Attendees:
George Colgrove Res. Eng.
Devon Sanborn, Tech. Appr.
Jason Tremblay Res. Eng.

May 16, 2014

FIELD REPORT

Assessment of Fiber Reinforced Polymer (FRP) strips for Bridge Rehabilitation

References – Work Plan 2013-S-1

INTRODUCTION

The purpose of this study is to examine and evaluate the constructability, overall performance and cost effectiveness of using Fiber Reinforced Polymer (FRP) strips for bridge rehabilitation. Structures and Research personnel will assess the existing bridge condition prior to construction to document all distresses, construction practices, and visit the sites annually to assess and document any changes or failures.

PROJECT LOCATION

The project location is bridge 98, north and south bound on I-89 at mile marker 123.4m in Swanton, VT. The pier caps have structural distress that has reduced the bridge's capacity. The bridges received maintenance recently. The Agency would like to prolong the current life and capacity of the bridges and extend the date the structure will have to eventually be replaced. Prior to installing the FRP strips, the spalled concrete will be repaired.

MATERIAL

The selected material for this study is the SAFSTRIP Fiber Reinforced Strengthening Strip. From the product documentation, SAFSTRIP® "is a pultruded composite strip that improves the strength of an existing structural member when mechanically fastened to the structure. SAFSTRIP® has high bearing and longitudinal properties and is designed to strengthen the flexural capacity on the tension face of concrete girders, slabs and decks. Installation on bridges can occur without any interruption of service.

SAFSTRIP® is supplied in rolls and may be pre-drilled with holes at the required fastener spacing to receive fasteners. SAFSTRIP® measures 4" wide x 1/8" thick and is shipped in rolls up to 100 ft. long. SAFSTRIP® is designed to be easily field cut by the customer into shorter lengths using standard carpenter tools."

INSTALLATION

On Friday May 16, 2014 Research was present to witness the initial install of the FRP strips on the project site. The initial install began on the northerly pier of the south bound lanes of I-89. The Contractor had placed four FRP strips on the work platform. Each was predrilled with an alternating pattern. The FRP Strips and the predrilled pattern can be seen in Figure 1.

Prior to the install, the Contractor had experimented with alternative fasteners to those specified in the project plans. The first alternative fastener was a Hilti powder actuated fastener with a 0.158 inch diameter and a 1¾" length. This fastener is driven into concrete by the force generated from a Powers 0.27 caliber blank fired from a concrete nail gun (See Figure 2). This alternative had moderate amounts of success in new concrete; however in older concrete, the force of the nail being shot into the concrete caused the concrete around the fastener to burst (See Figure 3). This alternative fastener was abandoned.

Figure 1 FRP Strips to be installed

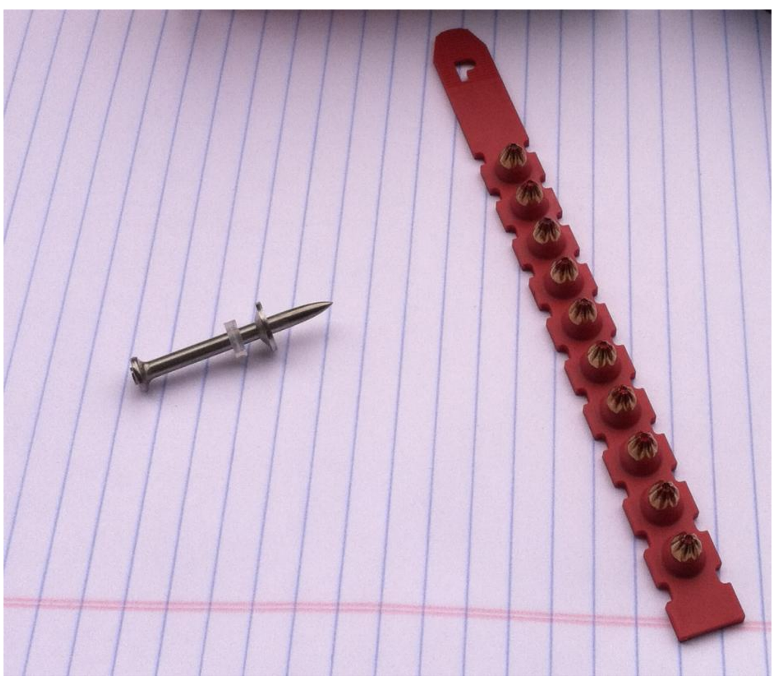

Figure 2 Hilti 0.158 inch x 1¾" Powder Actuated Fastener

Figure 3 Powder Actuated Faster Caused Concrete to Burst.

The next alternative tried was the Perma Seal coated Tapper Plus® Concrete Screw (See Figure 4). The screws required a ¼" hole to be drilled in the concrete face. The screw is then inserted with the threads digging into the wall of the hole for a tight fit. The coating also acts as a lubricant to make insertion easier. Though this option seems to work well for installation, it was standard steel with a coating. During installation, there is a risk of that coating being scraped off. With the application being subjected to potential chlorides in the nearby roadway spray; it was felt that this would not be a good long term solution. An alternative to the Tapper Plus would be using a product similar to the Tapcon® Concrete Screw. This is a similarly coated stainless steel screw that can be considered for this application. The use of the Tapper Plus® Concrete Screw requires a hole to be drilled. Because of this, the alternative did not provide much time savings.

The Contractor decided to use the fastener as specified in the plans. This was a $^{3}/_{8}$ inch Power-Stud™ swedge bolt (See Figure 5). Installation required a $^{3}/_{8}$ inch hole to be drilled in the concrete. The swedge bolt was then tapped into the hole. Once seated properly, a ratchet wrench was used on a nut to essentially pull the bolt out of the hole, thereby causing the anchoring collar to press into the concrete wall.

Figure 4 ¼” Tapper Plus® Coated Steel Concrete Screw

Figure 5 Chosen fastener - a 3/8 inch Swedge Bolt.

Installation required the strip to be placed and held in position. Using the predrilled holes, the Installer would drill a hole through the FRP strip and into the concrete for an exact match of the two holes. The Installer would then tap the swedge bolt into the hole with a five pound hammer. At that point the Installer would use a ratchet wrench on the nut to essentially pull the swedge bolt out of the hole until tight. The product has a limited torque of 28 ft-lbs. Figure 6 shows the sequence. Figure 7 shows a completed pattern of bolts. Figure 8 shows the completed installation on one pier.

Hold in Place | Drill | Tap in Swedge Bolt | Set Anchor

Figure 6 Sequence of Installing FRP Strips.

Figure 7 Completed Pattern of Bolts.

Figure 8 Completed FRP Installation

INSTALLATION PROBLEMS AND POSSIBLE SOLUTIONS

The first problem encountered was the difficulty in keeping the FPR strip in place while drilling. The space that the Installers were working was moderately cramped. When the drill started, the FRP strip jerked, which took it out of alignment. The Installers tried using “two-by-four” studs to wedge the strip in place which worked well. The Installer eventually bolted the strip in place every 18 inches or so, then went back to bolt the rest of the pattern. Research and the Installers discussed possible solutions. The idea of having an adhesive to adhere the strip in place was the most desirable solution. The adhesive could be applied by the fabricator with a peel-off cover to protect it before placement. It was felt that the adhesive would also seal the strip against the concrete surface to prevent roadway spray from permeating between the two materials.

In order to bolt the strip to the concrete, the Installer is required to drill a $^{3}/_{8}$” hole to accommodate bumps on the anchoring collar (See Figure 9). This is essential for the proper function of the anchor bolts. However, this creates a hole slightly larger than the shank of the swedge bolt (See Figure 10). This is essential to know if the bolting pattern was designed as a bearing connection rather than a friction connection. If the deflection of the horizontal concrete member is to a degree where the FRP strip goes into tension, then the strip will slide to the extent of the gap. If the deflection is such that the slide is slight, then the FRP strip will never be engaged. The connection will need to be reevaluated as a friction connection.

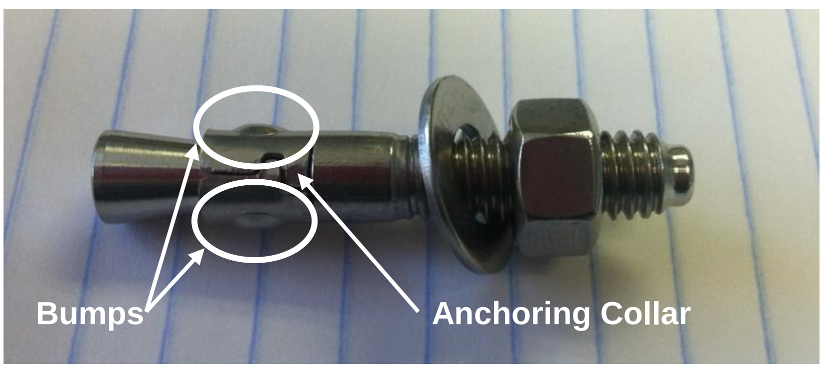

Figure 9 Swedge Bolt Features

Remedies discussed at the installation would be to do either of the following:

1. Replace the smooth washers with notched washers.
2. Calculate the friction required to prevent the FRP strips from sliding, then tighten the bolts to a necessary torque (without exceeding the maximum torque of 28 ft-lbs) to meet that friction resistance.
3. Insert a steel bolt sleeve with a flange to make a tight fit.

Figure 10 Swedge Bolt Anchored.

NEXT STEPS

The following are the necessary next steps.

1. The design needs to be evaluated for bearing verses friction connection between the concrete and FRP strip.
2. If the connection was a friction design, then we need a value for the necessary torque of the bolts to ensure we have the proper friction value.
3. If the connection was a bearing design, then we need a revaluation of the design to accommodate a friction design or implement a change to the bolting of the FRP strips.

FUTURE RECOMMENDATIONS

1. Specify an adhesive be applied to the FRP strips prior to their arrival to the project site.
2. Determine if coated stainless steel screws can be used rather than the anchor bolts. Screws will allow for tighter fit, thereby allowing for a bearing connection design. Though they do require drilling as do the swedge bolts, the process is sped up by only needing to insert the screw, rather than tap in and then setting the anchor. The screws will also lower the cost of the application.
3. Examine pretension techniques that may be incorporated into the installation process.