INVESTIGATION AND EVALUATION OF IOWA DEPARTMENT OF TRANSPORTATION BRIDGE DECK EPOXY INJECTION PROCESS

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InTrans Project:

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Preparation of this report was financed in part
through funds provided by the Iowa Department of Transportation
through its research management agreement with the
Institute for Transportation.

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Interim Report • April 2011

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ABSTRACT

Since the 1970's the Iowa Department of Transportation has used concrete overlays as a means of restoring its bridge decks and, as a result, the service life of the deck is commonly extended many years. This procedure has proven to be both effective and economically attractive. Despite that, concrete overlays cannot be considered a permanent repair as they are subjected to harsh conditions similar to the original bridge decks. As time passes the overlays often become delaminated from the original deck at or near the bond interface leading to cracking and the intrusion of water and chloride ions, which accelerate the deterioration of the bridge. A maintenance solution involving the injection of epoxy resin into the cracks and voids has been developed and this solution has been completed with success. Even so, the length of additional service life and the most effective methods and materials of injection remain unknown.

The problem is two-fold. First, a better prediction of typical expected service life must be determined to best plan for additional repair or replacement. This requires a study of both previously and newly injected bridges to identify the effectiveness and durability of epoxy injection of delaminated bridge decks. Second, the seasonal constraints imposed on the injection process coupled with the work load of Iowa DOT maintenance personnel create a logistical problem; quite simply, there is more work to be completed than can be effectively completed in the available time. A specification detailing the proper materials, equipment, and procedure must be developed to enable others to perform the work. Both field investigation and a thorough review of industry advances and practices will be used to develop the specification.

A majority of the effort for this project to date has been extended toward field investigation of previously injected bridges. The findings have been mixed thus far as there appears to be minimal evidence for what were considered to be potential indicators of overlay delamination. Still, valuable information was obtained from the field investigation. That, coupled with the national surveys, state surveys, and personal interviews should steer the study toward identifying the best practices for the State of Iowa.

1. INTRODUCTION

Background

The Iowa Department of Transportation (Iowa DOT) has been using concrete overlays on its bridge decks since the 1970's to restore the concrete deck surface and to lengthen the service life of the bridge deck. The bridge deck overlays inhibit chloride and water intrusion into the bridge deck and have proven effective as a maintenance treatment on Iowa bridges. Bridge deck overlays typically last 15 to 20 years before delamination at the bond interface requires repairs to or replacement of the overlay. The delamination of the overlay is often repaired by Iowa DOT maintenance staff by injecting the deck overlay cracks and voids with epoxy.

Anecdotal observation by Iowa DOT field staff suggests that the epoxy injection process can delay repair of the overlays by another five to ten years but currently there is no documentation to substantiate this. The process for epoxy injecting bridge deck cracks and delaminations is also not formally documented resulting in variations in materials, equipment, and procedures used in the various districts.

Annually, there is a need to perform this treatment on 120 to 180 Iowa DOT structures. Currently, this work is only performed by Iowa DOT bridge crews since there are not adequate specifications for contract treatment. Due to seasonal limitations and the work load of the Iowa DOT bridge crews, it would be beneficial to have the ability to contract for bridge deck epoxy injection when necessary.

Objective

The objective of this project will cover three main focus areas: 1) determination of the effectiveness, durability, and typical service life of epoxy injected delaminated bridge decks, 2) evaluation of the current state of the practice in the epoxy injection industry, and 3) development of procedures and specifications for epoxy injection.

Report Content

This report will focus on the efforts and progress thus far in the project; parts of objectives 1) and 2) have been completed and will be presented and discussed within. The inherent nature of objective 3) disallows significant progress at this point in the project, thus little discussion of the objective will be included in this interim report.

2. LITERATURE REVIEW

Early History

Epoxies have been used in the construction industry for only a relatively short period of time. It wasn't until the 1930's when the first known patent on epoxy was issued that several basic epoxy systems were explored and developed (ACI Committee 503). Many are used as adhesives and coatings today.

Several field tests were completed in the late 1940's and early 1950's, including the use of epoxy as an adhesive to bond two pieces of hardened concrete, a bonding agent for raised traffic line markers on concrete highways, and surfacing materials on highways (ACI Committee 503). Favorable results provided incentive to pursue the use of epoxies in other applications.

Since then, many formulations have been developed that are specific to the end-use requirements. The characteristics of epoxies are unique and have enabled their use in many applications. Epoxies adhere well to numerous surface types, have very good strength characteristics in comparison to concrete, are affected little by temperature variations, and are generally resistant to chemical attack. Even more, epoxies are resilient to abrasion and can undergo deformation and return to its original shape without ill effect provided the elastic limit has not been exceeded (ACI Committee 503).

Quality Control

Generally, careful attention should be paid to the surface preparation of injected elements. Given the nature of concrete overlays and the inability to easily access the bond surface, the likelihood of preparing the surface to ideal conditions is slim. Nonetheless, ACI has prescribed preferred conditions that can be achievable in overlay injections. First, delaminated portions should be sound, as adhering a weak surface is nothing more than a practice in futility. Second, the surfaces should be dry and clean. With epoxy injection of bridge decks this is a bit more difficult to control but properly using a vacuum bit while drilling injection ports can at least minimize any additional contamination to the delaminated plane. Third, the surface must be at the manufacturer's prescribed temperature to maximize the curing process. The properties of epoxy can significantly change if not cured as instructed (ACI Committee 503).

John Trout, the founder of the Lily Corporation, a manufacturer and supplier of products used in injecting and dispensing two-component construction epoxies, has written several articles and books detailing the practice of epoxy injection. The need for quality control is one significant point of emphasis in many of his writings. He states there are two ways of ensuring good quality; procedural specifications and performance specifications. With procedural specifications an injector can follow the best practices of epoxy injection, yet may not achieve good quality. So much is left unknown when the final product is not visible. Even more, significant resources are required to make certain the means and methods were closely followed by the injector. Performance specifications, on the other hand, enable a contractor to do what he has found to be the best method and then verify through core samples the quality of the final product. Not only is the owner assured he received the product for which he paid, but the contractor is able to evaluate his methods. Trout stresses the importance of core sampling for this very reason (Trout).

Case Studies

Even though the use of epoxy has become more popular in the construction industry, epoxy injection of bridge decks has not been a common practice in many states. Only a handful of states have ever performed bridge deck injection and even fewer have documented the successes or failures of the practice. A couple of studies have been conducted that shed some light on the subject, however.

In a study conducted in the State of Kansas (Smith), multiple bridges were epoxy injected and compared to non-injected bridges near the same location. The study successfully demonstrated that the injection of a bridge deck was a robust method of repair and that a deck remained intact especially when reinjected after four years. Continued observation was conducted for seven years after the final injection of the decks and it was determined that a deck remained serviceable and can be effectively repaired up to approximately four years after final injection. Additional injections or other repairs can be planned at this time. It was concluded that epoxy injection provides an effective method of prolonging the life of the original deck.

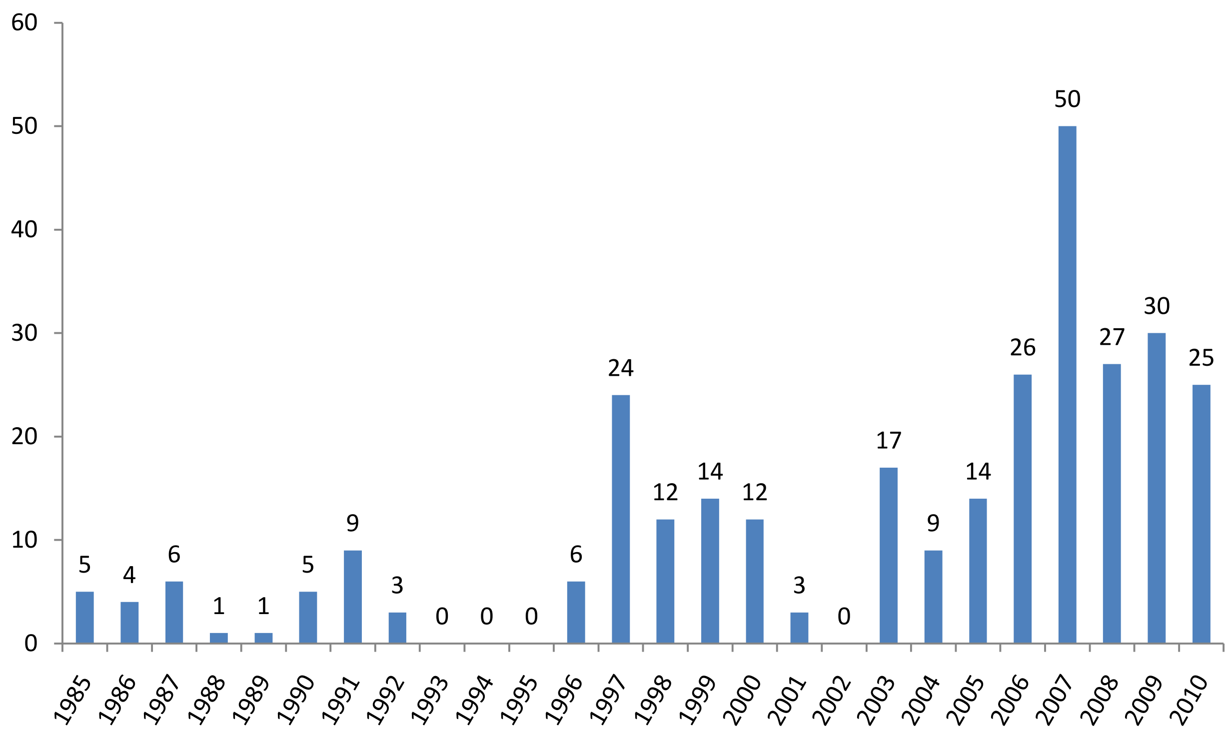
The Federal Highway Administration, Demonstration Project Team conducted a study in the State of Iowa (Whiting) which looked to extend the service life of bridge decks by rebonding delaminations with injected epoxy. In this case, a deck with a delaminated concrete overlay was injected so that the effectiveness of the repair could be determined. Several conclusions were made after observing the performance of the repairs for many years. Most notably, the repaired delaminations remained intact through five years. The portions of delaminated deck and injected areas remained nearly the same over that period of time. In comparison to other forms of deck rehabilitation or reconstruction, epoxy injection appeared to be a cost effective method if conducted at the proper time. Injection performed too early or too late could negate any cost savings.

3. PERFORMANCE EVALUATION

Field Investigation

One of the original intents of this study was to identify and conduct a performance evaluation of 30 bridge decks epoxy injected in 2003. The year was selected due in part to the observable degradation of previously injected decks at or around seven years post injection. As it turns out, fewer than 30 bridges were injected in the year 2003, thus requiring bridges injected in additional years to be included in the performance evaluation. Once the bridges which were re-injected, reconstructed, or re-overlaid were removed from consideration, the final sample was taken from bridges injected in the years 2003 through 2006. Table 3-1 presents the number of epoxy injected bridge decks in Iowa each year since 1985.

Table 3-1 Total Number of Epoxy Injected Bridge Decks in Iowa Since 1985



During the fall of 2010, 26 bridges identified as being injected between the years 2003 and 2006 were visited and a performance evaluation of each was conducted. In addition to visual inspection of the deck surface, sounding of the concrete overlay was completed. Sounding the deck was performed by dragging chains and hammer tapping; delaminated portions of the overlay are revealed by tonal fluctuations. Though this process cannot be considered highly scientific, it has been widely accepted as a standard practice for locating delaminated sections. Figure 3-1 shows the tools used while sounding the overlays. Included are: a chain drag, chain whip, five-pound maul, and masonry hammer.

Figure 3-1 Delamination Detection Tools

A map locating the delaminated portions of the overlay was generated upon completion of sounding. This was achieved by creating a grid of the entire bridge deck surface and transferring the located delaminations to a corresponding grid created on the map. The map shows the locations and sizes of delaminated portions of overlay, and generally gives a snapshot of the overall health of the surface. From these maps data were collected and used to analyze the group of bridges. An example of a delamination map is provided in Figure 3-2.

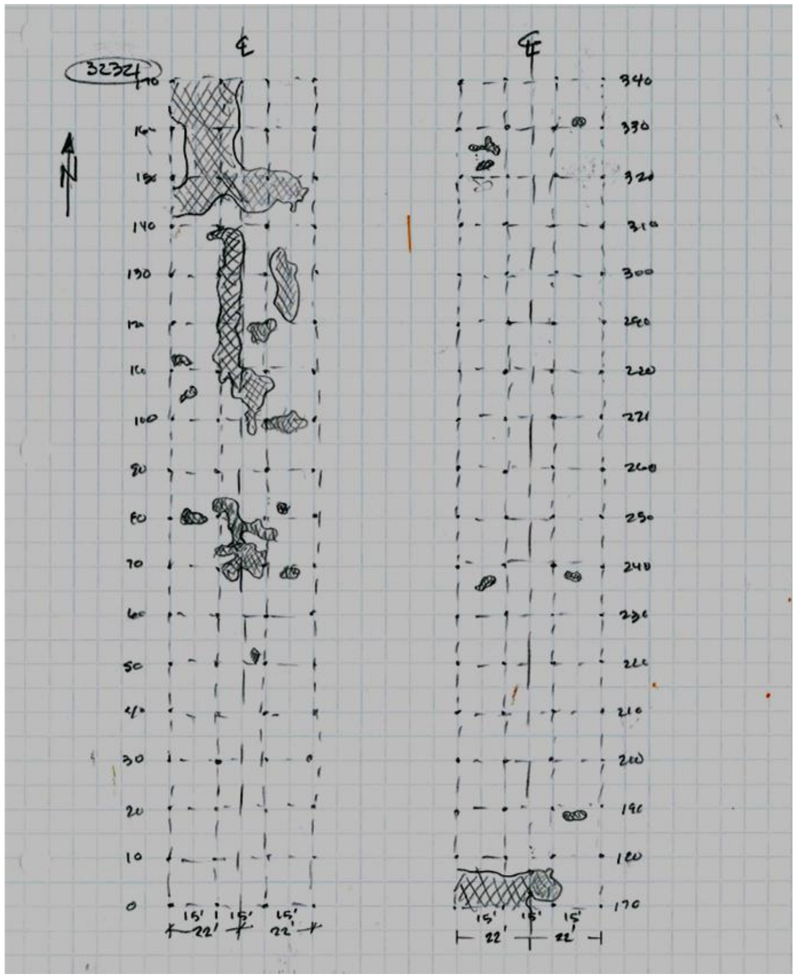


Figure 3-2 Typical Delamination Map

In addition to sounding the deck, photographs were taken to visually document the surface condition. Figure 3-3 shows an example of conditions seen at many of the bridges. It was common to find delaminated portions of the overlay at or very near locations where both longitudinal and transverse surface cracking was present. It appears that cracking often results in delamination and vice versa, as intuition would suggest. Additionally, delaminated portions of the deck often appeared to originate where cold joints are present, such as at the centerline of bridge. This agrees with the cases of cracking as cold joints are another port of entry for water and chloride ions. Even more, the condition of the overlay was commonly the poorest where the bridge approach slab met the overlay. This may be due to several factors including: water entry at approach slab-overlay interface, snow plow impact, or magnified localized stresses attributable to thermal behavior (especially at acute angle portions of skewed decks).

Figure 3-3 Photographic Documentation of Delamination

<u>Information Synthesis</u>

Once the bridge visits were completed, the cumulative information was studied for any observable performance trends with anticipation that a trend would be discovered and a dependent variable would be identified. Table 3-2 presents the variables which were evaluated. Plots were created for each case to see what, if any, variables may predict the performance of the overlay (See Figure 3-4). Unfortunately no appreciable trends were discovered.

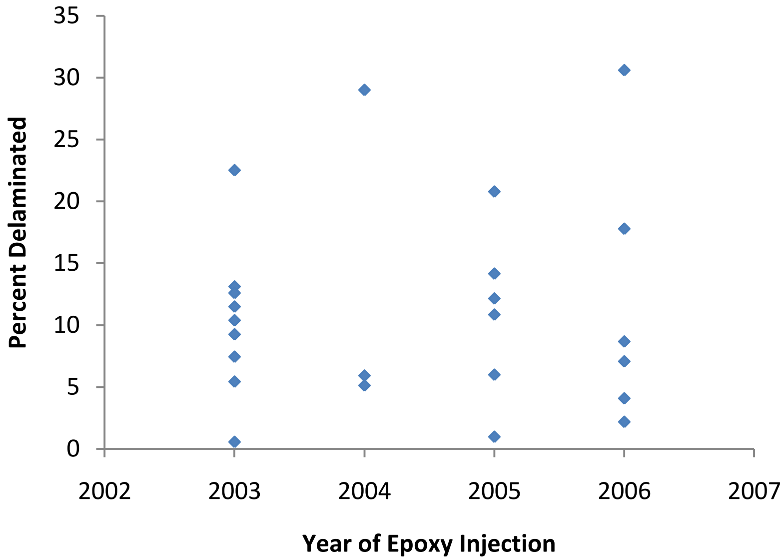
It should be noted that there was valuable information gleaned from the field evaluations even though specific trends were not discovered. The general condition of epoxy injected overlays is revealed through some key metrics which are presented in Table 3-3. Knowing that on average only 11 percent of the total deck surface is delaminated may give evidence for the effectiveness of the epoxy injection procedure. This is especially evident knowing that each of the bridges evaluated in this study has been injected between five and eight years ago. Overall, the injections collectively appear to be performing well through eight years of service. This observation agrees with that by the DOT bridge crews. As was previously stated, the bridge crews have suggested the epoxy injection can delay repair of the overlays by five to ten years.

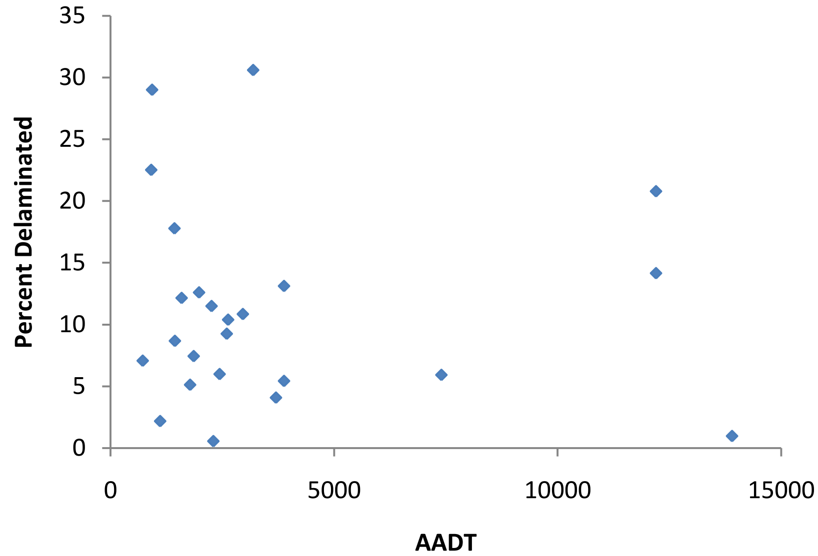
Table 3-2 Field Evaluation Information Studied for Observable Trends

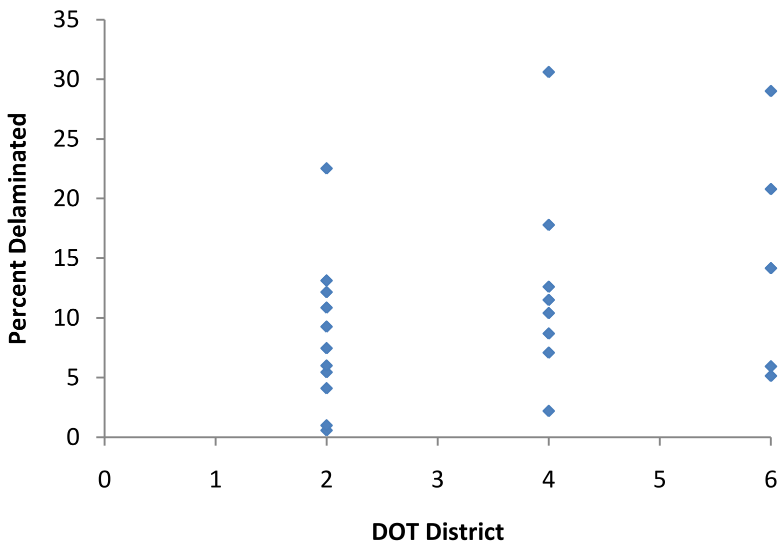
Independent Variable	Dependent Variable
Year of Epoxy Injection	Percentage of Delaminated Portion of Deck Overlay Total Number of Individual Delaminations Total Number of Individual Delaminations per sq.ft.
Annual Average Daily Traffic	Percentage of Delaminated Portion of Deck Overlay Total Number of Individual Delaminations Total Number of Individual Delaminations per sq.ft.
DOT District Number	Percentage of Delaminated Portion of Deck Overlay Total Number of Individual Delaminations Total Number of Individual Delaminations per sq.ft.
Year of Bridge Construction	Percentage of Delaminated Portion of Deck Overlay Total Number of Individual Delaminations Total Number of Individual Delaminations per sq.ft.

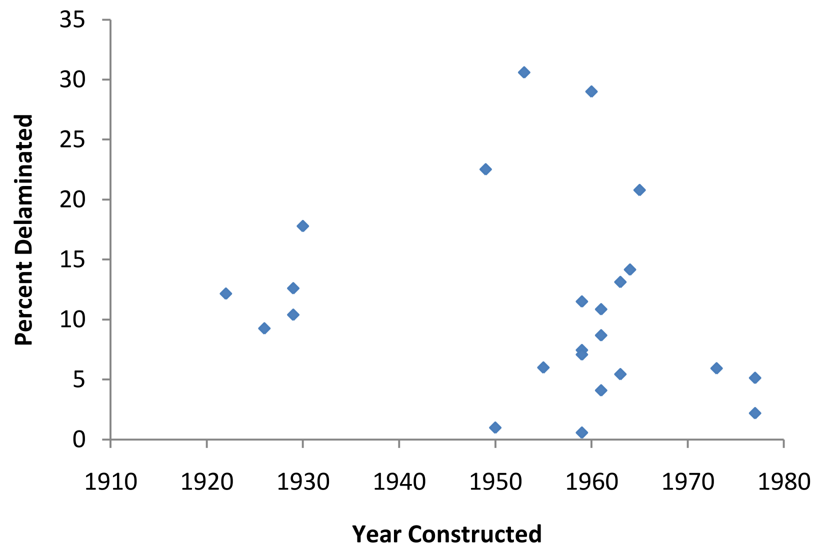
Table 3-3 Notable Information from Field Evaluations

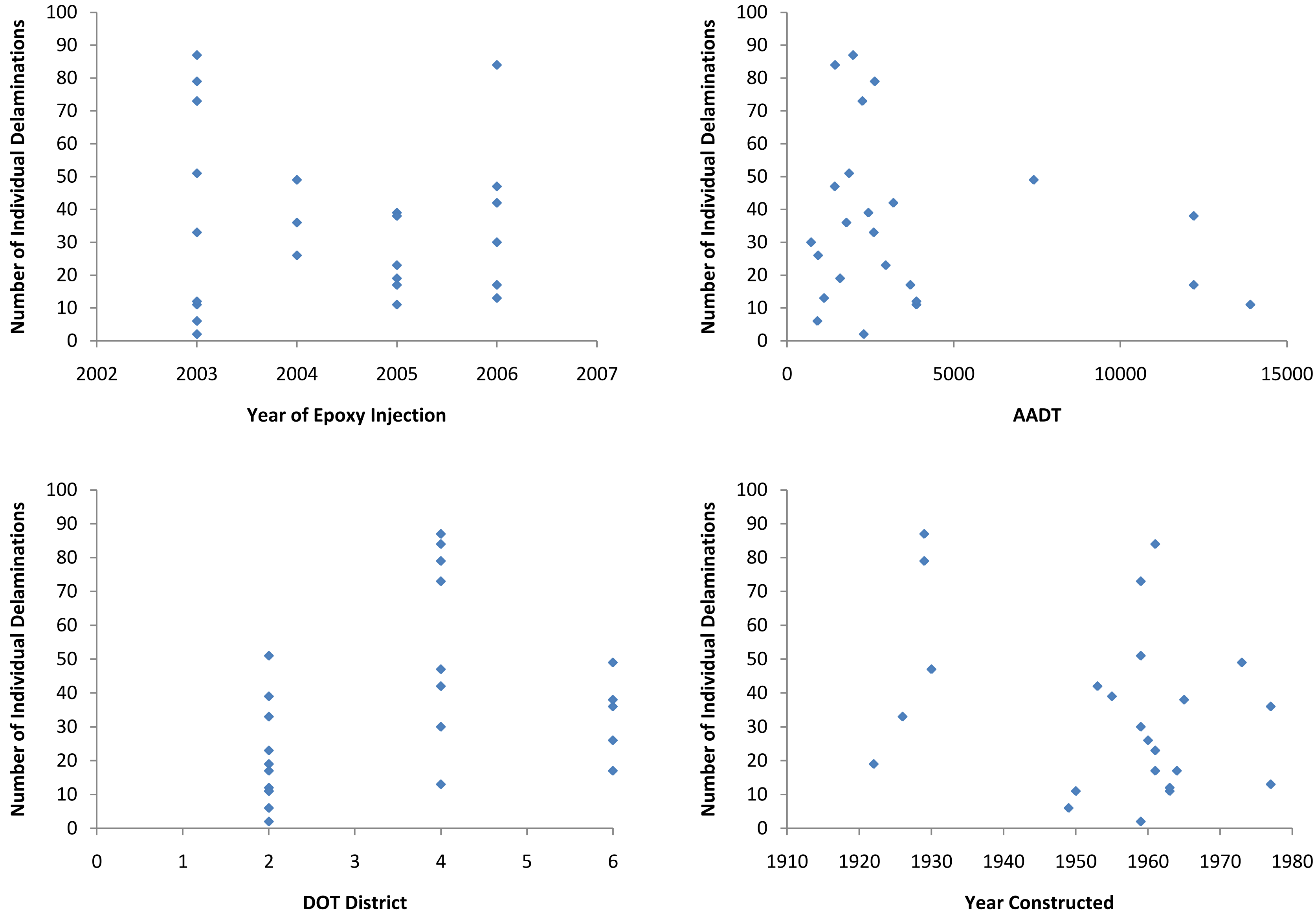
Maximum percentage of delaminated overlay	30.6%
Average percentage of delaminated overlay	11.2%
Maximum number of individual delaminations per sq.ft	1.17
Average number of individual delaminations per sq. ft.	0.50


Percent Delaminated
0
5
10
15
20
25
30
35
2002
2003
2004
2005
2006
2007
Year of Epoxy Injection


Percent Delaminated
0
5
10
15
20
25
30
35
0
5000
10000
15000
AADT


Percent Delaminated
0
5
10
15
20
25
30
35
0
1
2
3
4
5
6
DOT District


Percent Delaminated
0
5
10
15
20
25
30
35
1910
1920
1930
1940
1950
1960
1970
1980
Year Constructed


Number of Individual Delaminations
Year of Epoxy Injection
Number of Individual Delaminations
AADT
Number of Individual Delaminations
DOT District
Number of Individual Delaminations
Year Constructed

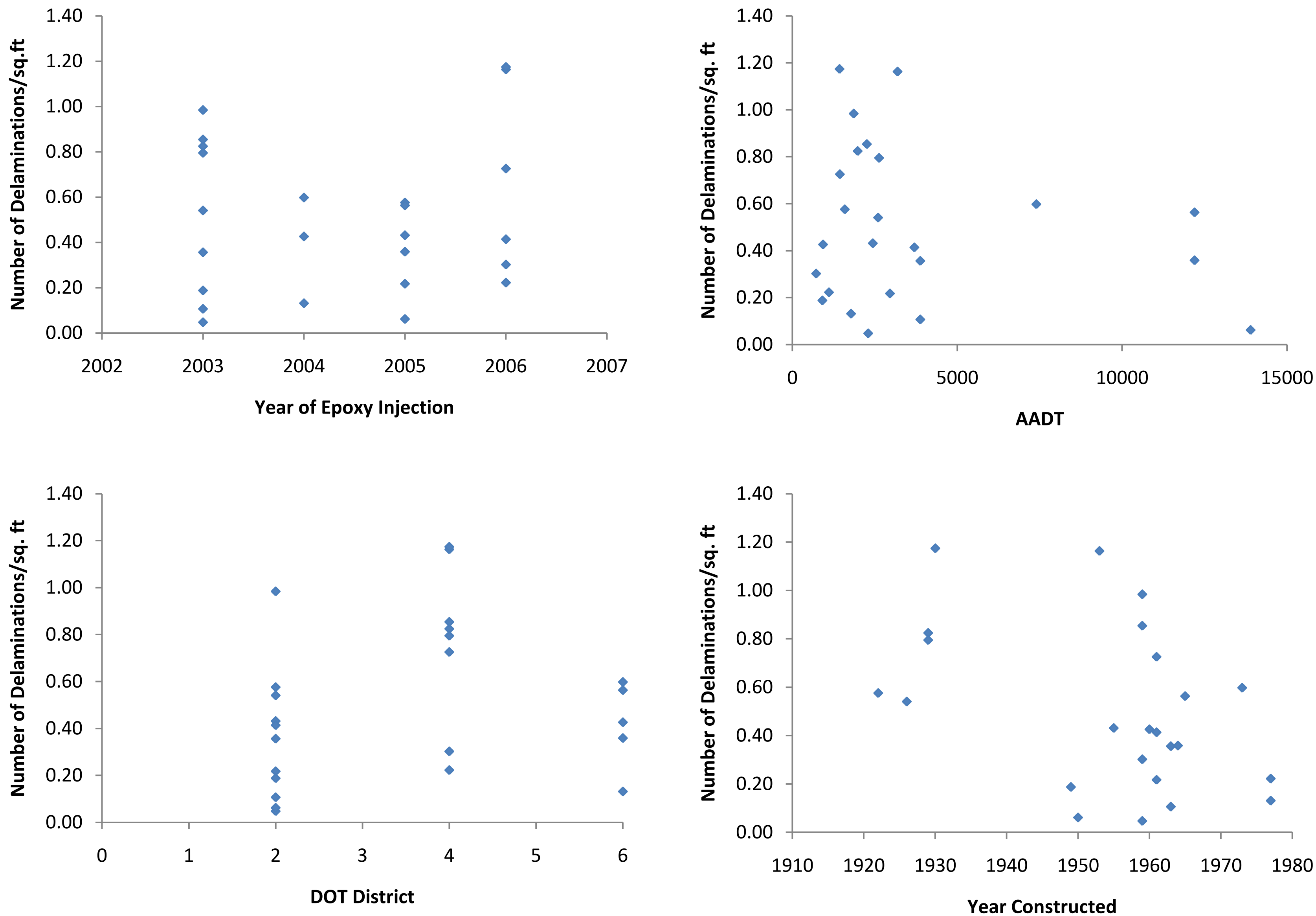


Figure 3-4 Plots Created from Performance Evaluation Data

4. STATE SURVEY AND INTERVIEW

Procedure

To document the state-of-the-practice in Iowa, the bridge crew leaders from each district were interviewed to learn about their respective procedures, materials, equipment. Prior to the interview, and similar to the national study which will be discussed later, an online survey request was sent to each of the six bridge crew leaders; four responses were received. Table 4-1 presents each of the questions.

Table 4-1 Iowa Bridge Crew Survey Questions

Question 1	Identify the epoxy typically used for the injection process.
Question 2	Identify the primary equipment typically involved in the epoxy injection process.
Question 3	At what pressure is the epoxy injected into the delaminated portions of the deck?
Question 4	Is the epoxy injection process inhibited by weather, temperature, or other conditions independent of the actual injection process?
Question 5	How soon is traffic allowed back on to the injected deck?
Question 6	Who typically completes the injection process and are formal written instructions given to follow?
Question 7	Describe the method of injection used in your district.
Question 8	Rate the effectiveness of the epoxy injection as a maintenance method and how long the typical service life is estimated to be. ❑ 0 to 5 Years ❑ Not Effective ❑ 5 to 10 Years ❑ Slightly Effective ❑ 10 to 15 Years ❑ Moderately Effective ❑ 15 to 20 Years ❑ Very Effective ❑ More than 20 Years
Question 9	Provide any additional information that you feel may be pertinent to this review.

The survey responses were used to gain insight and set a benchmark used to compare and contrast the practices within each district. Also, they formed the basis for the individual interviews. The individual surveys and interviews are summarized in the following sections. Each question is given followed by the district's respective response.

Response Summaries

1) *Identify the epoxy typically used for the deck injection process within your district.*

District 1

Symons 303N Epoxy Resin is used. Part A (resin) is mixed with Part B (hardener) in a 2:1 ratio, respectively. This product was chosen primarily because of its low cost in comparison to similar products.

District 2

Symons 303N Epoxy Resin is used. Part A (resin) is mixed with Part B (hardener) in a 2:1 ratio, respectively.

District 3

Symons 303N Epoxy Resin is used. Part A (resin) is mixed with Part B (hardener) in a 2:1 ratio, respectively. This product was selected based on the state approved products list and because other districts are using this product. The achieved results are satisfactory.

District 4

Adhesive Technology CrackBond SLV302 is used. Part A (resin) is mixed with Part B (hardener) in a 2:1 ratio, respectively. This product was chosen primarily because of its low cost in comparison to similar products. Prior to last year, Symons 303N was being used. It was found that the CrackBond was easier to work with (higher viscosity) than the 303N (lower viscosity created pumping problems).

District 5

Adhesives Technology Corp CrackBond SLV302 is used. Part A (resin) is mixed with Part B (hardener) in a 2:1 ratio, respectively. This product was chosen primarily because it's generally less expensive and somewhat more viscous than similar products. Some independent research has confirmed the product to be satisfactory.

District 6

Adhesive Technology CrackBond SLV302 is used. Part A (resin) is mixed with Part B (hardener) in a 2:1 ratio, respectively. This product was chosen primarily because of its low cost in comparison to similar products. Formerly, Symons 303N was used but other options were pursued when the material cost annually increased. No differences have been noticed between each product.

2) *Identify the primary equipment typically involved in the epoxy injection process.*

District 1

A generator, air compressor, 1 1/2" hammer drill, shop vacuum, and AST epoxy injection machine are used.

District 2

A generator, air compressor, 1 1/2" hammer drill, vacuum bit, shop vacuum, and AST epoxy injection machine are used.

District 3

A generator, air compressor, 1 1/2" hammer drill, shop vacuum, Lily CD15 epoxy injection machine, and Tempest mixer are used.

District 4

A generator, air compressor, 1 1/2" hammer drill, shop vacuum, Tempest mixer, and Lily CD15 injection machine are used.

District 5

A generator, air compressor, 1 1/2" hammer drill, shop vacuum, Tempest mixer, and Lily CD15 injection machine are used.

District 6

A generator, air compressor, 1 1/2" hammer drill, shop vacuum, Tempest mixer, and Lily CD15 injection machine are used.

3) *At what pressure is the epoxy injected into the delaminated portions of the deck?*

District 1

15 to 20 psi per the guidelines of the manufacturer is the typical injection pressure.

District 2

The epoxy is typically injected between 24 psi and 30 psi.

District 3

30 to 35 psi is the typical injection pressure. If pumping tends to be easy, the pressure can be backed down to 20 psi.

District 4

20 psi is the typical injection pressure. The pressure should never exceed 30 psi.

District 5

18 to 30 psi is the typical injection pressure. Anything more could pop off the delaminated portion of the overlay.

District 6

The epoxy is injected at a pressure near 100 psi when epoxy is free flowing. When completion of a void is imminent, the pressure is backed down to around 30 to 40 psi.

4) Is the epoxy injection process inhibited by weather, temperature, or other conditions independent of the actual injection process?

District 1

The injection typically is not performed in the rain. Water can infiltrate the port holes and become trapped within the delaminated portions of the deck. Sometimes drilling holes from below is required to drain the excess water. Additionally, the vacuum bit on the hammer drill can easily become clogged if used in the rain. As a general rule, injection occurs above 55 degrees. If injection occurs below 55 degrees, the injection pump struggles to push the epoxy. The epoxy sets up much quicker in hot weather and slower in cold weather.

District 2

The injection typically is not performed in the rain or 24 hours after a significant rain. Water can infiltrate the port holes and become trapped within the delaminated portions of the deck. Additionally, the vacuum bit on the hammer drill can easily become clogged if used in the rain. Injection occurs above 60 degrees and below 100 degrees. The quantity of work does not require injection before or after ideal summer temperatures. The epoxy sets up much quicker in hot weather and is harder for the injection machine to pump in cooler weather.

District 3

Rain will disrupt the injection process primarily because the vacuum bit on the hammer drill can easily become clogged. Injection should occur between 50 and 95 degrees. If injection occurs below 50 degrees, the viscosity of the epoxy is too low and will not pump correctly. If injection occurs above 95 degrees, the epoxy sets too quickly.

District 4

The injection typically is not performed in the rain or even if the surface is wet. The vacuum bit on the hammer drill can easily become clogged if used in the rain. As a general rule, injection should be completed above 50 degrees and below 100 degrees. If injection occurs below 50 degrees, the injection pump struggles to push the epoxy. If injection occurs above 100 degrees the epoxy sets up very quickly making it difficult to work with. The ideal injection temperature is 80 degrees.

<u>District 5</u>

The injection typically is not performed in the rain. The epoxy does not mix well with water. Additionally, the vacuum bit on the hammer drill can easily become clogged if used in the rain. The injection process can occur above freezing temperatures. If injection is completed at low temperatures, a short lead is required out of the mixer. There is no maximum temperature limit. However, it is important to know that epoxy sets much quicker in hot weather and slower in cold weather.

<u>District 6</u>

The injection typically is not performed in the rain or even if the surface is wet. The vacuum bit on the hammer drill can easily become clogged if used in the rain. Formerly, injection would not be conducted if temperature was 40 degrees or cooler. Now, injections are conducted only when temperature is 70 degrees or greater. Ideally, injection would be conducted only between 70 degrees and 90 degrees. Injection becomes very difficult if temperature is 100 degrees or warmer as the epoxy sets up very quickly making it difficult to work with. A 25 ft whip from the tempest mixer to the injection port is used.

5) *How soon is traffic allowed back on to the injected deck?*

<u>District 1</u>

Traffic is allowed back on the deck almost immediately after final injection and clean-up. It would be interesting to learn how quickly the epoxy sets up.

<u>District 2</u>

Traffic is allowed back on the deck almost immediately after final injection and clean-up.

<u>District 3</u>

Traffic is allowed back on the deck almost immediately after final injection and clean-up.

<u>District 4</u>

Traffic is allowed back on the deck almost immediately after final injection and clean-up.

<u>District 5</u>

Traffic is allowed back on the deck almost immediately after final injection and clean-up.

District 6

Traffic is often allowed back on the deck almost immediately after final injection and clean-up. However, if time allows, holding traffic for a couple of hours especially in colder temperatures would be ideal. It feels like the epoxy may start to pump if traffic is let on the bridge too early. This should be somehow verified.

6) *Who typically completes the injection process and are formal written instructions given to follow?*

District 1

DOT staff completes the injection. Each shop is "trained" and is able to inject thereafter. Formal written instructions are not provided. All training is hands-on.

District 2

DOT staff completes the injection. (Kevin +1) Formal written instructions are not provided. Initially the process was learned from the District 1 bridge crew.

District 3

DOT staff completes the injection. Usually a two-man crew is needed (Greg +1). Sometimes if a stretch of good weather is forecasted, the injection ports can be pre-drilled a couple of days prior to injection. All training is and has been hands-on. There are no formal instructions for the injectors to use. Information and best practices are shared between DOT districts.

District 4

DOT staff completes the injection. Usually only one person with minimal help from flaggers is required. No formal instruction is given, only hands-on learning.

District 5

DOT staff completes the injection. One of three "trained" employees along with one or two additional employees is required. There is no formal training or instruction manual. All "training" is hands-on.

District 6

DOT staff completes the injection. One "trained" individual along with an additional helper is required. One additional helper can be used on longer bridges. No formal instruction is given, only hands-on learning and independent research. Without "training" or with limited experience performing injections, some common problems are often presented: 1) Lack of attention to pump and mixer sometimes results in system breakdown, 2) Too many or too few injection ports are drilled, 3) Too much pressure is used to inject the epoxy, 4) Delaminations are not injected tightly, and 5) Unable to identify problems with materials or equipment.

7) *Describe the method of injection used in your district.*

District 1

First, the deck is sounded using chains and hammers to determine the delaminated areas to be repaired. Second, the best place to drill the injection holes is found by using a hammer. Next, 1/2” holes are drilled and checks for air movement between holes using compressed air are completed. The air movement determines the best place to start injection. Then, a 1/4” rubber tube with a rubber stopper or cork on the end is placed in the injection port and injection is started. Using the injection machine and the air compressor, epoxy is injected at 15 to 20 psi. While injecting, the movement and location of epoxy is determined by sounding the deck with a hammer and by viewing other port holes. Once the epoxy has moved through the delaminated portions, the holes are corked to prevent epoxy from leaking out.

District 2

First, the deck is sounded using a sounding stick to determine the delaminated areas to be repaired. Second, a hammer is used to find what appears to be the center of the void. Next, 1/2” holes are drilled into the void and occasionally compressed air is blown into them to push out any dust that may be in the void. Then, a 1/4” rubber tube with a rubber stopper or cork on the end is placed in the injection port and injection is started. Using the injection machine and the air compressor, epoxy is injected at 24 to 30 psi. While injecting, the movement and location of epoxy is determined by sounding the deck with a hammer and by viewing other port holes. Once the epoxy has moved through the delaminated portions, the holes are corked to prevent epoxy from leaking out.

District 3

First, the deck is sounded using sounding rods to determine the delaminated areas to be repaired. Next, holes are drilled 18” to 24” apart in large areas and 8” to 9” apart in small areas. The holes are to remain 5” to 6” from the perimeter of the delaminated areas. Compressed air is blown into the ports. Then, a rubber tube is placed over the injection ports and injection is started. Using the injection machine and the air compressor, epoxy is injected at 30 to 35 psi. While injecting, the movement and location of epoxy is determined by sounding the deck with the sounding rod and by viewing other port holes. The dispenser will slow and/or back pressure will be present at the injection port once the epoxy has filled the void. Once the epoxy has moved through the delaminated portions and the excessive back-pressure is released, the injection ports are capped.

District 4

First, the deck is sounded using sounding rods and hammers to determine the delaminated areas to be repaired. Next, holes are drilled with hammer drill and vacuum bit. The hole locations are determined by the size of void and sounding tone. If a higher tone is found, holes are drilled closer together. If a lower tone is found, holes are drilled farther apart. Once drilled, the holes are blown out with a wand in quick, short bursts so as to not increase severity of the delaminated portions. Then, a rubber tube is placed over the injection ports and injection is started. Using the injection machine, epoxy is injected at 20 psi. While injecting, the movement and location of epoxy is determined by sounding the deck with the sounding rod and by viewing other port holes. Once the epoxy has moved through the delaminated portions, the injection ports are capped.

District 5

First, the deck is sounded using chains to determine the delaminated areas to be repaired. A metal shaft hammer is used to locate the perimeter of the delamination. Next, 1/2" holes are drilled approximately 18" apart for large delaminations. For small delaminations only two holes are drilled. No compressed air is blown into the ports because fines can be blown into the cracks thus plugging them from epoxy injection. Then, a rubber tube is placed over the injection ports and injection is started. Using the injection machine, epoxy is injected between 18 and 30 psi. While injecting, the movement and location of epoxy is determined by sounding the deck with hammers and by viewing other port holes. Also, it is an indication the void has been filled when the dispenser slows and there is backpressure at the port. Once the epoxy has moved through the delaminated portions, the injection ports are capped.

District 6

First, the deck is sounded using a length of rebar to determine the delaminated areas to be repaired. Next, holes are drilled with hammer drill and vacuum bit. The injection port is located at the center of the delamination and a number of vents are drilled around the perimeter. The holes are then vacuumed and sometimes compressed air is blown into them if needed. After, a rubber tube is placed over the injection ports and injection is started. Using the injection machine, epoxy is injected at 100 psi until the delamination is nearly filled at which time the pressure is backed down to around 30 or 40 psi. While injecting, the movement and location of epoxy is determined by sounding the deck with the rebar rod and by viewing other port holes.

Port holes are capped once the epoxy has reached that hole. The delamination is filled when the injection machine starts to work harder and back pressure is found at the injection port.

8) Rate the effectiveness of the epoxy injection as a maintenance method and how long the typical service life is estimated to be.

District 1

The effectiveness is moderately effective and the typical service life is estimated to be 10 to 15 years. It is rare to re-inject a bridge multiple times.

District 2

The procedure is considered moderately effective and the typical service life is estimated to be 10 to 15 years while some decks could be longer. Some bridges require re-injection between 5 and 10 years.

District 3

The effectiveness is very effective and the typical service life is estimated to be 10 to 15 years as long as the deck is a good candidate for injection.

District 4

The effectiveness is very effective and the typical service life is estimated to be 15 to 20 years. The service life of some bridges is less, though some bridges probably should not be injected originally.

District 5

The effectiveness is very effective and the typical service life is estimated to be 10 to 15 years. It isn't uncommon to go back to a previously injected bridge three to five years after initial injection to re-sound and inject any new voids.

District 6

The effectiveness is very effective and the typical service life is estimated to be 10 to 15 years. Some minor failures are seen around five years after initial injection. A reinjection is usually needed around 10 years. The process is generally viewed as only a tool for buying time and saving money. It is not a permanent fix.

9) *Provide any additional information that you feel may be pertinent to this review.*

District 1

Some locations have excess moisture in the delaminations, therefore compromising the injection process. Map cracking is sometimes visible from below the deck prior to injection. After the injection has been completed the map cracking disappears.

District 2

There has never been a prescribed level of deterioration that dictates when a bridge deck is to be injected with epoxy. The deciding factors could be different from district to district.

District 3

As a rule-of-thumb, it has been found for estimating purposes that a deck will accept 1 gallon of epoxy per 10 sq. ft of deck.

District 4

It is important to bring sand along to use for any epoxy that ends up on the deck surface.

District 5

No additional comments.

District 6

An emphasis should be placed on training because a proper injection is the key to success. The maximum rate of injection is 40 gallons per day. Time and resources can be saved if the injection is coupled with deck patching. Traffic control is already onsite.

Summary

Generally speaking the injection process, materials, and equipment used are similar between districts; even so, there are some notable differences. Table 4-2 summarizes some of the more significant similarities and differences. Additional summary points are provided thereafter.

Table 4-2 Notable Differences of Injection Process Between Districts

	What type of epoxy is used for injection?	At what pressure is the epoxy injected?	At what temperatures will you inject the epoxy?	What equipment is used to inject the epoxy?
District 1 Denny Howe	Symons 303N Epoxy Resin	15 – 20 psi	Min = 55 deg, Max = No Max	AST PCV 310/210
District 2 Kevin Smith	Symons 303N Epoxy Resin	24 – 30 psi	Min = 60 deg Max = 100 deg	AST PCV 310/210
District 3 Greg Mize	Symons 303N Epoxy Resin	30 – 35 psi	Min = 50 deg, Max = 95 deg	Lily CD15 and Tempest Mixer
District 4 Delmar Gettler	Adhesives Technology Corp. CrackBond SLV302	20 psi, Never exceeds 30 psi	Min = 50 deg, Max = 100 deg	Lily CD15 and Tempest Mixer
District 5 Junior Jones	Adhesives Technology Corp. CrackBond SLV302	18 – 30 psi, Never exceeds 30 psi	Min = 32 deg, Max = No Max	Lily CD15 and Tempest Mixer
District 6 Mark Carter	Adhesives Technology Corp. CrackBond SLV302	100 psi when free flowing, 30 – 40 psi when nearing finish	Min = 70 deg, Max = 100 deg	Lily CD15 and Tempest Mixer

- The injection process is viewed as moderately effective to very effective.
- The delaminations are found by various methods of sounding. A “high-tech” method is not used in any of the districts.
- Formal training of the injection process has never been completed nor have instructions been provided. Only a couple of people within each district complete the injection.
- Generally, warm weather and no rain are required to complete the injection.
- Traffic is allowed back on the bridge almost immediately after injection has been completed.

5. National Survey

<u>Procedure</u>

A national survey was conducted to document the state-of-the-practice for epoxy injection beyond the State of Iowa. Questions were developed and sent to transportation agencies around the nation through the online survey tool, SurveyMonkey.com. Thirty-two responses to the survey request were received and, while several responses indicated epoxy injection was not used as a maintenance procedure, many provided information regarding their uses of epoxy resin. Table 5-1 lists the survey questions asked of each respondent. Due to the length and limited direct application to this study, the responses received are given in entirety in Appendix A.

Table 5-1 National Survey Questions

Question 1:	If epoxy injection is a maintenance method used in your state, please list typical applications and for how long each has been used as a maintenance method.
Question 2	Please identify the epoxy typically used for the injection process.
	❑ ASTM C881 Type___Grade___Class___
	❑ Other
Question 3	Please list the equipment typically involved in the epoxy injection process.
Question 4	Is the epoxy injection limited by conditions unrelated to the actual process?
	❑ Weather
	❑ Temperature
	❑ Maintaining Traffic Flow
	❑ Other (please specify)
Question 5	Who typically completes the epoxy injection process?
	❑ DOT Maintenance Staff
	❑ Hired Contractor
	❑ Other (please specify)
Question 6	Has an instruction manual or specification been developed that outlines the process the injector should use?
	❑ Yes, Contact the individual below to obtain copy of manual/specification (optional).
	❑ No, A manual/specification has not been developed.
Question 7	Please describe the most common method of epoxy injection used in your area.
Question 8	Please rate the effectiveness of the epoxy injection maintenance method.
	❑ Not Effective

	❑ Slightly Effective
	❑ Moderately Effective
	❑ Very Effective
Question 9	How long is the typical service life of the epoxy injection?
	❑ 0 to 5 Years
	❑ 5 to 10 Years
	❑ 10 to 15 Years
	❑ 15 to 20 Years
	❑ More than 20 Years
Question 10	Please indicate the state for which you are completing this survey and provide any additional information that you feel may be pertinent to this review.

Summary

Notably, none of the respondents indicated that epoxy resin injection of overlaid concrete decks was specifically a part of a regular maintenance regimen. Rather, where epoxy resin injection is performed, the procedure is typically administered to elements such as abutment and bent caps, columns, prestressed girders, piles, and deck surfaces. Regardless, the information gleaned with respect to epoxy resin materials can be beneficial. Table 5-2 shows which respondents indicated that epoxy injection is used in some capacity within their state.

Table 5-2 Applications of Epoxy Injection by State

State	Application	State	Application	State	Application
Arizona	Crack repair in decks, girder fascias, and substructure	Maryland	Not used	Oregon	Crack repair
Arkansas	Not used	Maryland	Substructure units	Oregon	Crack repair of structural members with shear issues
California	Crack repair in concrete girders, abutment walls, and columns	Michigan	Crack repair for concrete piers, segmental concrete structures, and prestressed beams	Pennsylvania	Not used
Delaware	Not used	Minnesota	Not used	South Dakota	Crack repair in prestressed girders, columns, caps, and abutments.
District of Columbia	Not used	Missouri	Surface crack repair	Tennessee	Crack repair in substructures
Florida	Repair of beams, piles, pile caps, barrier walls, and seawalls	Montana	Not Used	Texas	Crack repair
Georgia	Repair of columns and bents	Nevada	Crack repair of new and existing concrete elements, including bridge decks	Utah	Thin bonded epoxy overlays
Hawaii	Not used	New Hampshire	Not used	Virginia	Crack repair in substructure units
Idaho	Crack repair for columns, substructures, and girders	New Mexico	Thin bonded epoxy overlays	West Virginia	Crack sealing bridge decks and void fill
Illinois	Crack repair in substructure units	New Mexico	Not used	Wyoming	Crack sealing for abutment and bent caps and columns
Kansas	Bridge deck Delamination repair and crack repair of substructure members	North Carolina	Crack repair for pier caps and columns		

REFERENCES

ACI Committee 503. Use of Epoxy Compounds with Concrete. Detroit, MI: American Concrete Institute, 1993.

Smith, Barbara J. Epoxy Injection of Bridge Deck Delamination. Washington, DC: Transportation Research Board, 1992.

Trout, John. Quality Control on the Injection Project. n.d.

Whiting, John E. Bridge Deck Rehabilitation: Rebonding a Delaminated PCC Overlay By Epoxy Injection. Washington, DC: Federal Highway Administration, 1989.

APPENDIX A – NATIONAL SURVEY RESPONSES

Arizona

Q1: Epoxy injection is used in deck cracks, girder fascias, and substructure units.

Q2: ASTM C881 Type I or IV, Grade I or II

Q3: The equipment used to meter and mix the two injection adhesive components and inject the mixed adhesive shall be portable, positive displacement type pumps with interlock to provide positive ratio control of exact proportions of the two components at the nozzle.

Q4: Temperature

Q5: Hired Contractor

Q6: Yes, Contact the individual below to obtain a copy of manual/specification

David Benton, P.E. Phone: (602) 712-7910 Email: DBenton@azdot.gov

Q7: Various ports injection

Q8: Moderately Effective

Q9: Unknown

Q10: Arizona

Arkansas

Q1: Arkansas has not used epoxy injection to repair bridge deck overlays.

Q2: No Response

Q3: No Response

Q4: No Response

Q5: No Response

Q6: No Response

Q7: No Response

Q8: No Response

Q9: No Response

Q10: Arkansas Highway and Transportation Department

California

Q1: California DOT, Caltrans, stopped repairing bridge decks by epoxy injection in 1985. Caltrans uses high molecular weight methacrylate to repair bridge deck cracks.

Q2: ASTM C881 Type1, Grade 1, Class B or C

Q3: Contractor selects equipment suitable for application.

Q4: None

Q5: Hired Contractor

Q6: No, A manual/specification has not been developed

Q7: Repair cracks in concrete girders, abutment walls, and columns.

Q8: Very Effective

Q9: More than 20 years

Q10: California. Caltrans uses high molecular weight methacrylate to repair concrete cracks in bridge decks.

District of Columbia

Q1: The District of Columbia does not employ epoxy injection as a maintenance method to repair concrete overlays.

Q2: No Response

Q3: No Response

Q4: No Response

Q5: No Response

Q6: No Response

Q7: No Response

Q8: No Response

Q9: No Response

Q10: District of Columbia

Florida

Q1: Repair of beams, piles, pile caps, barrier walls, and seawalls. For at least 10 years.

Q2: Use epoxies for FDOT Qualified Products List at:

http://www.dot.state.fl.us/specificationsoffice/ProductEvaluation/QPL/default.shtm

Q3: Either hand pump or pneumatic pump depending on job. Equipment may be specified by supplier.

Q4: Weather, Temperature, Maintaining Traffic Flow, per manufacturer's instructions.

Q5: Hired Contractor

Q6: Yes, Contact the individual below to obtain copy of manual/specification

FDOT specification 926. Available from FDOT website.

Q7: Beam and barrier wall impacts. Sealing deck cracks

Q8: Very Effective, Very effective for impact damage, less effective for sealing cracks resulting from corrosion.

Q9: 10 to 15 years, Service life depends on location and environment.

Q10: Florida Department of Transportation

Georgia

Q1: Georgia DOT uses epoxy injection to repair columns and bents but does not use it for concrete overlays.

Q2: N/A

Q3: N/A

Q4: N/A

Q5: N/A

Q6: No, A manual/specification has not been developed.

Q7: N/A

Q8: N/A

Q9: N/A

Q10: Georgia DOT

Hawaii

Q1: Hawaii has not used epoxy injection to repair overlays. We also have very few overlays on our decks.

Q2: No Response

Q3: No Response

Q4: No Response

Q5: No Response

Q6: No Response

Q7: No Response

Q8: No Response

Q9: No Response

Q10: Hawaii

Idaho

Q1: Idaho has not used injection in regards to deck overlay bond to substrate. We do use injection for columns and substructures and some superstructure girder repairs.

Q2: No Response

Q3: No Response

Q4: No Response

Q5: Hired Contractor

Q6: No Response

Q7: No Response

Q8: Moderately Effective

Q9: 5 to 10 years

Q10: Idaho

Illinois

Q1: Typically used in concrete substructure repair. Our current specification has been in use since 2007.

Q2: ASTM C881 Type IV, Grade 1, Class A, B, or C. The class supplied shall be governed by the range of temperature for which the material is to be used.

Q3: Oil-free compressed air and/or vacuum to remove dust/debris from crack. One-way injection ports installed every 6 to 18 in. Mechanical pressure equipment to inject the epoxy bonding compound into the crack.

Q4: Nothing currently in our spec.

Q5: Hired Contractor

Q6: Yes, Contact the individual below to obtain copy of manual/specification

Jayme F. Schiff Acting Engineer of Structural Services IDOT Bureau of Bridges and Structures 2300 S. Dirksen Parkway Springfield, IL 62764 217-782-2125 Jayme.Schiff@illinois.gov

Q7: Repair cracks in concrete substructures

Q8: Moderately Effective

Q9: 10 to 15 years. This is an estimate, since we have only been using our current specification since 2007.

Q10: State of Illinois

Kansas

Q1: Paul Virmani – FHWA – 202493052 Prior to FHWA, I worked at the Kansas DOT (1973 to 1976). Epoxy injection for delamination repair for bridge decks as well as for crack repair for substructure members. This was one of the repairs developed by Kansas DOT.

Q2: You can get details from Kansas DOT or I can get for you.

Q3: Contact Kansas DOT.

Q4: Temperature

Q5: DOT Maintenance Staff

Q6: Yes, Contact the individual below to obtain copy of manual/specification

Kansas DOT

Q7: No Response

Q8: Moderately Effective

Q9: 10 to 15 years

Q10: I am making this survey as one of the researchers working for the Kansas DOT at that time.

Maryland

Q1: We have not used injection as a maintenance/rehab method on delaminated bridge deck overlay.

Q2: N/A

Q3: N/A

Q4: N/A

Q5: No response

Q6: N/A

Q7: No Response

Q8: No Response

Q9: No Response

Q10: Robert Healy Deputy Director – Maryland DOT Office of Structures 410-545-8063

Maryland

Q1: Maryland does not use epoxy injection for the repair of bridge decks, only cracks in substructure units. Answers below will be related to how we use the epoxy injection for repair of substructure units.

Q2: ASTM C881 Type I – Different grades are used.

Q3: Pump

Q4: Weather, Temperature

Q5: Hired Contractor

Q6: Yes, Contact the individual below to obtain copy of manual/specification

Jeff Robert Maryland SHA. jrobert@sha.state.md.us

Q7: No Response

Q8: Moderately Effective

Q9: 10 to 15 years

Q10: Maryland State Highway Administration responder: Jeff Robert Office of Structures jrobert@sha.state.md.us

Michigan

Q1: Michigan has been utilizing epoxy injection since the mid-1970's or earlier. The maintenance method is typically applied to cracked or damaged structural concrete including piers, segmental concrete structures, and prestressed concrete beams.

Q2: MDOT maintenance crews typically use Axson AkaBond 818 FG or Dedoes Tru Grip 150. Other tested and approved products are specified in section 914.06 of the Construction & Technology Division Materials Source Guide.

Q3: Electric inverter or generator. Webac two component electric epoxy pump. Dedoes Tru Grip Superseal or Axson AkaBond 551 epoxy paste adhesive. Lily Injecti-Port nozzles. ND Industries superglue and accelerator.

Q4: Weather, Temperature, Maintaining Traffic Flow, Common limitations include a required surface temperature of at least 50 degrees Fahrenheit, and a crack size width no exceeding 0.125". Larger cracks require a modified epoxy.

Q5: DOT Maintenance Staff

Q6: No, A manual/specification has not been developed. As-needed training classes are provided by experienced MDOT staff.

Q7: Two component structural moisture insensitive resin injection.

Q8: Very Effective, The materials are effective when installed according to manufacturer's specifications. The two brands previously listed produce certain colors during the mixing process which ensure proper proportioning.

Q9: More than 20 years

Q10: Michigan. The epoxy pump mix proportioning may change over time and needs to be checked often. Otherwise inconsistencies may develop.

Minnesota

Q1: Epoxy injection to bond delaminated low slump concrete overlays has not been used in Minnesota. Delaminations are repaired with conventional concrete patching methods. Most delaminations are corrosion induced, and are not due to bond failures.

Q2: No response

Q3: No response

Q4: No response

Q5: No response

Q6: No response

Q7: No Response

Q8: No Response

Q9: No Response

Q10: Minnesota, Submitted by: Paul Kivisto Metro Region Bridge Engineer (651) 366-4563

<u>Missouri</u>

Q1: Missouri doesn't typically use epoxy injection.

Q2: We do not inject, but do allow filling of surface cracks by routing and filling with Type III, Grade 1, Class B or C epoxy

Q3: N/A

Q4: N/A

Q5: No Response

Q6: No, A manual/specification has not been developed

Q7: N/A

Q8: N/A

Q9: N/A

Q10: Missouri DOT. Went to a workshop in Iowa over 10 years ago on epoxy injection but have never used it on bridge decks or overlays. MoDOT repairs dry cracks in concrete by routing and filling with Type III epoxy, see #2 above.

<u>Montana</u>

Q1: Epoxy injection isn't typically used in Montana for this application.

Q2: No Response

Q3: No Response

Q4: No Response

Q5: No Response

Q6: No Response

Q7: No Response

Q8: No Response

Q9: No Response

Q10: Montana.

<u>New Hampshire</u>

Q1: New Hampshire does not use epoxy injection.

Q2: No Response

Q3: No Response

Q4: No Response

Q5: No Response

Q6: No Response

Q7: No Response

Q8: No Response

Q9: No Response

Q10: New Hampshire

New Mexico

Q1: Not used.

Q2: N/A

Q3: N/A

Q4: N/A

Q5: N/A

Q6: N/A

Q7: N/A

Q8: N/A

Q9: N/A

Q10: New Mexico DOT. Jimmy Camp. Comments: New Mexico has basically stopped using concrete overlays on bridge decks because of the delamination issues, added dead load, and costs. New Mexico has been using thin bonded epoxy overlays instead for about 10 years and is very satisfied with thin bonded epoxy overlays to extend bridge deck life.

New Mexico

Q1: We generally do not epoxy inject any bridge overlays in our state. When we get a section that is spalled out we usually just patch it. Our climate in this state generally has a mild climate.

Q2: No Response

Q3: No Response

Q4: No Response

Q5: No Response

Q6: No Response

Q7: No Response

Q8: No Response

Q9: No Response

Q10: New Mexico Department of Transportation

North Carolina

Q1: We occasionally have used epoxy injection to fill cracks in pier caps and columns but never to inject under delaminated areas of concrete overlays.

Q2: No Response

Q3: No Response

Q4: Weather, Temperature, How bad the cracking is and whether the injection will be successful.

Q5: DOT Maintenance Staff

Q6: No, A manual/specification has not been developed

Q7: No Response

Q8: Moderately Effective

Q9: 5 to 10 years

Q10: North Carolina, We seem to be using epoxy injection less and less as time goes on. Dan Holderman, State Bridge Management Engineer (dholderman@ncdot.gov)

Nevada

Q1: Crack repair of new and existing concrete elements, including bridge decks.

Q2: AASHTO M235 Type IV, Grades 1, 2, or 3, Class A, B, or C

Q3: Contractor's means and methods (equipment not specified). Injection pressure of 25 psi is required.

Q4: Weather, Temperature, Material must be placed in accordance with manufacturer's requirements.

Q5: Hired Contractor

Q6: No, A manual/specification has not been developed

Q7: No Response

Q8: Very Effective

Q9: More than 20 years

Q10: Nevada Department of Transportation

Oregon

Q1: RCDG crack repair – Usually done under contract but occasionally

Q2: ASTM C881 Type __ Grade __ Class ___

Q3: Pumps, ports, etc. Hand applied equipment as well depending upon size of job.

Q4: Weather, Temperature, Maintaining Traffic Flow. We use according to manufacture recommendations.

Q5: Hired Contractor

Q6: Yes, Contact the individual below to obtain copy of manual/specification

Scott Nelson, P.E. scott.d.nelson@odot.state.or.us

Q7: Pump/port

Q8: Moderately Effective, Some sealed cracks have recracked due to movement. Generally not a strength issue but a serviceability issue.

Q9: 10 to 15 years

Q10: Oregon

<u>Oregon</u>

Q1: Typically injection of structural members with shear issues. By filling the cracks the shear capacity should increase in theory.

Q2: ASTM C881 Type __ Grade __ Class ___ Crack injection epoxy. Several different manufacturers. See ODOT Construction website Qualified Products Listing for names.

Q3: Mixers and pumps

Q4: Weather, Temperature

Q5: Hired Contractor

Q6: Yes, Contact the individual below to obtain copy of manual/specification

See ODOT specification website. The specification SP538.

Q7: Seal the outside of cracks and install small ports for injection and escapement. Pump from the low elevations until full.

Q8: Moderately Effective

Q9: Impossible to gauge

Q10: Oregon

<u>Pennsylvania</u>

Q1: Epoxy injection is not used to repair delaminated concrete overlays.

Q2: N/A

Q3: No Response

Q4: No Response

Q5: No Response

Q6: No Response

Q7: No Response

Q8: No Response

Q9: No Response

Q10: Pennsylvania

South Dakota

Q1: Crack repair in structural concrete elements such as prestressed girders, columns, caps, abutments, etc. Also, have used on cracked timber beams

Q2: ASTM C881 Type IV, Grade I, Class B or C

Q3: Low pressure epoxy injection pump.

Q4: Weather, Temperature, Maintaining Traffic Flow.

Q5: Hired Contractor

Q6: No, A manual/specification has not been developed.

Q7: Low pressure epoxy injection with the use of crack surface sealers and port to port injection.

Q8: Very Effective

Q9: More than 20 years

Q10: South Dakota DOT

Tennessee

Q1: Typically injecting cracks in substructures, not sure how long it's been used but more than 15 years.

Q2: To get on QPL C881 or C882. Slant shear hardened to hardened concrete 2 day 1000 psi 14 day 1500 psi.

Q3: Equipment if supplied by subcontractor in a contracted repair. Maintenance forces do not typically do this type of work.

Q4: Manufacturer's recommendations

Q5: Hired Contractor

Q6: Yes, Contact the individual below to obtain copy of manual/specification

Brian Egli Brian.Egli@tn.gov

Q7: Not sure, up to the injection subcontractor

Q8: Moderately Effective

Q9: 15 to 20 Years

Q10: Tennessee DOT

Texas

Q1: Repairs for cracks in structural concrete members. 25+ years for all.

Q2: Other. See our specs at: ftp://ftp.dot.state.tx.us/pub/txdot-info/cst/DMS/6000_series/pdfs/6100.pdf

Q3: See specs at: ftp://ftp.dot.state.tx.us/pub/txdot-info/cmd/cserve/specs/2004/standards/s780.pdf

Q4: See: ftp://ftp.dot.state.tx.us/pub/txdot-info/cmd/cserve/specs/2004/standards/s780.pdf

Q5: Hired Contractor

Q6: Yes, Contact the individual below to obtain copy of manual/specification ftp://ftp.dot.state.tx.us/pub/txdot-info/cmd/cserve/specs/2004/standards/s780.pdf Brian Merrill 512-416-2232 or Brian.Merrill@txdot.gov

Q7: Not sure what this means

Q8: Moderately Effective, depends on if the cause of the cracks is also addressed.

Q9: 15 to 20 Years

Q10: Texas

Utah

Q1: Thin bonded polymer overlay – 10 years (This application bridges the cracks and seals the deck) Low viscosity healer/sealer – 5 years (This application fills the cracks well but quickly wears off the deck riding surface).

Q2: Meets ASTM C881 and our standard specification (03372) which can be found on the UDOT website www.udot.utah.gov

Q3: Type II for low ADT roads that is usually mixed in 50 gallon barrels and applied manually with squeegee brooms. Type I for high ADT facilities that requires a mechanically mixed and metered system to ensure high volume application with reliability.

Q4: Weather, Temperature, Maintaining Traffic Flow

Q5: Hired Contractor

Q6: Yes, Contact the individual below to obtain copy of manual/specification Chris Potter cpotter@utah.gov 801-964-4463 www.udot.utah.gov (Thin bonded polymer overlay specification 03372)

Q7: Thin bonded polymer overlay type I which is mechanically mixed and metered

Q8: Moderately Effective, Effective if the preparation is done properly. In Utah the summers are dry, hot and can be windy so curing compounds are applied to retain the moisture and facilitate the hydration process. These compounds have wax and if the waxes are not completely removed prior to applying the overlay they will prematurely debond (usually within 5 years). It sometimes requires shot blasting twice to remove the compounds completely if the deck is new.

Q9: 10 to 15 years, If the preparation is done correctly.

Q10: Utah. Utah does not apply polymer overlays to decks over 5 years old because experience has shown that the corrosion process has already started and the concrete will delaminate through the overlay. The overlay may also be retaining moisture and accelerating the corrosion process.

Virginia

Q1: The Virginia Department of Transportation has used epoxy injection to repair rigid cracks in concrete substructure units for 30 plus years.

Q2: Virginia Department of Transportation (VDOT) Epoxy Type EP4-LV. See Section 243 of the 2007 VDOT Specifications. Copy available upon request.

Q3: Air compressor, injection pump, injection ports, abrasive blasting equipment, torch, standard hand and power tools.

Q4: Temperature, Typically the air and concrete temperature should be greater than 50 degrees F.

Q5: Hired Contractor

Q6: Yes, Contact the individual below to obtain copy of manual/specification

J.L. Milton Bridge Preservation Specialist Structure and Bridge Division Virginia Department of Transportation. Phone: (434) 856-8278 Cell: (434) 841-1463 Fax: (434) 947-2689 Email: Jeffrey.Milton@VDOT.Virginia.gov

Q7: The means and methods are described in the VDOT Special Provision for Epoxy Injection Pressure Crack Sealing. Copy available upon request.

Q8: Epoxy injection of cracks in concrete substructure units (as described in the referenced Special Provision) is effective for dormant cracks.

Q9: 10 to 15 years

Q10: Virginia Department of Transpiration

West Virginia

Q1: It has been used for at least 2 decades in applications that range from filling voids to crack sealing in bridge decks.

Q2: Other, We have utilized various ASTM C881 types, grades, and classes from very viscous to materials with the consistency approaching tree sap.

Q3: Equipment would include port drilling devices and pumping apparatuses.

Q4: Weather, Temperature, Maintaining Traffic Flow, All conditions shown would be limiting factors as well as crack type, depth, and width.

Q5: Other, We have utilized hired contractors as well as our own DOH staff

Q6: Yes, Contact the individual below to obtain copy of manual/specification

Yes, our construction manual, specifications, as well as, Material Division publication reference this process. All our documents and materials are readily available by contacting the Director of Materials Divisions, and many are on our website.

Q7: Porting and pumping the epoxy material is most common.

Q8: Moderately Effective, Moderately effective to very effective provided appropriate process was implemented properly.

Q9: 5 to 10 years. We do not have data readily available; however, I would expect 5 to 10 years.

Q10: West Virginia contacts: Jim Shook (james.d.shook@wv.gov) Jimmy Wriston (jimmy.d.wriston@wv.gov) Aaron Gillispie (aaron.c.gillispie@wv.gov)

Wyoming

Q1: Crack sealing for abutment and bent caps and columns.

Q2: Other. Epoxy Type I, grade 2 bonding compound type V, grade 2

Q3: Handgun or pot for injection

Q4: No Response

Q5: Hired Contractor

Q6: Yes, Contact the individual below to obtain copy of manual/specification

Keith Fulton State Bridge Engineer 5300 Bishop Blvd Cheyenne, WY 82009 307-777-4427. Spec can also be found at:

http://www.dot.state.wy.us/wydot/engineering_technical_programs/manuals_publications/2010_Standard_Specifications

Q7: No Response

Q8: Moderately Effective

Q9: 5 to 10 Years

Q10: Wyoming

APPENDIX B – ASTM C 881

Type

Type I: For use in non-load bearing applications for bonding hardened concrete to hardened concrete and other materials, and as a binder in epoxy mortars or epoxy concretes.

Type II: For use in non-load bearing applications for bonding freshly mixed concrete to hardened concrete.

Type III: For use in bonding skid-resistant materials to hardened concrete, and as a binder in epoxy mortars or epoxy concretes, used on traffic bearing surfaces (or surfaces subject to thermal or mechanical movements).

Type IV: For use in load bearing applications for bonding hardened concrete to hardened concrete and other materials and as a binder for epoxy mortars and concretes.

Type V: For used in load bearing applications for bonding freshly mixed concrete to hardened concrete.

Type VI: For bonding and sealing segmental precast elements with internal tendons and for span-by-span erection when temporary post tensioning is applied.

Type VII: For use as a non-stress carrying sealer for segmental precast elements when temporary post tensioning is not applied in span-by-span erection.

Grade

Grade 1: Low viscosity

Grade 2: Medium viscosity

Grade 3: Non-sagging consistency

Class

Class A: Below 40 deg F to manufacturer defined low

Class B: 40 to 60 deg F

Class C: Above 60 deg F to manufacturer defined high

Class D: 40 to 65 deg F

Class E: 60 to 80 deg F

Class F: 75 to 90 deg F

*Classes A, B, and C are defined for types I through IV. Classes D, E, and F are defined for Types VI and VII according to the range of temperatures for which they are suitable.