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VERMONT AGENCY OF TRANSPORTATION

Research and Development Section
Research Report

ASSESSMENT OF JAHN PERMEABLE MORTAR SYSTEM IN A HISTORIC BRIDGE ABUTMENT APPLICATION

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June 2015

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Reporting on Work Plan 2011-R-05

STATE OF VERMONT
AGENCY OF TRANSPORTATION

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16. Abstract

Increasingly, the importance of historic preservation is competing with the requirements to enhance structural capacity of older unique structures. Preservation of the functional and aesthetic qualities limits potential change to meet the expanded needs of the traveling public. The Taftsville Covered Bridge in Woodstock, Vermont was deteriorating at a time the public needed increased capacity. Then in 2011, the tropical storm remnant of Hurricane Irene rendered the bridge impassable. Significant damage to the substructure and superstructure occurred. The bridge required a complete deconstruction and reconstruction to correct deficiencies and enhance capacity. Design and construction techniques focused on retention of the historic presence and value the bridge offered for over a century and a half.

The Taftsville Covered Bridge has been repaired and improved many times over its life. This project continued that trend by restoring one abutment and pier with added strength by the use of Jahn mortar and grout. The existing laid-up stone was repointed with Mortar with minimal addition of new stone where large gaps were located. Once the shell formed by the existing stone and the new mortar set up, a flowable grout was placed within the stones to bond the stones together, thereby strengthening the substructures. The containment of the stones provided increased reliability in addition to strength. The feature the Agency hoped to maintain was the high permeability of the abutment. The permeability of the Jahn system minimizes damage caused by internal hydrostatic pressures and the effects of chlorides locked within the stone substructures observed in other mortars and grout systems.

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TABLE OF CONTENTS

ABSTRACT

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The Taftsville Covered Bridge has been repaired and improved many times over its life. This project continued that trend by restoring one abutment and pier with added strength by the use of Jahn mortar and grout. The existing laid-up stone was repointed with Mortar with minimal addition of new stone where large gaps were located. Once the shell formed by the existing stone and the new mortar set up, a flowable grout was placed within the stones to bond the stones together, thereby strengthening the substructures. The containment of the stones provided increased reliability in addition to strength. The feature the Agency hoped to maintain was the high permeability of the abutment. The permeability of the Jahn system minimizes damage caused by internal hydrostatic pressures and the effects of chlorides locked within the stone substructures observed in other mortars and grout systems.

INTRODUCTION

As historic bridges throughout Vermont, such as the Taftsville Covered Bridge (Figure 1), are in need of rehabilitation, emphasis is put on preserving their distinct historic look while ensuring the safety of the public and longevity of the existing structure. In most cases, the goal with preservation efforts is to retain the original materials and construction to the greatest possible degree. For the Taftsville Covered Bridge, the superstructure required extensive reconstruction to address deficiencies. This portion of the rehabilitation work used as much of the original design, timber and construction means and methods that was feasible to maintain the bridge’s historic appearance while providing the enhanced structural capacity required by the traveling public. Only essential structural enhancements were made, which required new materials and components that were not in the original structure.

Figure 1 Taftsville Covered Bridge in the 1940's

Similar structural capacity enhancements were necessary in the substructure as well. Existing stone and concrete masonry components of the substructure were intact (Figure 2) with the exception of the westerly abutment. The westerly abutment was reconstructed with stone-faced reinforced concrete. The two surviving substructure components were identified for preservation. Typically, this type of preservation is accomplished by removing and replacing the deteriorated mortar with new pointing mortars and grouts to fill in the gaps and void spaces between stones in the wall. During design and construction, it is vital to account for lateral forces that build up behind the wall from rain events, frost penetration and groundwater. In the case of piers and abutments, consideration must also include vertical forces applied by the superstructure's weight and applied live loads. Preservation considerations were centered on maintaining the visual appearance of the surviving pier and abutment. All structural enhancements were hidden from the sight for that reason.

Figure 2 The Taftsville Covered Bridge in 2006 showing the Pier and Abutment that were preserved (cmh2315fl)

This study centered on permeable grouts and mortars that were used to shore up the pier and abutment. Permeable grouts allow moisture to seep slowly out from within the abutment stonework thereby reducing the risk of increased lateral instability due to hydrostatic pressure buildup. The mortar used must adhere to the stone with the specific strength and stiffness requirements and must have a lower compressive strength and a greater vapor permeability than the masonry abutments. (SKELLY and LOY, Inc., 2007) The intent of the rehabilitation project was to treat the surviving dry-laid stone foundation components with a proprietary permeable mortar that fulfilled these functions. (Power, 2011) Specifically, the grouting system used in this study was the Jahn M110 Historic Pointing Mortar and the Jahn M40 Crack and Void Injection Grout.

The Vermont Agency of Transportation (VTrans) began this study to examine and evaluate the impacts of the constructability, overall performance and life cycle cost of a permeable mortar and grout system. The materials used in this study were designed by Cathedral Stone Products specifically for the Taftsville covered bridge rehabilitation project. In the ensuing years, the Agency's Research and Development Section will be assessing the product's durability in a bridge abutment and pier application. A comparative analysis will be made regarding performance, cost and on-site construction timesavings of the experimental products versus standard rehabilitation practices. The constructability benefits will be weighed against construction costs.

PROJECT BACKGROUND

Project Location

Jahn Permeable Mortar and injectable grout was used on the Taftsville Covered Bridge project, Woodstock BHO 1444 (52). The bridge is located on Town Highway 2, or the "*Covered Bridge Road*," spanning the Ottauquechee River, roughly 105 feet east of its intersection with US 4 in the town of Woodstock (Figure 3). Proposed work included bridge rehabilitation including retrofit of timber superstructure and repair of masonry foundations.

Taftsville Covered Bridge History

The historic commemorative plaque placed at the project site provides (Figure 4):

> "*The Taftsville Covered Bridge is a rare example of early vernacular wooden truss covered bridges in the United States. All evidence indicates the builder, a longtime Taftsville resident named Solomon Emmons III, used no existing*

patented bridge truss design, and that the design and construction techniques are unique. Constructed entirely of local wood and stone in 1836, at a cost of $1800, it is the oldest covered bridge in Windsor County, and is the third oldest bridge in the state. At approximately 189 feet in length at the floor, and 200 feet at the roof, it is the second longest covered bridge in Vermont. On August 28, 2011, Tropical Storm Irene devastated the south abutment, closing the bridge for two years while extensive repairs and renovation efforts were made."

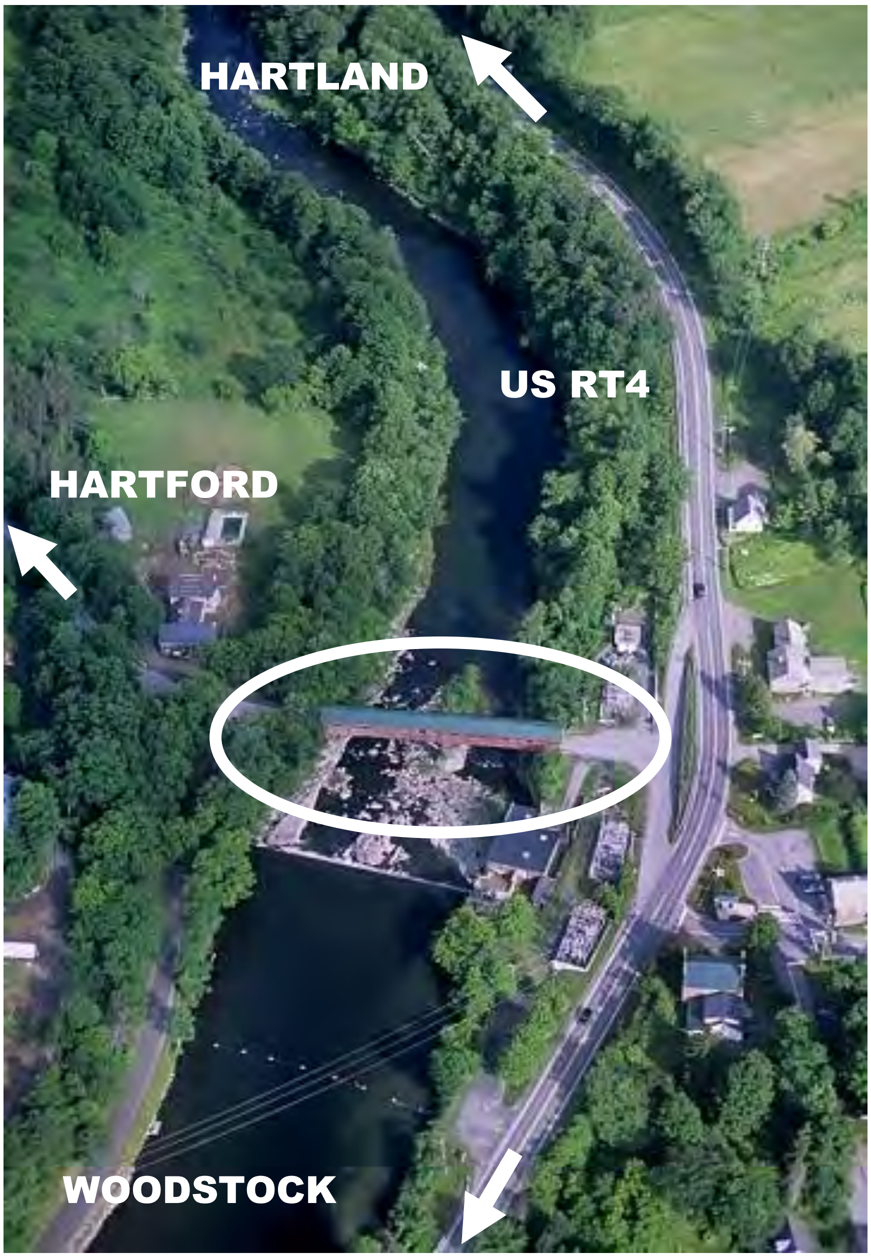

Figure 3 Project Location (Jim Wark 2008)

Figure 4 New historic plaque at the Taftsville Covered Bridge (VTrans 2013)

Originally built in 1836, the Taftsville Covered Bridge is a 198 ft. long (along the roofline), 14.8 ft. wide single lane covered bridge (Figure 5). It was built to maintain the connection across the river for the community and the businesses established by the Taft brothers with the major nearby throughway NE Route 13, now known to as US Route 4. (my Champlain Valley, 2013) (Power, 2011) In 1793, a footbridge, which was washed away in 1807, had been built at the location. Two other bridges had been built in the same location (one washed out in 1811 and the other in 1828) before the present bridge was constructed. (The Bridger, 2013) (Christianson, 2006) For 177 years, "*the bridge has served several communities — including the village of Taftsville, the town of Woodstock and the surrounding towns of Pomfret, Hartland and Hartford*." (Cassidy, 2013) The bridge was first painted red in 1959. On August 28, 1973, the bridge was included in the National Register of Historic Places. (Bridgehunter.com, 2015)

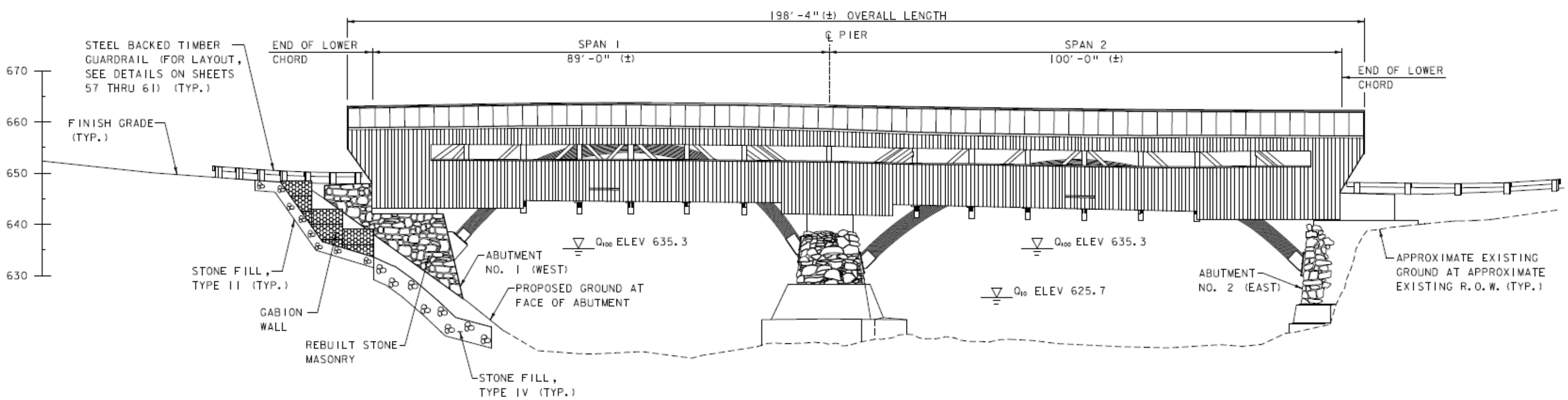

Figure 5 Profile of the Taftsville Covered Bridge

The covered bridge comprises of two spans; 89 feet and 100 feet and is rated to carry 8 tons. Its design is roughly along the lines of a long Multiple Kingpost Truss with semi-independent arches (Figure 6). The United States National Park Service suggests its significance is because the "*Taftsville Bridge is a rare survivor of the early craftsman tradition of wooden truss bridge building. It shows no influence from any of the patented bridge truss designs, but the builder may have been aware of the Swiss tradition from published literature of the time*." (Christianson, 2006)

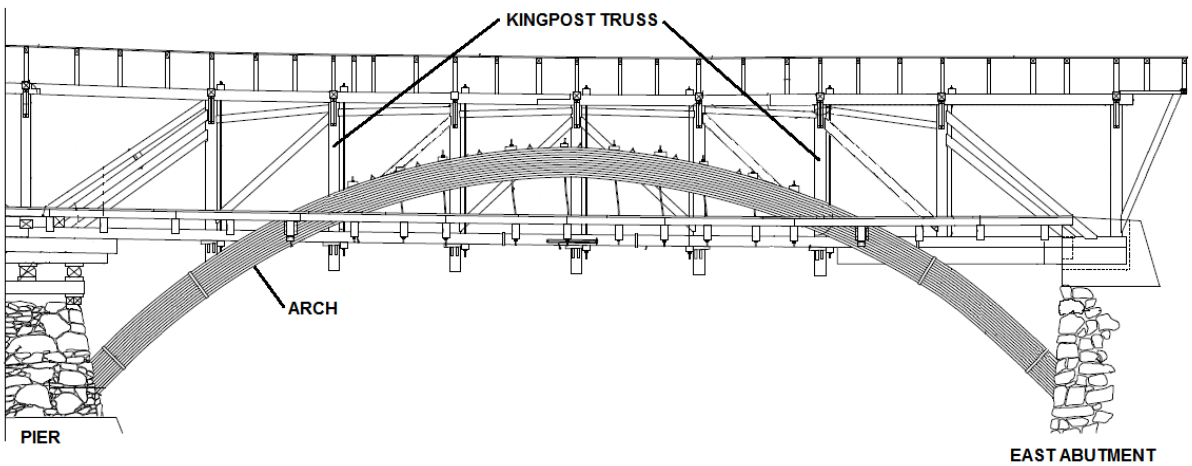

Figure 6 Configuration of the easterly span showing arches

The bridge was rehabilitated in 1869 where it was raised 3 feet and rehabilitated once again in 1910 (Bridgehunter.com, 2015) (Christianson, 2006). It is suspected that the laminated timber arches were added in 1914 to accommodate load-rating requirements set by the Vermont Highway Department in 1913. A little later, the windows were opened along the sides of the bridge. (Christianson, 2006) (Figure 7) In 1952, the bridge underwent extensive reconstruction activities by Miller Construction. According to the scope of the project, Woodstock SA 5, "*the project contemplates the squaring, aligning, raising the trusses one foot, installing new concrete foundation pads and backwalls at abutments, replace of all defective truss members, adjustment of arches and arch bases, installing new steel braces at top chord, repairing of the top chord lateral system, a complete new floor system, and plank guard rail at bridge ends. Also such repairs to end overhangs, siding, etc. as is necessary for a complete and satisfactory job*." Repairs to the abutment included new concrete caps being built on each abutment and short wingwalls at each corner of the bridge superstructure. Minor maintenance work was done in the

1980's with the addition of distribution beams and in 1993 where repairs to the roofing and tie beams were made.

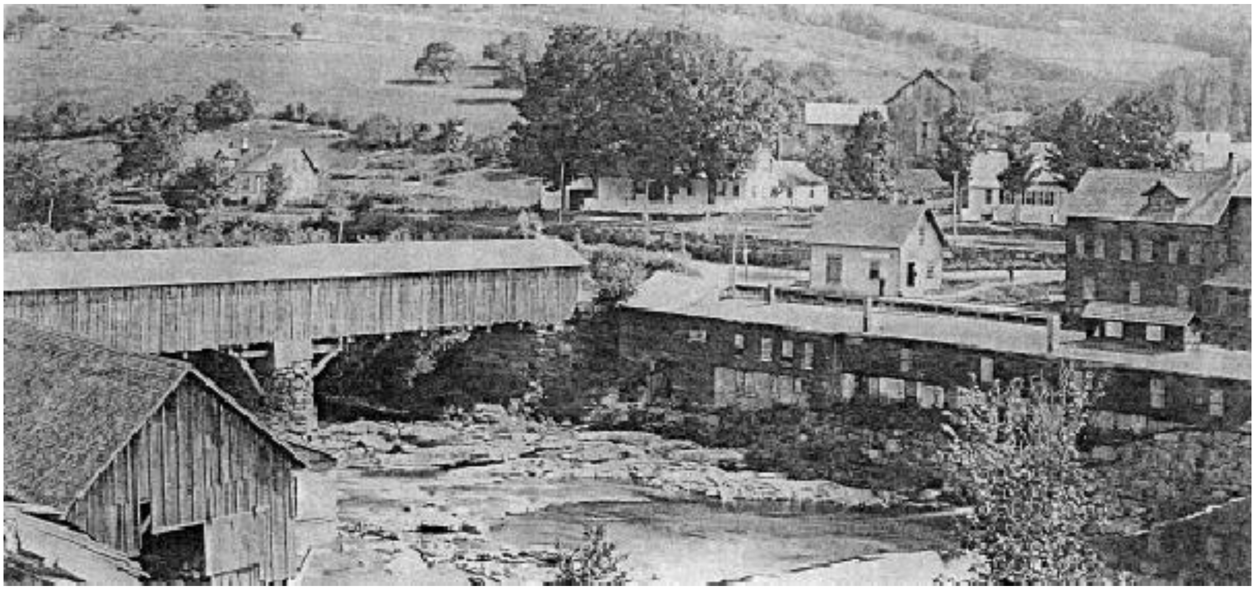

Figure 7 The Taftsville Bridge at the time the laminated arches were added, but before the windows were opened. (Mid 1910's)

On August 28, 2011, the Tropical Storm Irene caused significant damage to the crossing. In particular, the westerly abutment was undermined and partially collapsed (Figure 8), causing damage to the timber structure of both spans of the bridge. Though the bridge remained standing, the westerly abutment continued to break apart in the months after the storm. That winter, the westerly span was removed except for the arches (Figure 9). The timber was carefully removed, labeled and stockpiled at the town garage for later use in the rehabilitation project. For nearly two years, the surviving components of the structure lay dormant. In late 2012, construction began on the bridge and on September 7, 2013 the bridge was reopened after extensive $2.5 million reconstruction was completed. (Cassidy, 2013)

Figure 8 Westerly abutment partially collapsed (VTrans 2011)

Figure 9 Westerly span dismantled leaving only the arches (VTrans, 2011)

Bridge Condition

Before the extreme weather event, the 2010 Inspection summary notes indicated, "*The structure is in need of full rehabilitation due to a heavy sag in* [the easterly] *span, twisted arches in both span areas, significant horizontal sweep of both spans towards the downstream channel and overall racking of the structure towards the downstream channel*." At the time, the structure was rated stable for scour. The summary from the 2008 inspection references the abutments and piers, and states "[the westerly] *Abutment upstream wing and stem are quite unstable. The pier is somewhat unstable on the upstream side.*" Average annual daily traffic (AADT) at the location of this bridge was 1500 vehicles as of the 2008 reporting.

According to McFarland Johnson, the engineering firm hired to design and specify the rehabilitation work for the covered bridge, the dry-laid stone abutments and pier have flaws and weaknesses. McFarland Johnson continued with this assessment by saying, "[The original builders] *just got the best stones that they could, field stones or whatever and tried to do the best they could to stack them up*." (Power, 2011) The pier comprises of dry-laid stone down to the riverbed. The pier and abutments have a concrete skirt encasing the stone pier placed after the original construction, which can be seen in Figure 9. (Historic Covered Bridge Committee, 2008)

The tropical storm eventually undermined the westerly abutment at the downstream end. The abutment fractured (Figure 8) resulting in the downstream westerly arch to pull out of the stone socket securing it in place. (Figure 10) In turn, the westerly span twisted, causing damage at connections throughout both spans. The covered bridge was scheduled for a nearly $3 million National Covered Bridge rehabilitation project that was scheduled to begin in September 2012. Much of the work that was planned for that project was incorporated in the project resulting from the storm activities.

MATERIAL DESCRIPTION

The materials used in this project that are included in the testing are:

- Jahn M110 Pointing Mortar
- Jahn M40 Injection Grout

The material used in this study requires some up front compatibility testing. According to Cathedral Stone Products, the stone in the restoration project must be tested first for compression, porosity, and properties of expansion and contraction, and the grout will then be developed accordingly. Through their experience, Cathedral Stone Products has learned that replicating original mortars is not always appropriate because the original mortars may not have been a good match for the masonry. First, compression strength must always be less than that of the masonry. The mortar must be elastic enough to maintain filled joints when the masonry shrinks; therefore, the mortar must match or exceed the movement of the masonry. In addition, moisture should be allowed to escape the same day that it enters the mortar. A compatible mortar must be breathable. (Historic Covered Bridge Committee, 2009) Jahn has formulated its mortars to provide these properties.

Figure 10 Downstream westerly arch dislodged from abutment (VTrans 2011)

Figure 11 Jahn Products (Cathedral Stone Products, Inc)

Training is recommended and in some cases, required for applying the Jahn grouting system as well as other Jahn products supplied by Cathedral Stone Products. Training is offered on a regular basis at the company headquarters in Hanover, Maryland. Training includes hands on repair of limestone, sandstone, terra cotta and brick materials. The company provides the training to stone or brick masons, craftspeople, specifiers, preservation professionals and contractors who wish to achieve long lasting results and provide the best possible finish for projects they are awarded. Formal training was not required for the products used in this study.

Jahn M110 Pointing Mortar

The Jahn M110 Pointing Mortar is used predominately on restoration of historic structures. According to product literature, "*These single-component, cementitious, mineral based pointing mortars are specifically formulated for the restoration of mortar joints in all types of masonry*." The mortar does not contain latex or other acrylic bonding agents or additives. It has been formulated to be compatible with historic masonry. The reported features of the product are: (Cathedral Stone® Products, Inc., 2012)

- The mortar is unaffected by the corrosive properties of salts
- The mortar is free of shrinkage
- Placement can be accomplished in a single lift. There is no need to apply the grout in several lifts
- Product variation is controlled in the factory therefore prevents field chemistry change from occurring

- The mortar comes in several standard formulas as well as allowing for custom formulation for specific projects.
- The customer can specify specific color requirements
- Formulated as a single component – Only needs water
- Free of Latex and Acrylic bonding agents, thereby allowing salts, water vapor and liquid water to leach out to the surface, ultimately preventing failure caused by salt expansion and effects of the freeze/thaw cycles

Mortar Requirements

The mortar requires a clean surface for best results. Any dust, dirt, grease, laitance and/or any other coating or foreign substance must be removed. Any of these contaminates may prevent proper adhesion between the mortar and the stones. All surfaces in the joints that will be in contact with the mortar should have a final rinse with clean water. The ambient temperature range for application should be between 40°F to 90°F. The minimum thickness of the applied mortar is ½ inches. (Cathedral Stone® Products, Inc., 2012)

Being attentive on the mixing of water into the powder is essential. Conditions such as temperature and humidity as well as the chosen formulation of the mortar can affect the amount of water that is necessary. Typically, the mixing ratio is 1 part water to about 4 to 5 parts powder. Higher ambient temperatures require more water. Excessive water can negatively affect the color of the grout repair. The stonemason can mix the product by hand until the mortar is thoroughly consistent. Prior to application, all surfaces must be moistened using clean water. The stonemason must be mindful of any surface drying out before the mortar is placed. The stonemason must keep the surface moisten by misting after application for curing for at least a 72 hour period. Misting should begin within 30 to 60 minutes for hot dry conditions or longer (several hours) for cooler and damp conditions and should continue several times a day. (Cathedral Stone® Products, Inc., 2012)

Jahn M40 Injection Grout

The Jahn M40 Crack Injection Grout is used for crack repair and filling voids. Cracks widths between 3/16 to 9/16 inches or wider may be repaired by the means of low pressure or gravity fed equipment. The injection grout is formulated in the same manner as the pointing mortar. The features of the grouting product are: (Cathedral Stone® Products, Inc., 2012)

- Formulated as a single component – Only needs water
- Provides compatible physical properties of the substrate its being applied to, so both the substrate and the grout reacts similarly to environmental conditions
- Free of Latex and Acrylic bonding agents, thereby allowing salts, water vapor and liquid water to leach out to the surface, ultimately preventing failure caused by salt expansion and effects of the freeze/thaw cycles
- Strong bonding properties

- Product variation is controlled in the factory therefore prevents field chemistry change from occurring
- Low viscosity ensuring deep and thorough penetration
- Simplified manual or mechanical application
- Water based formula allowing for safe and easy cleanup

Grout Requirements

The requirements for the grout are similar to those for the pointing mortar. First, the surfaces the product will be applied on needs to be cleaned in the same manner as the mortar. Mixing the product requires a little more attention. The ratio of water to powder is 1 part water to 2 to 2.5 parts powder. The grout can be mixed by hand, though it may be best to use a slow speed drill (400 to 600 RPM) with a Jiffler-type mixing paddle (Figure 12). Mixing should not be less than 3 minutes. Like the mortar, the ambient temperatures should be between 40° F and 90° F.

Figure 12 A Jiffler Type mixer for a hand held power drill (Alexander Screw Products, Inc.)

The steps involved in placing the injection grout are similar to the mortar. The surfaces need to be moistened. This may include flushing the interior voids with clean water. Ports are inserted into the masonry at specified elevations in a downward angle and sealed with pointing mortar. The grout is injected through these ports until the grout starts running freely out of the other ports at the same height. Cleanup with a hand sponge should occur immediately with clean water before the grout has time to set. After a day or two, any sealants used to contain the grout should be removed. (Cathedral Stone® Products, Inc., 2012)

CONSTRUCTION

On Monday October 1, 2012, Alpine Construction of Schuylerville, New York broke ground for the rehabilitation work on the covered bridge. The subcontractor chosen to work on the stone pointing was P&P Landscaping. The first phase of the pier repairs was to reset stones on the upstream side, or the pier nose, that were dislodged from flooding and debris from past weather events.

Alpine constructed an enclosure around the pier (Figure 13) and on February 5, 2013, the stonemasons began initial application of the Jahn Pointing Mortar on the westerly face of the pier. (Chase, 2013) The purpose of this initial activity was for testing and training on how to prepare the dry-laid stone for the mortar, mix the mortar to the right consistency and apply to it. Cathedral Stone Products was onsite to oversee the testing and to train the stonemasons. The contractor provided heat in the enclosure to bring the atmospheric and stone temperatures up to the specified level for stone pointing and grouting. Initial observations indicated that the mortar mix had to be adjusted initially to obtain the consistency required for pointing stones.

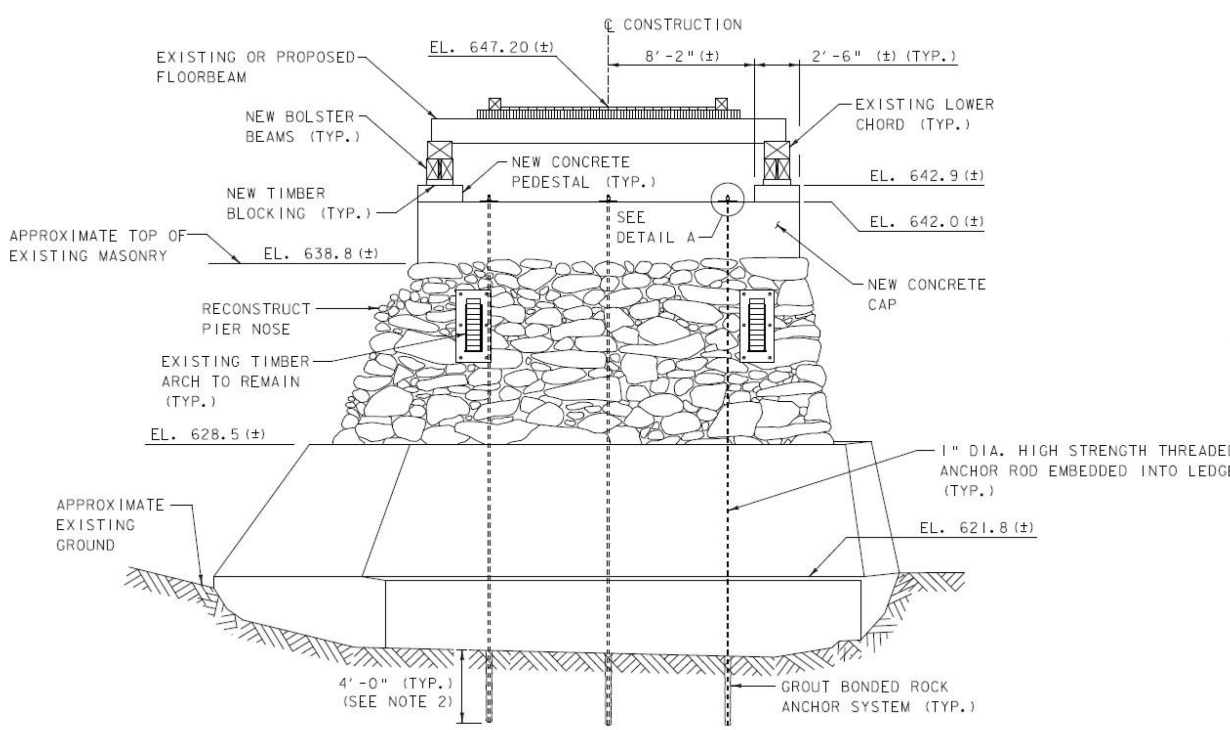

Figure 13 Details of the Bridge Pier (VTrans 2012)

Cathedral Stone Products commented in a Historic Covered Bridge Committee Meeting held on October 8, 2009 that pointing some stones maybe difficult. When completed, the pointing should not be visible. Stones would be inserted deeply enough to prevent shifting but also to allow for moisture and salts to leach outward. The stonemasons would need to use care in pointing stones in these areas. There were areas on the abutment and pier where the gaps were large, which resulted in inserted stones being visible. (Historic Covered Bridge Committee, 2009)

The stonemason used a narrow pointed mason's trowel to pry out small loose stones and debris from the dry-laid stone joints. Using a brush or their hands, the stonemason would remove dust and dirt from within the joints. The crew had access to an air compressor, which they used to clean fines out of the joints. It was determined that a power washer would be the best option to conduct the final cleaning of the stones. Where there were gaps, the stonemason would size up a stone provided on the rigging, and fit it into the opening, carefully matching the shape of the stone to the shape of the gap. In places, several stones were required. Smaller stones were worked deep into the larger gaps (Figure 14 and Figure 15). The stones for this work came from the collapsed westerly abutment that was being excavated. The larger stones were broken apart to make smaller stones for chinking.

Figure 14 Up-close view of stone pointing and mortar work (VTrans 2013)

Figure 15 Completed mortar work (VTrans 2013)

Once the stone pointing and cleaning was complete, the stonemasons would mix a portion of the Jahn Pointing Mortar. The grout was given a blackish color to give the appearance of a void, to simulate the open joints of dry-laid stone. When cured, the color would become more of a dark gray. The stonemasons would work the mortar deep into the stone joints. Repeated application would continue until the mortar either could no longer be worked into the joint or the stonemason felt the joints were sealed. The mortar was then worked into a smooth concave surface using a joint filler tool allowing the original stones to protrude out to maintain their original appearance.

With the experience level adequate for the job, the mortaring process continued on the pier on all faces. Since the work was being accomplished in February, the stones and surroundings in the enclosure needed to be warm enough to meet the specifications of a 50°F minimum. This was done by indirectly heated air blowing into the enclosure. By February 22, the stone pointing was complete. On February 26, the enclosures were made ready to begin pointing stones on the easterly abutment (Abutment #2, see Figure 16). This work was done directly below the superstructure. The stonemasons began pointing on February 28. By March 1, the pointing was complete with the exception of the bottom two feet, as that was outside the heated enclosure. This would be completed later in May. (Chase, 2013)

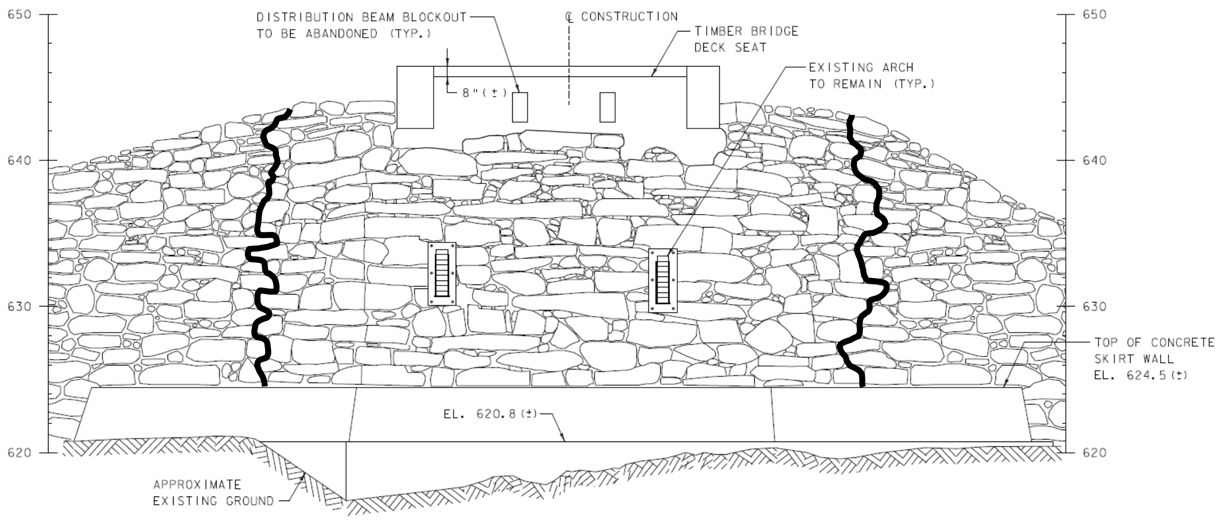

Figure 16 Details of the Easterly Abutment (dark lines shows approximate extent of pointing – VTrans 2012.)

On April 17, the contractor began grouting the interior voids of the pier. The sealed dry-laid stones from the pointing efforts were used as a form to keep the injected grout in place. During the stone pointing, the stonemasons inserted weep tubes in the stone joints. As with applying the pointing grout, the interior of the stones needed to be cleaned to ensure a bond was made between the grout and the internal stones. The interior of the pier was flushed with water. During the flushing process, small particles dusting the interior stones were washed off. These particles traveled with the flowing water, ultimately filling in the small voids within the previously applied mortar. The Jahn M40 MAX BLACK consolidating grout was then prepared and injected into the pier interior to be filled from the bottom up through injection ports. The grout was place in this manor in two lifts. With the initial fluid properties of the grout, remaining leaks in the dry-laid stone and applied mortar were filled. Once the grout cured, the entire pier became one structural unit.

The final work on the pier was placing a new 3-foot high reinforced concrete cap (Figure 17) for the midspan of the bridge span to rest on and to distribute the vertical loads from the bridge into the pier. The cap was affixed to the stone pier by 28 anchor rods that were drilled and grouted into the stone. Six shafts in a 3-by-2 grid were drilled through the concrete cap and on through the grouted stone mass ending 4 feet into the existing riverbed ledge below the pier. 1-inch diameter high-strength threaded steel anchor rods were inserted into the shafts and embedded into the ledge using grout. The rods were bolted and tightened to a specified tension.

Grout was then placed in the shaft. The tensioned rods provide bending resistance caused by lateral forces applied to the pier.

Figure 17 Completed pier showing the concrete cap and abutment (VTrans 2013)

PERFORMANCE AND OBSERVATIONS

Research and Development has visited the project site once a year since the project has been completed. In a discussion with the CEO of Cathedral Stone Products, Denis Rude, he said that as the salts leach out of the interior of the pier and abutment, a white powder like substance would appear on the surface of the grout. This powder would eventually blow off the surface with wind or be washed of by rain. There were concerns that the repairs to the pier and abutment would cause an efflorescence to form in places. The use of the Jahn products was intended to prevent such efflorescence from forming. In the last two years, the white powdery substance has been observed forming; however, it is not accumulating (Figure 18). There seems to be a consistent light dusting in places. Overall, the grout appears to functioning as expected.

Figure 18 Up-close view of white powdery residue on mortar (VTrans 2013)

Another purpose of using the Jahn products was to strengthen the dry-laid stone pier and abutment to preserve the overall historic appearance of the bridge. Concerns were that the mortar would be obvious from a distance. Observations at various distances from the substructure units gave an appearance of dark joints between stone (Figure 19 and Figure 20). The mortar and pointed stones were virtually invisible to the eye from afar. Even up close, the dark grey color of the mortar has aged in a way that it is not obvious in most places on each substructure unit. Places where the mortar is visible are where there were large gaps in the dry-laid stone (Figure 21).

Figure 19 Pier before Tropical Storm Irene in 2011

Figure 20 Pier after Construction in 2014

Figure 21 Downstream face of pier showing final construction (VTrans 2014)

SUMMARY AND RECOMMENDATIONS

The Taftsville Covered Bridge has survived 177 years of floods, changing load requirements and risk of replacement when significant work was required to maintain an important crossing. The covered bridge has changed over time: by gaining laminated timber arches and windows; by having its footings reinforced with concrete skirting; by receiving a new roof and deck as well as benefitting from some new supporting beams. The history of the bridge is how it has been adapted to the needs of the time. Yet in each of its phases, the bridge has kept its pristine look, which has survived the ages. In 2011, its fate was left to a Tropical Storm. In the morning, Vermonters saw that it had once again survived. As with each phase of the bridges development, new technology and new understanding was used to give the covered bridge new strength and new life. The bridge now has within its stones an advanced mortar and grout system that will guard it against the internal mechanism of hydrostatic pressures, and expansion due to salt buildup. The supports of the bridge have added strength and durability to continue fulfilling its purpose long into the future.

At this point in the study, observations regarding the use and early performance of the Jahn products are under way. Research and Development will continue site visits to the covered bridge for a minimum of three years or when conclusions can be made on the performance of the Jahn products. A site investigation should occur following a rain event to determine how quickly moisture can seep out of the pier. In another two years, a comparison will be made between the Jahn products and similar products used elsewhere in the state. Laboratory testing as spelled out in the workplan should commence in the near future. These tests should include compressive strength, freeze/thaw durability and volume sustainability. The laboratory testing will be used to corroborate with the field mix design used with the Taftsville project.

If the products continue to perform successfully, the Agency may wish to consider using a modified higher strength mix of the Jahn system to patch concrete wall and floor systems. The advantage of the material allowing moisture and salts to seep out of the structure may be used in concrete units that are susceptible of spalling. Often potholes in concrete decks are patched with a durable higher strength concrete than the original bridge deck. This concrete may also be impervious as well. As moisture and salts migrate through the concrete, they reach the patch and stop. The concentration of moisture and chlorides then deteriorate the original concrete surrounding the patch. It can be speculated that a modified Jahn product will allow the moisture and chlorides to pass into the patch and rise up to the deck surface to be evaporated and blown off by passing vehicles or washed off by rain.

Figure 22 The Taftsville Covered Bridge (VTrans 2014)

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Approved Date
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Date: June 10, 2011

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS AND RESEARCH SECTION

WORK PLAN FOR RESEARCH INVESTIGATION
Assessment of Jahn Permeable Mortar System In a Historic Bridge Abutment Application
Work Plan No. WP-2011-5

OBJECTIVE OF STUDY:

As historic bridges throughout Vermont are in need of rehabilitation, more emphasis is put on preserving their distinct look while ensuring the safety and longevity of the existing structure. In many cases, it is desirable to retain the original stone and concrete masonry for historical purposes. Typically this is accomplished by removing and replacing the deteriorated grout with pointing mortars and grouts to fill in the gaps and void spaces between stones in an abutment wall. During design and construction, it is vital to account for lateral forces that may build up behind the wall from rain events, frost penetration, and groundwater. Permeable grouts and mortars allow moisture to escape and drain from within the abutment stonework ultimately reducing the risk of lateral instability due to hydrostatic pressure buildup. In addition, the mortar must adhere to specific strength and stiffness requirements. Finally, the designed mortar system must have a lower compressive strength and a greater vapor permeability than the masonry abutments (1).

The purpose of this study is to examine and evaluate the impacts of the constructability, overall performance, and life cycle cost of a permeable mortar system that will be designed by Cathedral Stone Products specifically for the upcoming Taftsville covered bridge rehabilitation project, Woodstock BHO 1444(52). Research personnel will assess the product's durability in a bridge abutment application. A comparative analysis will be made with regards to performance, cost, and on-site construction time savings of the experimental products versus standard rehabilitation practices. The constructability benefits will be weighed against construction costs.

BACKGROUND:

On October 8th, 2009, a meeting was held with the Historic Covered Bridge Committee concerning the Taftsville covered bridge in Woodstock, VT. Cathedral Stone Products provided a presentation on custom grout products with consideration to porosity, compression strength, and the ability to expand and contract in relation to the specific types of stone in the pier. The minutes of the meeting highlighted the following topics related to their material and the project. The items below were extracted directly from the minutes (2).

(1) The composition of the mortars the company develops always varies according to the type of masonry – stone or brick.

(2) Amount and Type of Cement. Both the amount and type of cement used in the mortar will be carefully controlled. The final product must be breathable and avoid producing efflorescence. High quality white Portland cement is recommended but without salt content.

(3) Pointing. Pointing some of the stones will be difficult. The pointing shouldn't be visible, but inserting it deeply enough so that it doesn't shift but still allows moisture and salt to pass through it will require care for some areas of the pier.

(4) Grouting. Preparing the grout will be comparatively simple and test samples are developed. However, the entire pier must be cleaned by flushing in order to promote adherence, and the methods used for flushing the pier will be especially important. Testing will be conducted to determine the extent to which the grout flows through the pier adequately. Formal weep-tubes may not be necessary – the grout has a tendency to find its own way out, and the holes are then plugged with clay temporarily. The process of inserting the grout should begin from the bottom up, and occur in stages as the grout solidifies and cures.

(5) Calculating Composition of Grout. The stone will be tested first for compression, porosity, and properties of expansion and contraction, and the grout will then be developed accordingly. The company has learned that replicating original mortars is not always appropriate because those original mortars may not be a good match for the masonry. Compression strength must always be less than that of the masonry. Moisture should be allowed to escape the same day that it enters the mortar, and water/vapor transmission tests are not particularly useful if that goal isn't being met. In sum, the mortar must be very breathable. The mortar must also be elastic enough to fill joints when the masonry shrinks. In sum, the mortar must match or exceed the movement of the masonry.

(6) Quality Control. Inspection of progress should be included in the contract specifications to assure quality control. In addition to adequately cleaning of piers prior to application of the grout, excess grout must be cleaned from stone immediately during the grouting process and not allowed to harden. A resident engineer will be available to oversee quality control.

Also, according to the minutes, the Members of the Historic Covered Bridge Committee were in favor of using the Cathedral Stone Products system and reached consensus that its use may be the best approach.

This mortar system has been utilized on other non-VTrans projects throughout Vermont on a wide array of projects.

- Norman Williams Library (Woodstock)
- Vermont Veterans Home (Bennington)
- Vermont State House (Montpelier)
- Shelburne Farms (Shelburne)
- Starr Library (Middlebury College)
- Lakeview Cemetery (Burlington)

LOCATION:

Jahn Permeable Mortar will be used on a covered bridge project, Woodstock BHO 1444 (52), Taftsville Covered Bridge. The bridge is located on Town Highway 2, Taftsville Covered Bridge Road, roughly 0.02 miles easterly from its intersection with US 4 in the town of Woodstock. Proposed work includes bridge rehabilitation including retrofit of timber superstructure and repair of masonry foundations.

The bridge was originally built in 1836 with the last major reconstruction occurring in 1952. It is a 198 ft. long, 14.8 ft. wide single lane covered bridge, spanning the Ottauquechee River. The bridge was rated as stable for scour as of the 2010 inspection. Average annual daily traffic (AADT) at the location of this bridge was 1500 vehicles as of the 2008 reporting.

Inspection summary notes during the 2010 inspection indicated, "The structure is in need of full rehab due to a heavy sag in span No. 2, twisted arches in both span areas, significant horizontal sweep of both spans towards the downstream channel and overall racking of the structure towards the downstream channel." The summary for the previous inspection in 2008 reference the abutments and piers, and states "Abutment #1 upstream wing and stem are quite unstable. The pier is somewhat unstable on the upstream side."

PROPOSED WORK:

According to McFarland Johnson, the consultant performing analysis on the bridge, the following improvements to the abutments have been recommended (3):

- Retain existing concrete abutment bridge seats
- Incorporate wedged, recessed stainless steel ties at the stem faces
- Seal concrete encasement cracks with an approved sealant
- Where appropriate, repoint voids in abutment and pier faces with stone
- Point stone masonry with permeable mortar (in stem areas only)
- Place consolidation grout in abutment AND PIER stems
- Install vertical tension anchors at the pier

All proposed work will be incidental to pay items special provision (repairing stone masonry abutments) and special provision (repairing stone masonry pier).

MATERIAL:

The Jahn M110 Permeable Pointing Mortar (4) and Jahn M40 Crack Injection Grout (5) is manufactured by Cathedral Stone Products.

Jahn M110 is a single-component, cementitious, mineral based pointing mortar, formulated for restoration of mortar joints in masonry. The mortar is completely vapor permeable and is formulated to have a lower compressive strength than the surrounding masonry. Jahn M40 is designed to fill and repair both cracks and voids using low pressure mechanical or gravity fed equipment.

COST:

According to McFarland Johnson, the estimated quantities and material cost for the Jahn permeable mortar system will be as follows:

• 100 pails of Jahn M110 pointing mortar	Cost: $ 4,700
• 4,300 cubic feet of Jahn 40 grout	Cost: $344,000
	Total Cost: $348,700

SURVEILLANCE AND TESTING:

The experimental mortar system will be monitored during placement in accordance with the Agency's "Standard Specifications for Construction" as well as the manufacturer's specifications. The evaluation shall include the following:

1. A preconstruction site visit will be conducted to characterize the preconstruction condition of the bridge abutments. All observations will be recorded along with photo documentation.

2. Installation will be monitored on-site for at least a portion of the process. Contact will be made with the product representative(s) onsite and with the Resident Engineer to document all construction observations and/or concerns. Written and photographic documentation will be taken. The total quantity of product used for this structure will be documented along with material and labor costs.

3. Site inspections will be completed at least biannually after the installation to monitor the condition of the abutments. As precipitation and freeze/thaw cycles will be the most detrimental to the effectiveness of the material, one set of visits will preferably be performed during the springtime thaw. Observations about the general performance and appearance of this test area will be recorded, along with comments detailing the differences and similarities between these and conventional Vermont approaches including a cost comparison.

    4. Laboratory Testing

a. Compressive Strength – The neat material shall exhibit a minimum 3 day compressive strength of 17.2 MPa (2500 psi), a minimum 7 day compressive strength of 24.1 MPa (3500 psi) and a minimum 28 day compressive strength of 34.5 MPa (5000 psi) when tested in accordance with AASHTO T106.
b. Freeze-Thaw Durability – Resistance to rapid freezing and thawing shall be determined in accordance with AASHTO T 161. Procedure A, as modified by the Agency's Materials and Research Section for use of a 3 percent sodium chloride solution. The material shall exhibit no more than an 8 percent loss in mass (weight) after 300 cycles.
c. Volume Stability – The material shall exhibit a maximum height change of +0.3 percent and a minimum height change of 0.0 percent when tested in accordance with ASTM C 1090.

STUDY DURATION:

The project will be under evaluation for the length of time required to obtain valid conclusions on the performance and effectiveness of the Jahn permeable mortar system, but not less than three years.

PROJECT SCHEDULE:

It is anticipated the project will be advertised for construction in July 2011. Construction is anticipated to begin later in 2011.

REPORTS:

An initial report will be prepared after installation is complete. A final report will be published once the evaluation is complete, between three to eight years of service life as deemed appropriate, to adequately evaluate the systems performance.

Reviewed by: Christopher C Benda For

William Ahearn, P.E.
Materials and Research Engineer
Date: 8/5/2011

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