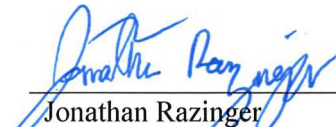


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**December 5, 2017**

**FINAL FIELD REPORT**

**U2017 - 09**

## **Assessment of Fiber Reinforced Polymer (FRP) Strips for Bridge Rehabilitation**

### *Overview:*

The Fiber Reinforced Polymer (FRP) strips and reinforcement were installed on all four concrete bents of Bridge 98 during the spring of 2014 as part of a rehabilitation project. This concrete bridge element rehabilitation method was chosen over standard rehabilitation methods due to the highlighted benefits of utilizing this technology to strengthen and extend the life of concrete elements at low costs. The FRP strips were added to increase the flexural and tensile strength of the concrete bents to prevent future cracking and exposure of moisture of the underlying steel reinforcement. This report summarizes observations regarding the performance of the FRP strips during the August 2017 field visit.

The purpose of this study was to examine and evaluate the constructability, overall performance and cost effectiveness of using this repair method. By using Fiber Reinforced Polymer (FRP) composites, VTTrans expects added longevity, strength and cost-effectiveness for rehabilitation of concrete bridge elements, while minimizing construction and traffic.

### **FRP Strips Site Visit – Bridge 98 on I-89, Swanton VT**

**EA:** Experimental Features – SPR 352

**Work Plan:** WP 2013 S-1

**Date:** Thursday, August 31<sup>st</sup>, 2017

**Time:** 12:15 PM to 1:15 PM

**Weather:** 65°F, Cloudy with some localized rain

A site visit to Bridge 98 on I-89 in Swanton was conducted as part of an investigative check of the installed Fiber Reinforced Polymer (FRP) strips. Observations and photos on the performance and appearance of the FRP strips after installation were collected and can be seen in figures below.

### *Background on Site:*

FRP strips were installed to both the northbound and southbound lanes of Bridge 98 at mile marker 123.4 on I-89 in the town of Swanton, as part of the Swanton IM 089-3(70) rehabilitation project. The objective of this project was to prolong the life of the concrete bridge, extending the eventual structure replacement date using a low-cost rehabilitation method.

*Bridge 98 FRP Strips Site Visit Photos & Notes:*



Schematic of the Bridge 98 layout for both the Northbound and Southbound lanes.



The top photo shows the overall view of the North end bent of the northbound lane of Bridge 98 on I-89 in the town of Swanton. The bottom photo shows the overall view of the South end bent of the northbound lane of Bridge 98. Four 4" wide x 1/8" thick FRP strips on the undersides of the bents can be seen in both photos.





The top photo shows the overall view of the North end bent of the southbound lane of Bridge 98 on I-89 in the town of Swanton. The bottom photo shows the overall view of the South end bent of the southbound lane of Bridge 98. Four 4" wide x 1/8" thick FRP strips on the undersides of the bents can be seen in both photos.

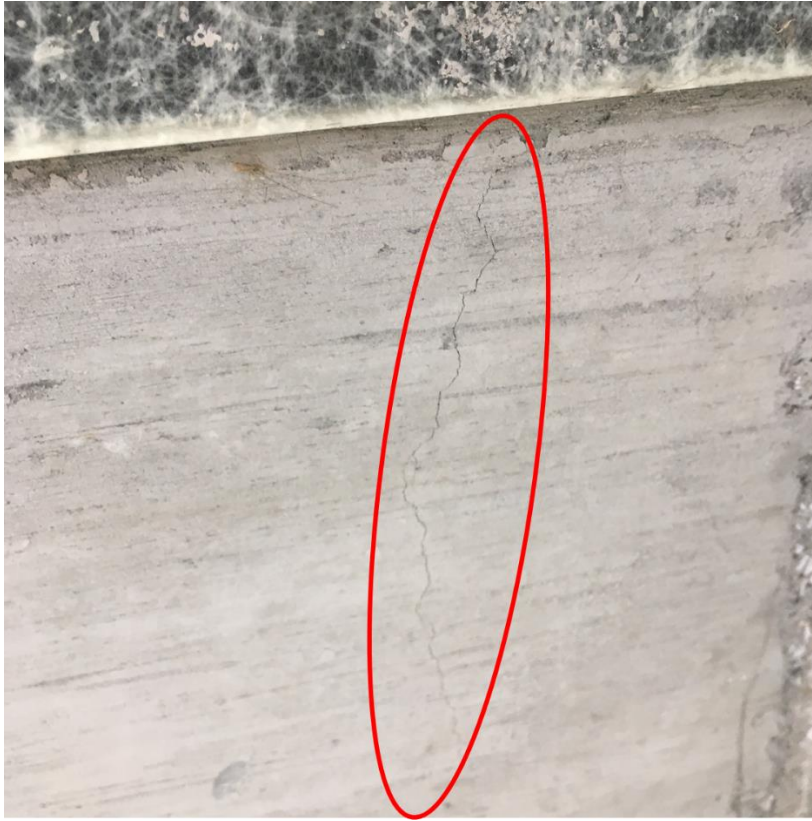




The top photo shows the close-up view of the East side of the South end bent on the southbound lane of Bridge 98. The bottom photo shows the close-up view of the East side of the South end bent of the northbound lane of Bridge 98. The photos show that there was no gaps between the FRP strips and the concrete. It should also be noted that no gaps were found at any of the 24 FRP strips on Bridge 98. The torque of randomly selected swedge bolts were tested to determine if vibrations or dynamic loading from bridge traffic had loosened the bolts. Eight bolts were selected at random per bent, four from each the west and east sides of the bridge bent. Bolts at the mid-span of each bent could not be reached due to not having a high enough ladder. The mid-span theoretically should be experiencing little to no movement or bending compared to the ends.

Torque Tested for Randomly Selected Swedge Bolts	
Location of Tested Bolts on Bridge 98	Turns needed to arrive at the specified 28ftlbs of torque per bolt
West side of South end on Southbound lane	4 nuts tested – took ½ turn
East side of South end on Southbound lane	2 nuts tested – took ½ turn and 2 nuts tested – took ¾ turn
East side of South end on Northbound lane	4 nuts tested – took ½ turn
West side of South end on Northbound lane	4 nuts tested – took less than ½, approximately 3/8 of a turn
East side of North end on Northbound lane	2 nuts tested – took ½ turn and 2 nuts tested – took 3/8 turn
West side of North end on Northbound lane	2 nuts tested – took ¼ turn and 2 nuts tested – took 3/8 turn
East side of North end on Southbound lane	1 nut tested – took ¼ turn, 1 nut tested – took ¾ turn and 2 nuts tested – took 3/8 turn
West side of North end on Southbound lane	2 nuts tested – took ½ turn and 2 nuts tested – took ¾ turn





Close-up of a hairline crack near the East side of the North end bent on the southbound lane of Bridge 98. The crack was spotted between two FRP strips on the underside of the bent.



Close-up of a crack on the front face of the horizontal member near the mid-span of the North end bent on the southbound lane of Bridge 98. What looks like rust can be seen dripping out of the crack (seen within the red circle), which means that moisture has entered the crack and has started corroding the reinforcing steel within the concrete bent.



The location of Bridge 98 with FRP strips is represented by the red circle on this map from Google Maps.

*Most Recent Bridge Management and Inspection Unit Observations:*

The Bridge Management and Inspection Unit conducted their last inspection on 6-29-2016. The inspection personnel concluded that both the Northbound and Southbound of Bridge 98 was in good condition and no reference or monitoring of the FRP strips. The inspection photos from the June 29<sup>th</sup> visit do not even show the FRP strips on the bents. The structure inspection, inventory and appraisal sheet for the Southbound of Bridge 98 can be found ([here](#)) and the June 29<sup>th</sup> 2016 photos can be found ([here](#)), while the structure inspection, inventory and appraisal sheet for the Northbound of Bridge 98 can be found ([here](#)) and the June 29<sup>th</sup> 2016 photos can be found ([here](#)).

*Summary:*

The performance and effectiveness of the FRP strips on Bridge 98 is supported by the visual inspection and photographic evidence gathered during the recent site visit. This study has surpassed its initial (12 month) study duration detailed in the approved FHWA Work Plan, but is still within the five year project extension for any additional observations or optional measurements. Previous and current field visit documentation suggests that the FRP strips on Bridge 98 performed below expectations and what was detailed by the manufacturer. Observations from this recent site visit and the prior June 25<sup>th</sup> 2015 site visit revealed that the nuts on the swedge bolts were loosening over time. When the torque of the bolts were checked at random, all of the bolts were below the specified 28ftlbs. For a majority of the checked bolts it took a ½ of a turn, from a torque wrench, to get the torque back up to 28ftlbs. The nuts from the randomly selected bolts were at a torque around or below 20ftlbs because that was the minimum torque that the torque wrench could read. From this random sampling, a majority of the bolts that keep the FRP strips in place lost approximately 8ftlbs or torque during a two year period between the summer of 2015 and 2017. The bolts were ordered to be tightened after the June 25<sup>th</sup> 2015 site visit also found that the bolts had loosened since their installation. The loosening of the nuts from the swedge bolts is most likely caused by vibrations and dynamic loading from the bridge traffic. This could be verified by installing vibrational and strain sensors on the bridge bents. Forces from vehicles are being transferred to the concrete bridge structure causing it to oscillate and move. The oscillations are then being transferred to the concrete bents and the FRP strips. The movement between the two are most likely causing the threads between the bolt and the nut to slip. The nuts most likely would have not loosened to this extent if self-locking fasteners or thread-locking fluid was used

during the installation of the swedge bolts and FRP strips. Results from this study will be given to the VTrans Structures Section for consideration on future low-cost concrete bridge element rehabilitation projects.