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AGENCY OF TRANSPORTATION

ASSESSMENT OF THE BDM WATERPROOFING MEMBRANE SYSTEM

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16. Abstract
Concrete bridge deck deterioration is one of the most extensive bridge maintenance problems affecting service life. Moisture and chloride intrusion can accelerate concrete bridge deck distress. Waterproofing membranes, when applied properly, extend the life of the bridge decks delaying the need for rehabilitation. They do this by preventing the penetration of chloride ions and other corrosives that ultimately lead to deterioration of the reinforcing steel and concrete. However, the waterproofing membranes can be difficult to apply and may be punctured or damaged during the construction process. Damaged areas readily allow for the penetration of contaminants, which are not easily expelled as they become trapped below the membrane. Additionally, bridge membranes, like all materials, age and need replacement, a process that requires specialized equipment and skill to remove the bituminous concrete pavement and underlying membrane without causing damage to the underlying concrete bridge deck. Overall, anecdotal evidence suggests varying degrees of success with respect to application, durability, and overall effectiveness.

Bridge membranes may be comprised of various materials, each with unique characteristics including method of application, bond strength, compressibility, and tensile strength. This study used a spray-on polyurethane membrane waterproofing system produced by Bridge Preservation LLC called Bridge Deck Membrane (BDM). Annual site visits show no evidence of deterioration or membrane penetration. Thus far, the BDM system has performed as expected, and with little issue.

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Abstract

Concrete bridge deck deterioration is one of the most extensive bridge maintenance problems affecting service life. Moisture and chloride intrusion can accelerate concrete bridge deck distress. Waterproofing membranes, when applied properly, extend the life of the bridge decks delaying the need for rehabilitation. They do this by preventing the penetration of chloride ions and other corrosives that ultimately lead to deterioration of the reinforcing steel and concrete. However, the waterproofing membranes can be difficult to apply and may be punctured or damaged during the construction process. Damaged areas readily allow for the penetration of contaminants, which are not easily expelled as they become trapped below the membrane. Additionally, bridge membranes, like all materials, age and need replacement, a process that requires specialized equipment and skill to remove the bituminous concrete pavement and underlying membrane without causing damage to the underlying concrete bridge deck. Overall, anecdotal evidence suggests varying degrees of success with respect to application, durability, and overall effectiveness.

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1. Introduction

The purpose of this study is to examine and evaluate the impacts of the constructability, overall performance, and life cycle cost of a spray applied polyurethane membrane waterproofing system produced by Bridge Preservation LLC called Bridge Deck Membrane (BDM). Reportedly, this product system may alleviate many of the drawbacks (limited placement conditions such as temperature and moisture constraints, some installation difficulties, and possible shoving of the hot mix asphalt overlay in some high-sloped applications) with respect to ease of application along with increased waterproofing capabilities. The system can be applied horizontally, vertically, and overhead and provides no seams to seal as are found with sheet membranes. Another important aspect of the finished membrane is that it is reported, by the manufacturer, to be resistant to damage from punctures and tearing.

The objective of this project is to assess the product's performance in a very specific bridge deck application. The bridge in which the system is to be installed is part of a rapid construction project, which will be performed during cold winter months. The bridge was damaged by Tropical Storm Irene during the summer of 2011 and needed to be repaired to serviceability during months where it is unfavorable to use a torch applied sheet membrane product as was typically specified by the Vermont Agency of Transportation.

The rationale behind using this product was based on two factors. First, the producer claimed the product can be applied in temperatures as low as -20°F without effect on set up time or curing. This can be very important for construction activities during Vermont's winter months. The manufacturer has affirmed the suitability of placement conditions at low temperatures, provided that the surface moisture content is below 5%. The second factor involved the timing of asphalt placement. Since this was a winter application, the bridge could not be paved over with asphalt immediately. The product provides for an aggregate to be placed over the surface to act as a wearing surface until pavement could be applied in warmer months later in the spring. According to the manufacturer, the membrane can withstand punctures from aggregate in this configuration, and if any were to occur, the membrane could be easily repaired with further spraying

2. Project Location and Summary

2.1. Project Location Description

The BDM system was used on one bridge replacement project, Warren ER-STP 013-4(36), bridge number 165 on VT 100 in the town of Warren, 50 feet north of the Warren and Granville town line (Figure 1). The bridge was produced under rapid construction techniques. The bridge is 21 feet long by 34 feet wide and has a reported average annual daily traffic (AADT) of 980.

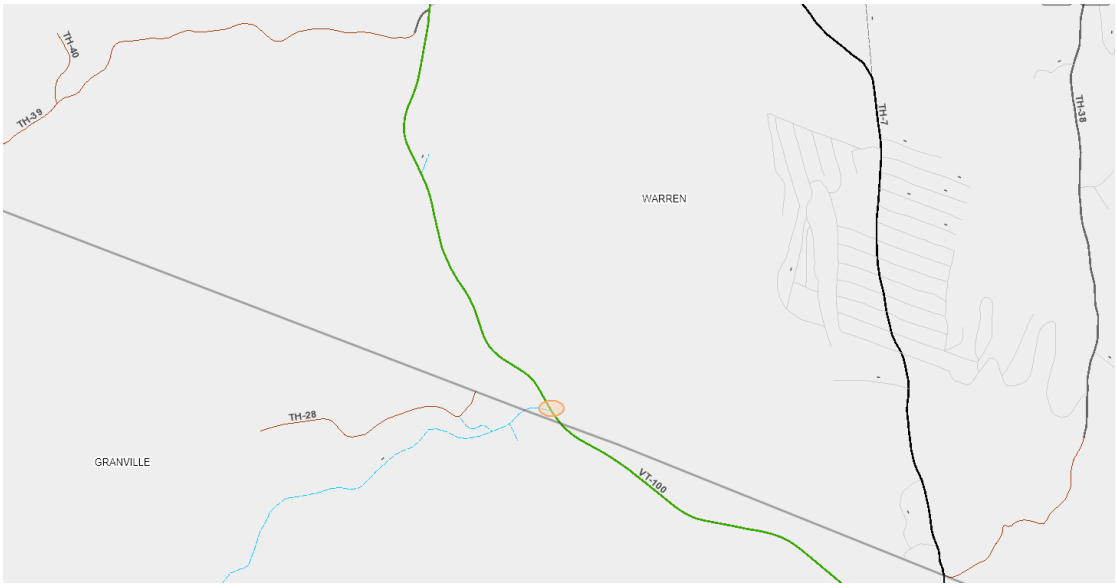

Figure 1: Location of Project, bridge 165 in the town of Warren

2.2. Material Description

BDM is a product of Bridge Preservation LLC. According to product literature [1], the complete system consists of a primer used to penetrate and seal the substrate, enhancing the system's bond to the deck and the membrane; and a polyurethane membrane that provides 100% effective waterproofing. Optional components could include a top coat, which would allow for the addition of an aggregate top coat or a tack coat which would provide adhesion of asphalt to an aggregated top coat (not utilized as part of this evaluation).

There are several reported benefits of this cold spray applied system as listed in the product literature, including:

- Consistent thickness when applied over irregular substrates
- No seams to seal, unlike those required in order to prevent leaks with pre-formed sheet membranes
- No powdered catalyst to measure and add at the jobsite by workers
- Can be applied horizontally, vertically, and overhead
- Can be used in close proximity to the public and other trades without issue
- Will not allow water vapors through the membrane
- Will accommodate both low and high temperature substrates
- Resists damage from punctures and tearing
- Can accept ballast and asphalt overlays within one hour of placement
- Electrically isolates decks from stray current

Of these, the major benefit to Vermont in this application is the product's ability to be applied in a wide range of temperatures and weather conditions; the recommended temperature range for application begins at -20°F. Due to its formulation it cures very rapidly, even in sub-freezing temperatures. When applied to dry surfaces, even in the middle of winter, the membrane reportedly can be ready for surfacing after only one hour.

2.3. Cost

According to RJ Watson, a primary distributor of the product, the estimated installed cost (material and labor) for the BDM system will be approximately $6.00 to $8.00 per square foot. For the proposed deck, 21 feet long by 34 feet wide, this results in a final installed cost of approximately $4,300 to $5,700.

3. Construction

The bridge was completely replaced using rapid construction techniques. The selected bridge structure was a precast rigid frame, provided by S. D. Ireland in an outdoor containment structure. Traffic was detoured around the preexisting structure starting on February 1, 2012. New structure placement was conducted over the next six weeks. The BDM membrane was installed on March 12, 2012 by G. S. Bolton as the subcontractor, with manufacturer and Materials and Research representatives on hand to observe.

The temperature at the time of membrane placement ranged from approximately 50-55°F. This is important to note, as a primary reason that the use of this spray applied membrane was requested for the project was its ability to be placed in very cold conditions. Being a late winter project, it was expected that the temperature would be at or below freezing during installation. As temperatures were considerably higher than freezing, the product's ability to handle cold weather installation was not able to be observed or verified.

On the day of membrane application, the surfaces which it was to be applied to were shot blasted and cleaned thoroughly. Foam backer rods were wedged into any open joints. The primer was rolled on all surfaces (Figure 2), followed by the membrane application. The membrane was sprayed onto all surfaces, using a mechanized spraying apparatus in a truck, hoses, and nozzles (Figure 3). The membrane is bright orange in color, which makes it easier to observe if all surfaces have been covered to a uniform nominal 80 mil thickness.

Once cured, gravel was placed on top of the membrane over the subsequent two days, to act as the travel service until the bridge could be paved over during warmer weather months. The bridge was open to traffic on March 17, 2012. With

the onset of warmer weather in May, the bridge was again closed to traffic to begin paving activities. Once the gravel was removed from the bridge deck, GS Bolton performed an inspection of the membrane on May 23 to ensure the gravel did not puncture or cause any weak spots. The membrane was deemed to be in good shape, with no damage from the gravel evident (Figure 4). Binder and base courses of asphalt were placed on the bridge and approaches on June 6, and the top course on June 18, 2012.

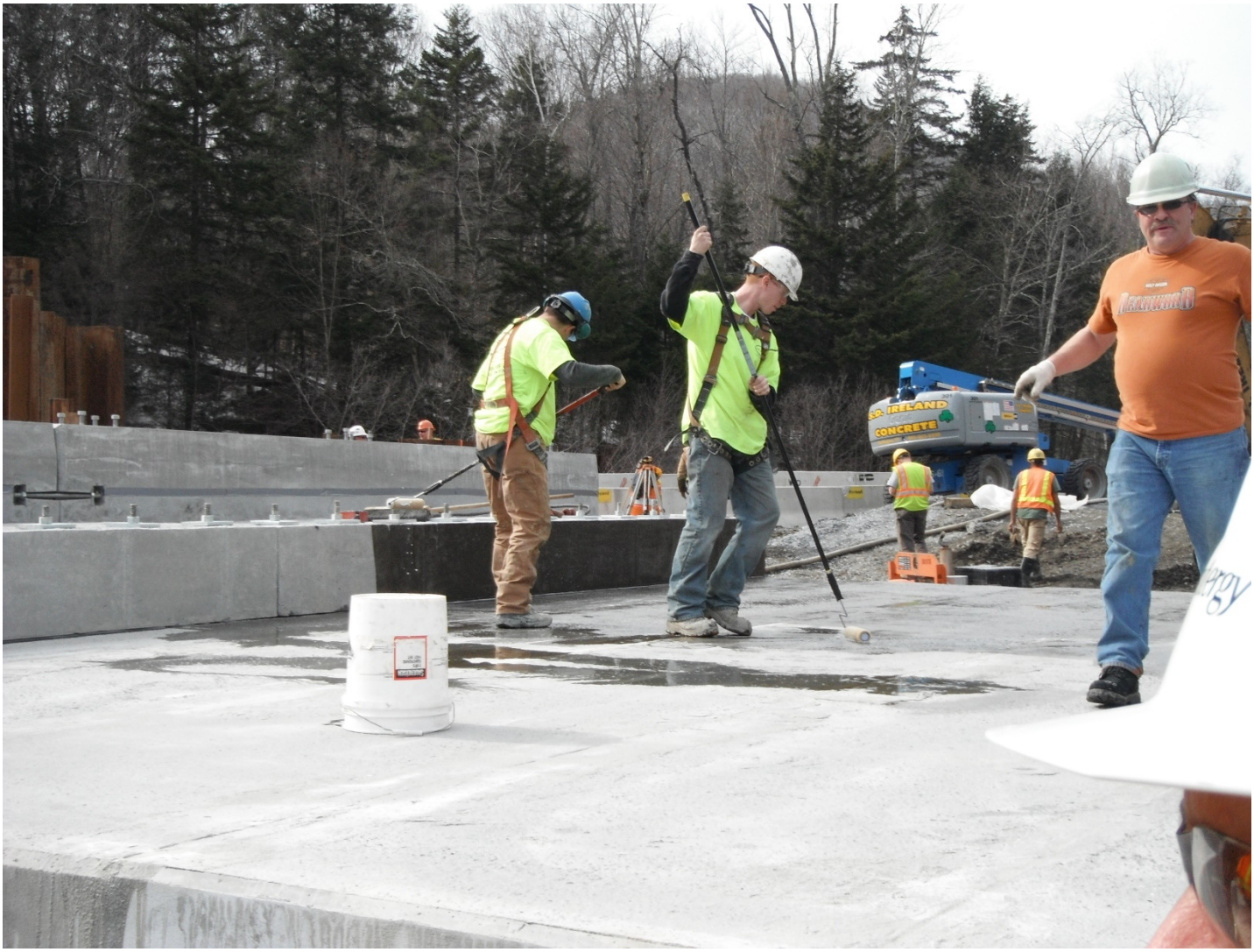

Figure 2: Installation of the BDM system, application of the primer (March 12, 2012)

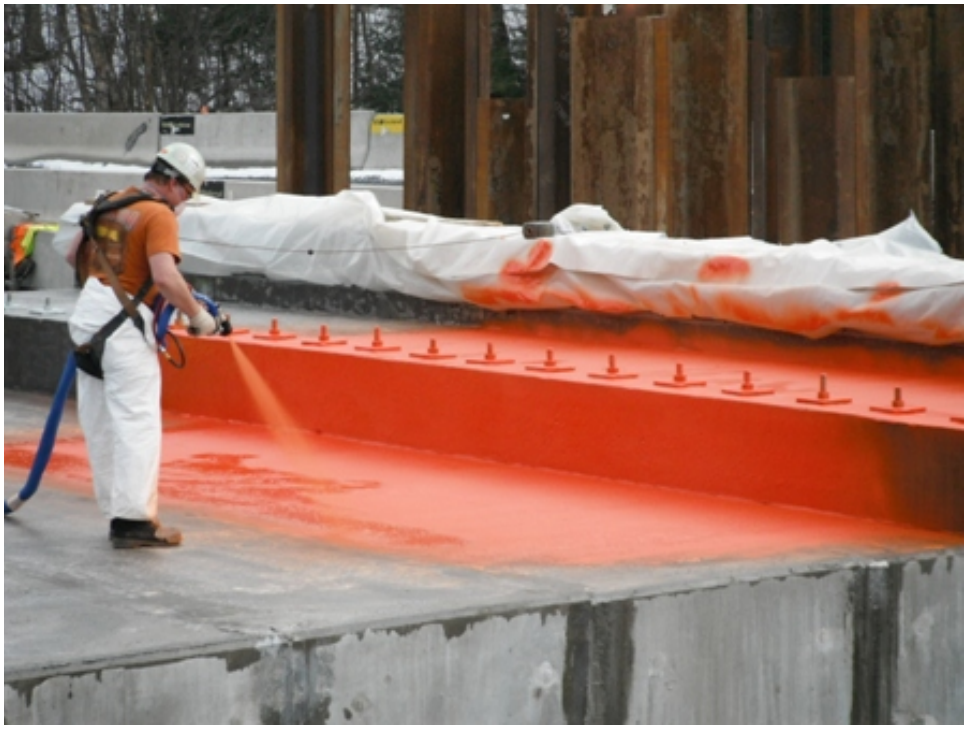

Figure 3: Application of the spray-on membrane (March 12, 2012)

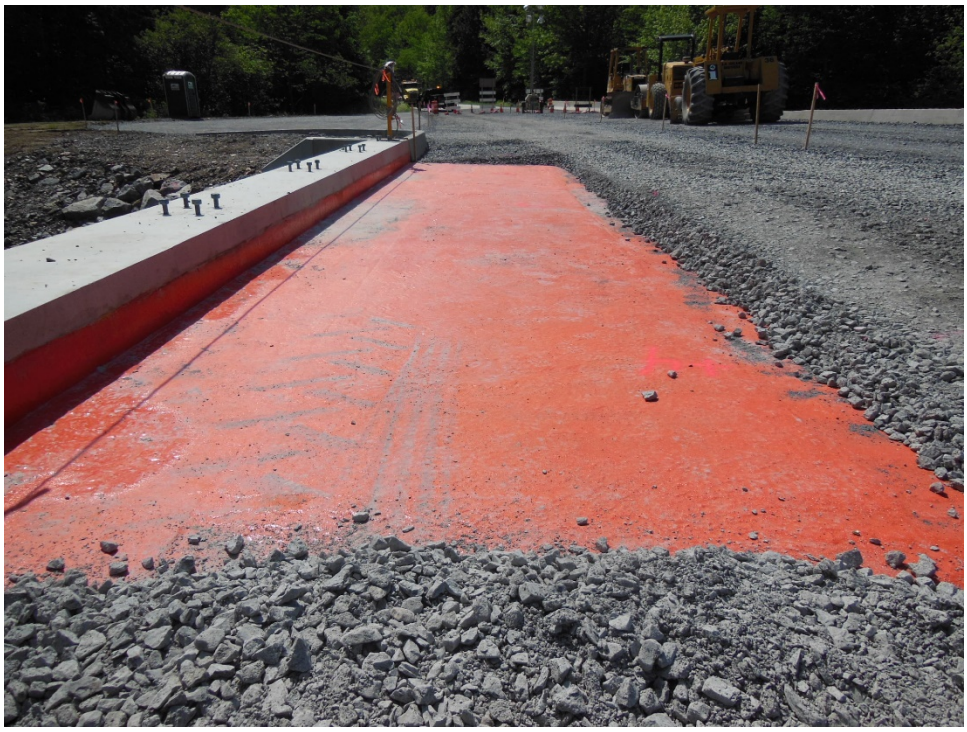

Figure 4: BDM with gravel cover (June 1, 2012)

4. Performance and Observations

The Research Section made several site visits to assess the condition of the project, to note changes and deficiencies in the pavement and membrane, and document performance.

A brief site visits approximately one year after construction noted no damage or deficiencies in the pavement or membrane.

A site visit to bridge was conducted on June 2nd, 2016, four years after construction. Observations and photos on the performance and appearance of the BDM after installation were collected and can be seen in Figures 5 - 12. Figures 1 & 2 show the overall view of Bridge 165 from both sides. Figures 6 – 10 show the overall condition of the bridge deck overlay. Figure 11 shows evidence of the BDM on the side of the asphalt overlay. Figure 12 shows a close-up view of the underside of the concrete bridge. Figures 8 and 9 show longitudinal cracking on the bridge overlay.

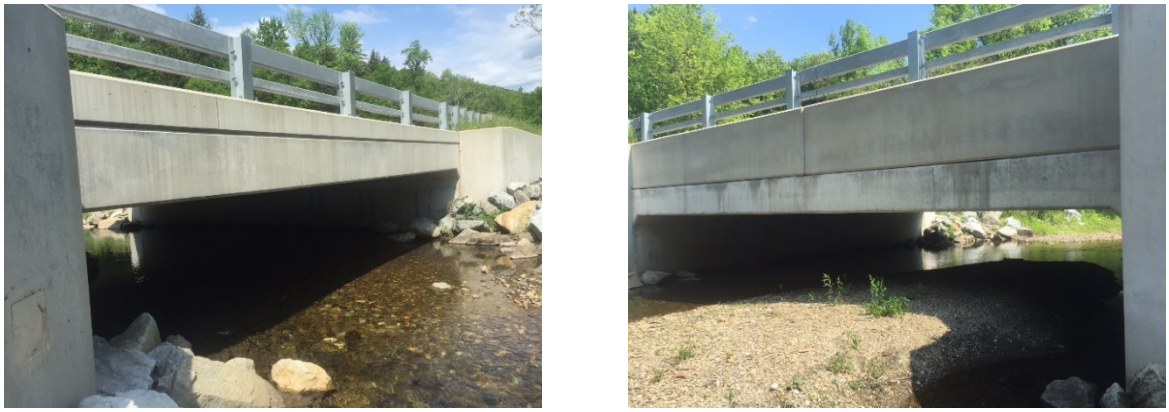

Figure 5: Overall view of Bridge 165 on VT 100 in Warren (June 2, 2016)

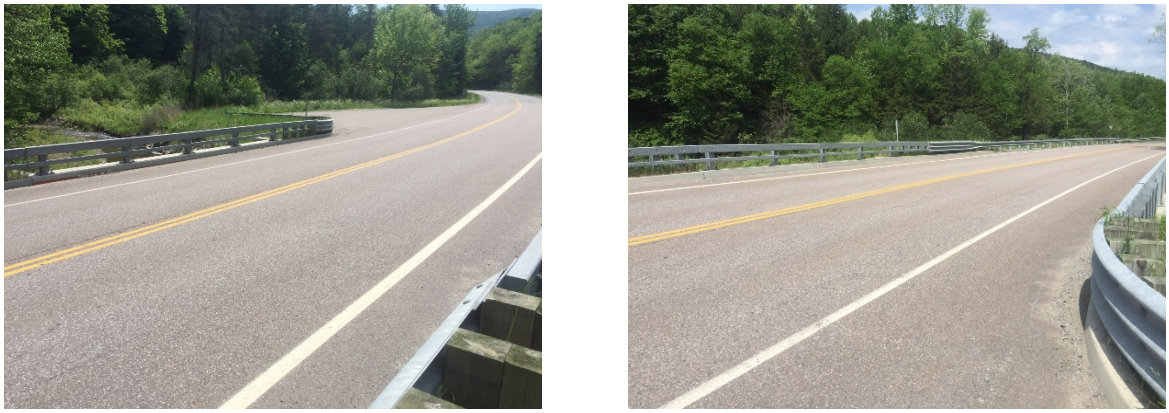

Figure 6: Overall view of bridge overlay (June 2, 2016)

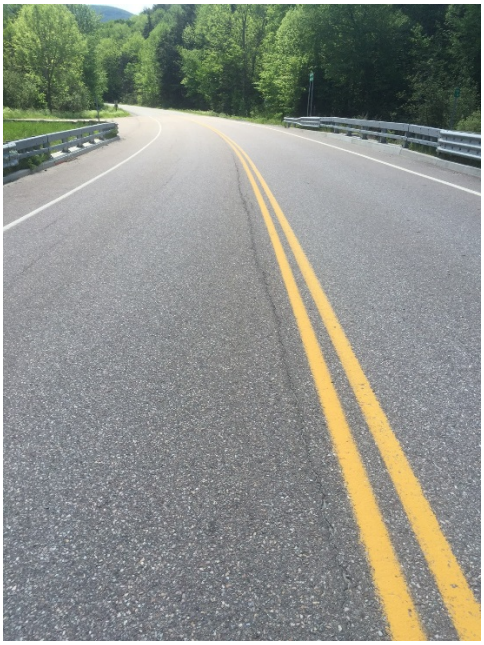

Figure 7: Centerline crack throughout bridge (June 2, 2016)

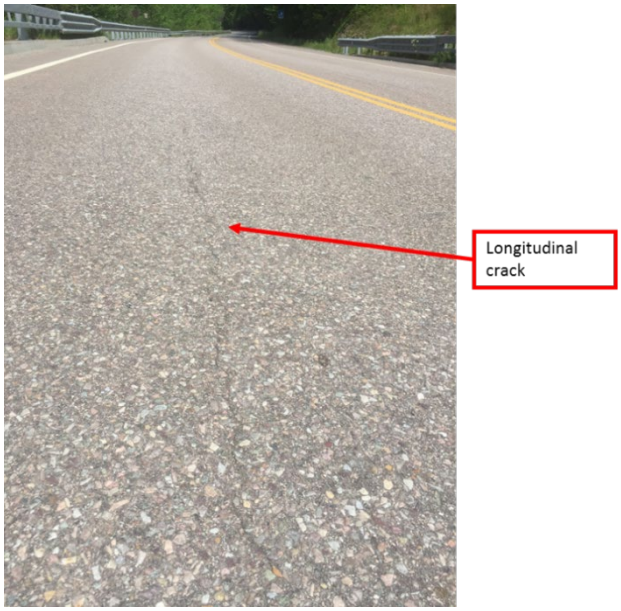

Figure 8: Longitudinal crack on southbound lane (June 2, 2016)

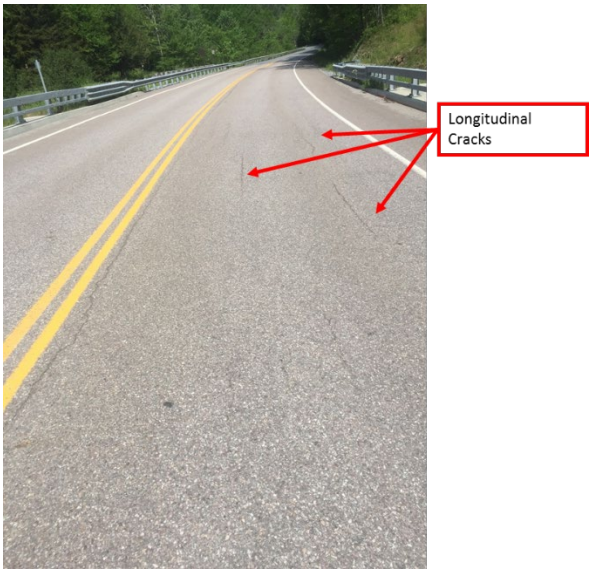

Figure 9: Longitudinal crack on northbound lane (June 2, 2016)

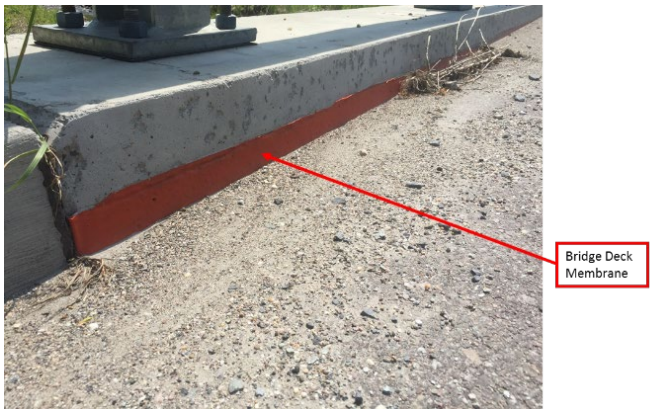

Figure 10: Bridge deck membrane (June 2, 2016)

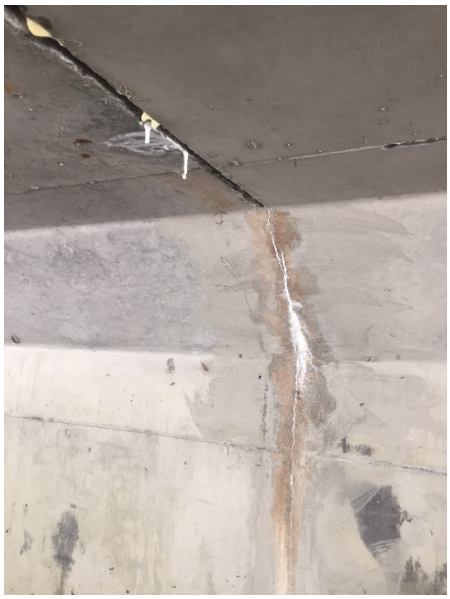
Figure 11: Bridge underside deposits (June 2, 2016)

From the visual inspection and photographic evidence, it can be said that the BDM is working and at this point it is inconclusive if the membrane is contributing to the longitudinal cracking on the bridge deck. During the inspection it was noticed that the longitudinal cracking was also occurring in the surrounding asphalt overlay, which means that the cracking could be attributed to the material properties of the asphalt overlay. While on the site visit it was noted that there was one longitudinal crack in the southbound lane and seven cracks on the northbound lane. The cracks ranged from approximately 3ft to 12ft. Figure 8 shows a centerline crack that runs the whole length of the bridge. Figure 11, which shows the underside of bridge 165, depicts some sort of white material seeping through bridge deck joints and cracks and depositing on the underside of the bridge. The depositing material is most likely chloride or salt from de-icing the roads during the winter season. The condition of the bridge deck is good in general, and further studies of the bridge deck would have to be conducted to determine if the BDM is contributing to the bridge deck cracking.

A site visit to bridge 165 in Warren was conducted on August 15th, 2017. Observations and photos on the performance and appearance of the Bridge Deck Membrane (BDM) after installation were collected and can be seen in Figures 12 - 19. Figures 12-14 show the overall view of Bridge 165 from both sides. Figures 15 – 18 show the overall condition of the bridge deck overlay. Figure 18 shows evidence of the BDM on the side of the concrete curb above the asphalt overlay. Figure 19 shows a close-up view of the underside of the concrete bridge and the wood debris that has collected on the north end, which can also be seen in Figure 14. Figure 17 show longitudinal cracking on the deck overlay.

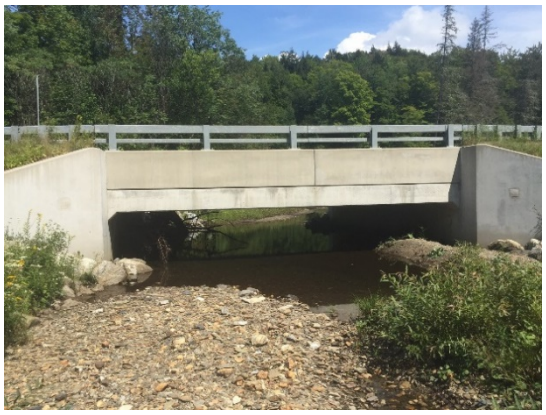

Figure 12: View of Bridge 165 on VT 100 in Warren, right side (August 15 ,2017)

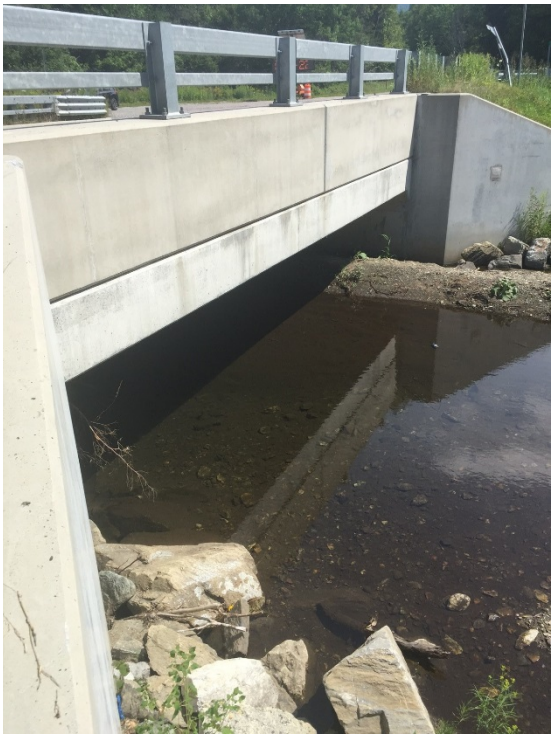

Figure 13: View of right side of bridge, facing south (August 15 ,2017)

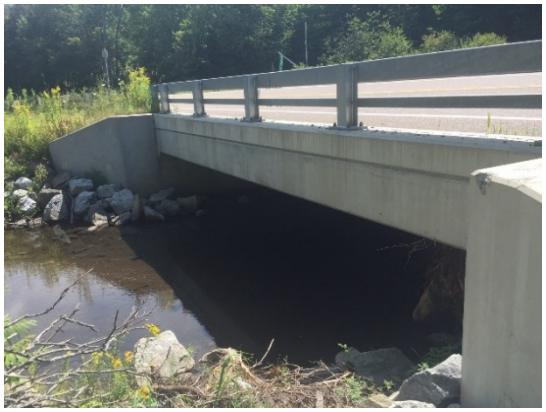

Figure 14: View of left side of bridge, facing north (August 15 ,2017)

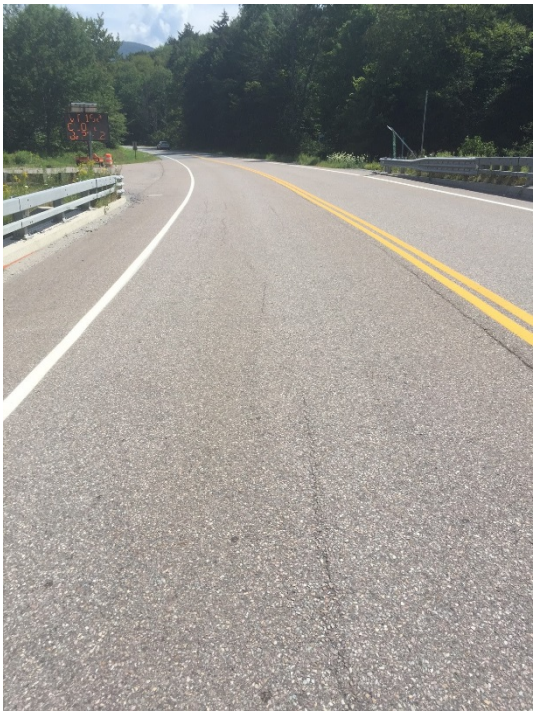

Figure 15: View of bridge overlay, looking south (August 15 ,2017)

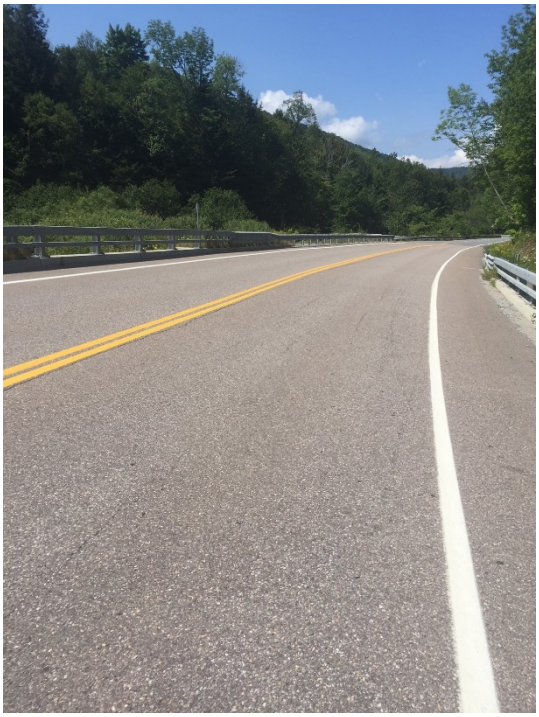

Figure 16: Bridge Overlay, looking north (August 15 ,2017)

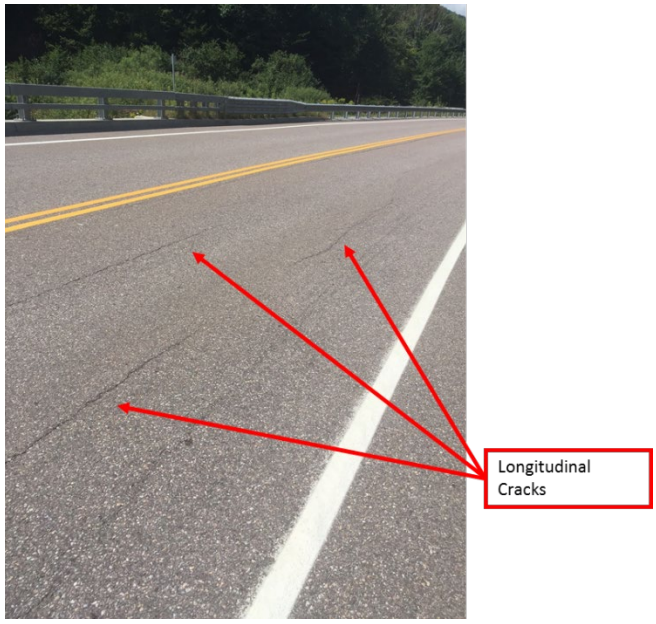

Figure 17: Longitudinal crack on northbound lane (August 15 ,2017)

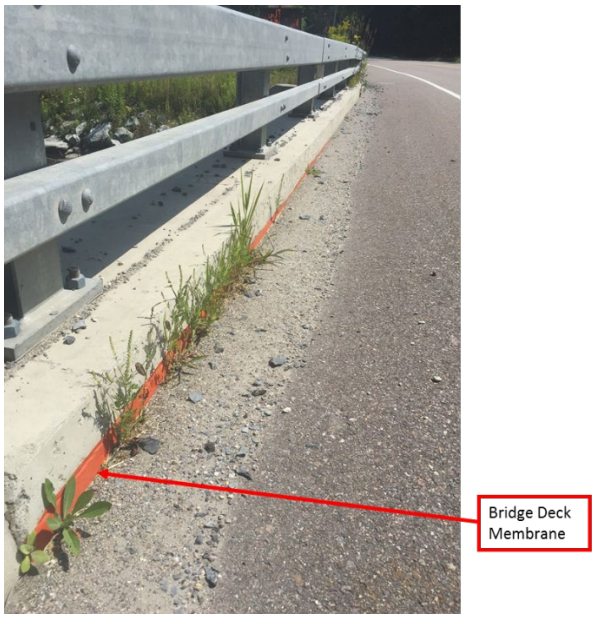

Figure 18: Bridge deck membrane (August 15 ,2017)

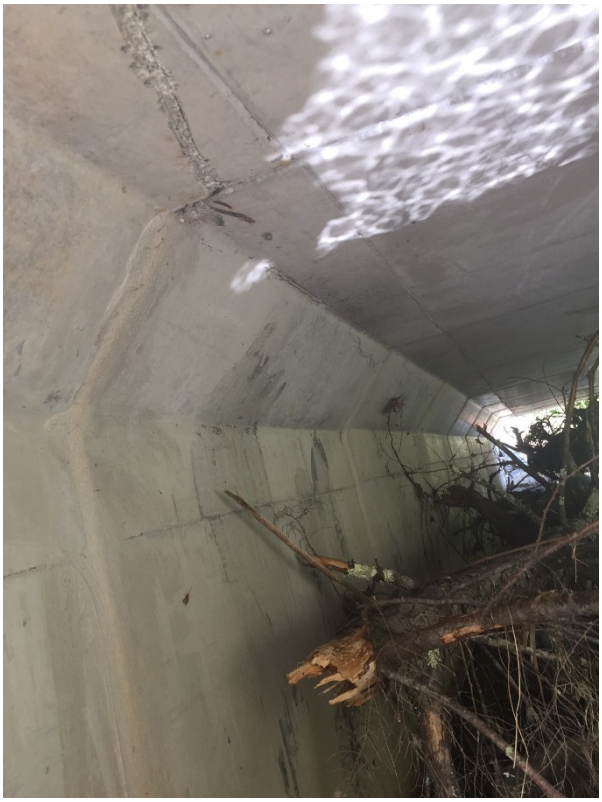

Figure 19: Underside with debris (August 15 ,2017)

From the visual inspection and photographic evidence, the BDM has been working properly. The only signs of deterioration are several longitudinal cracks on the pavement surface. As previously stated from the 2016 field visit, it was observed and monitored that the longitudinal cracking occurring in the surrounding asphalt overlay, again emphasizing the fact that the cracking could be attributed to the material properties of the asphalt overlay and not the bridge deck membrane. The site visit showed the single longitudinal crack on the southbound lane and eight longitudinal cracks on the northbound lane. The crack on the southbound side was located on the south end of the bridge, in the center of the wheel path, and was approximately 12ft long. The northbound lane had two cracks in the wheel path and one between the wheel paths, three cracks near the mid-span of the bridge within the wheel path that were approximately 9, 12 and 15ft long, and two cracks on the north end of the bridge in the center of the wheel path that were 6 and 12ft long. The centerline crack that runs the whole length of the bridge was again evident.

After the initial inspection of the surface pavement on bridge 165, a subsequent inspection of the underside of bridge was done. There was no evidence of the white material seeping through the bridge deck joints and cracks that was observed and noted during the 2016 site visit. The current inspection revealed no new cracks or leaking of the underside of the concrete bridge. The inspection did yield evidence of wood debris on the north side of the bridge, which can be seen in Figures 13 & 20.

In general, the bridge deck is in good condition and the BDM membrane study has surpassed its initial (3 years) study duration. The Bridge Management and Inspection Unit conducted their last inspection on 8-2-2017 and noted that the concrete structure was in good condition. The structure inspection, inventory and appraisal sheet can be found (here) and the photos can be found (here). The observations from the field visits regarding to the performance of the BDM is evidence that the product has performed as specified and that no further monitoring is needed. Results from this study will be given to the VTrans Structures Section for consideration on future bridge designs.

To be certain that the membrane was in good condition and is not contributing to the surface cracking, core samples through the surface overlay and into the concrete deck, full deck ground penetrating radar (GPR) scans or an overlay

replacement would have to be conducted. Since the membrane shows no signs of deteriorations in either the concrete deck or debonding in the overlay pavement, additional testing was judged as unnecessary.

5. Summary and Recommendations

Over the course of five years of observations, the Bridge Deck Membrane system performed well. The first signs of wear on the asphalt overlay were first noticed during the 2016 site visit, four years after construction, and appeared in the form of minor longitudinal cracking. It is inconclusive as to whether this cracking is caused by the bridge deck membrane or by the material properties of the asphalt overlay.

During the 2016 site visit, an inspection of the underside of the bridge was done. A white material was found to be seeping through the bridge joints and depositing on the underside of the bridge. This is most likely caused by salts and chlorides collecting during the deicing process. During the 2017 site visit, a follow up inspection of the underside of the bridge was performed. No further evidence of the white material was observed and no new cracks or leaks on the underside of the bridge were found. Overall, the bridge deck membrane has performed as specified and has shown few signs of wear.

6. References

(1) "Bridge Preservation, Bridge Deck Membrane", Bridge Preservation LLC product advertisement. http://bridgepreservation.com/bridge-deck-membrane/