limitations and additional material reduction factors. Possible failure modes that shall be considered are FRP rupture, concrete crushing, fiberwrap debonding, and concrete cover delaminations. The governing failure mode will limit the FRP design strain that can be developed, in turn limiting the additional capacity provided by the fibre-reinforced polymer system.

AUTOCAD DETAIL AND FINISHED PHOTO



INSTALLATION PROCEDURES

When utilizing FRP's in design & construction, bonding to sound substrate is a requirement. In this case of beam strengthening where the material was applied to only three faces, more invasive surface preparation involving mechanical grinders was required to achieve a minimum concrete surface profile of 2 based upon ICRI guidelines. Beyond theses standard surface preparation requirements, epoxy crack injection was also required at several locations. After completion of the surface preparation, existing corners with sharpened edges perpendicular to the composite fabric needed to be smoothed to a 19mm minimum radius. The epoxy was then mixed on site, and a prime coat applied to the substrate was allowed to become tacky to the touch before a thin coat of thickened epoxy was installed to ensure that there were no voids behind the precut and presaturated fiberwrap sheets.

PROJECT OVERVIEW

Because the strength increase requirement for the Trout Brook Bridge was minimal and unchanging at all locations, the FRP design was relatively straightforward. Each beam was to be strengthened to provide an increase in 120 kN for a specified length of 5 meters.

Therefore, an effective and durable glass composite FRP was selected, with a single ply applied at each location to achieve the desired strength requirement. The FRP wrap was applied transverse to the longitudinal axis of the beams, effectively creating a "U-Wrap." It should be noted that all composite materials were designed per CSA S6-06 standards.

CONCLUDING REMARKS

Over the past two decades, FRP composite strengthening systems have developed into a reliable alternative to traditional structural repair materials and seismic retrofit methods for reinforced concrete bridge structures. With the low-impact, cost-effectiveness and ease of installation of these materials, the number of projects with FRP's being specified for rehabilitation, strengthening, and protection of structural elements is continually growing. The Trout Brook Bridge upgrade provides one example of effectively utilizing fibre-reinforced composite systems on a bridge. In this case, the New Brunswick Department of Transportation required an increased load rating on their bridge to allow for the transport of heavier vehicular loading.

REFERENCES

•Canadian Standards Association, S6-06: Canadian Highway Bridge Design Code, 2006

•International Code Council, Acceptance Criteria 125: Acceptance Criteria for Concrete and Reinforced and Unreinforced Masonry Strengthening Using Externally Bonded Fiber-Reinforced Polymer (FRP) Systems, 2010

•ICC AC 178: Interim Criteria for Inspection and Verification of Concrete And Reinforced Masonry Strengthening Using Fiber-Reinforced Masonry Strengthening Using FRP Composite Systems. June 2003. International Code Council Evaluation Service.