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Investigations of Failures of Epoxy Polymer Overlays in Missouri

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Investigations of Failures of Epoxy Polymer Overlays in Missouri

Prepared for
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Organizational Results

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16. Abstract:
Missouri has had some epoxy polymer overlays that have exceeded their life expectancy of 10 – 15 years while other overlays have shown signs of failure within 2 years after placement. The purpose of this research study was to try and determine why some epoxy polymer overlays (EPO) have provided successful protection for over a decade and why some overlays have begun to fail after only a few years.

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Executive Summary

Epoxy Polymer Overlays have been used to seal bridge decks in the United States for over 40 years. Missouri placed the first epoxy polymer overlay (EPO) in June of 1989 on the Poplar Street Bridge over the Mississippi River in St. Louis. MoDOT now has well over 300 bridge decks treated with an epoxy polymer overlay.

Missouri has had some epoxy polymer overlays that have exceeded their life expectancy of 10 – 15 years while other overlays have shown signs of failure within 2 years after placement. The purpose of this research study was to try and determine why some epoxy polymer overlays (EPO) have provided successful protection for over a decade and why some overlays have begun to fail after only a few years. While an EPO provides protection from chloride penetration and water infiltration when it works correctly, it is more expensive than traditional deck sealers that are meant to last 3-5 years. When the EPO fails short of its lifespan it is not cost effective and can also be difficult to remove.

Organizational Results randomly selected 10 EPO bridges from each of the 10 districts to create a database of information. The study attempted to find correlations between the performance of the EPO with previous deck rating, product type, span length, girder type, number of freeze/thaw cycles, temperature at placement, and ADT.

An unexpected observation during the study was the presence of pitting on a majority of the bridge decks. Sixty-two out of ninety eight bridges had pitting of some degree. (The epoxy polymer overlay on two of the bridge decks had completely worn off.) One source of pitting is the presence of air bubbles in the epoxy component of the overlay. In discussions with epoxy suppliers it was noted that the use of certain types of paddles for mixing can lead to air bubbles within the epoxy. The proper type of paddle to be used is called a "jiffy paddle" or a "Sika paddle."

Epoxy Polymer overlays can provide a long lasting protection for bridge decks, but only if the bridge deck is still in decent shape. Once the deck deteriorates and requires patching on more than 5% of the deck, the overlay will most likely perform well for only a few years. MoDOT has had many successes with epoxy polymer overlays but also many failures. Many of the failures can be attributed to decks that were beyond the deterioration level of a good EPO candidate.

Introduction

Epoxy Polymer Overlays have been used to seal bridge decks in the United States for over 40 years. Missouri placed the first epoxy polymer overlay (EPO) in June of 1989 on the Poplar Street Bridge over the Mississippi River in St. Louis. MoDOT now has well over 300 bridge decks treated with an epoxy polymer overlay.

An epoxy polymer overlay usually consists of an epoxy polymer binder and fine aggregates used to construct a thin, 0.25” to 1.0”, overlay. The overlay is constructed in two lifts to achieve the desired thickness. An EPO overlay is more expensive than a traditional overlay; however it has several advantages:

- Adds very little dead load
- Very fast cure times
- Shallow depths which eliminates the need for raising the approach slabs
- Transition from overlaid lane to non-overlaid lane during construction
- A waterproof, long-lasting wearing surface
- Excellent skid resistance

Missouri has had some epoxy polymer overlays that have exceeded their life expectancy of 10 – 15 years while other overlays have shown signs of failure within 2 years after placement. The goal of this study was to determine the causes of the failures, enabling MoDOT to use EPOs only in locations that it will provide cost effective protection.

Objective

The purpose of this research study was to try and determine why some epoxy polymer overlays (EPO) have provided successful protection for over a decade and why some overlays have begun to fail after only a few years. While an EPO provides protection from chloride penetration and water infiltration when it works correctly, it is more expensive than traditional deck sealers that are meant to last 3-5 years. When the EPO fails short of its lifespan it is not cost effective and can also be difficult to remove.

Organizational Results randomly selected 10 EPO bridges from each of the 10 districts to create a database of information. Appendix A shows the locations of the bridges evaluated. Care was taken to include a range of ages for the bridges selected in each district. An attempt was made to speak with each District Bridge Engineer to discuss their experiences with EPOs, and a survey was conducted for each bridge where a rating was given from visual observation. The EPO rating was based solely on the overlay itself, not on the deck condition. The ratings are:

- Excellent—No visual defects found
- Good—less than 1% of the overlay showed problems
- Fair—1% to 5% of the overlay showed problems
- Poor—over 5% of the overlay showed problems.

A chart with the deck rating for each bridge is located in Appendix B.

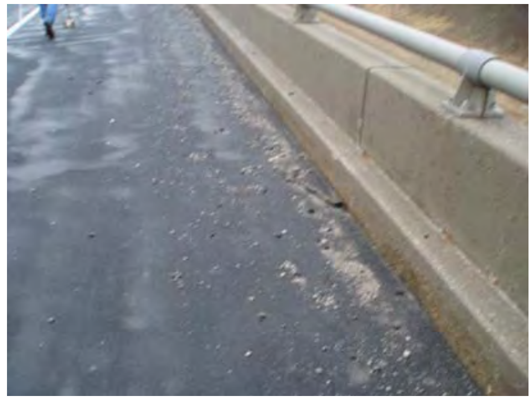
Types of defects for each bridge were also recorded. The defects noted were:

- Cracking
- Pitting
- Delamination
- Peeling
- Missing areas of epoxy
- Sunken/cracked areas
- Spalling/loose areas
- Post overlay patches


Cracking


Pitting


Delamination


Peeling


Missing areas of epoxy


Sunken/cracked areas


Spalling/loose areas


Post overlay Patches

Once each deck had been rated, background information was collected from each district. The background information, when available, included:

- Date of overlay
- Age of overlay
- Previous deck rating
- Product
- Contractor
- Weather at placement
- ADT
- ADT
- Girder type
- Longest span length
- Average number of freeze/thaw cycles for the district

Due to the age of some of the overlays and retention policies between districts, background information was attained for only 68 bridges.

Discussion

General Observations

Epoxy polymer overlays are not a “repair” for bridge decks. They are only a means of protecting a deck that is in fairly good condition but is at risk for chloride and water penetration. Once a bridge deck has defects over a significant surface area, an EPO will not provide long lasting protection for the bridge deck and can even hamper repair efforts in the future. MoDOT’s Bridge Division generally recommends placing EPOs on bridge decks that are rated a 7 or higher and have less than 5% of the deck requiring repairs. Information gathered during the investigation indicated that many of the bridges that received overlays had significantly more that 5% defects. Many of the failures observed in the site visits appeared to be a failure of the top surface of the deck as opposed to a failure of the epoxy. Where possible, epoxy that had separated from the deck was examined. In most cases there was a layer of concrete paste on the bottom surface of the epoxy indicating that the epoxy had not debonded from the deck, but that the top surface of deck had delaminated. See Figure 1.

Figure 1. Epoxy Polymer Overlay that has concrete paste attached to the bottom

EPOs are initially hydrophobic and should not be exposed to water until they have fully cured. MoDOT's specs require that the deck is dry and that rain is not in the forecast for 24 hours after placement. However there are some misconceptions about this requirement. Field logs have shown that some contractors consider the deck satisfactory as long as there is not standing water on the deck. One of the approved products is Sikadur 22, Lo-Mod. On the data sheet for the product it refers to a damp deck as being acceptable. However further in the data sheet, the limitations state that for "porous substrates" i.e., concrete bridge decks, the surface must be free of moisture. Inspectors must be aware that the deck must be free of moisture in order to get a good bond between the epoxy and the bridge deck. The Michigan DOT requires a moisture test, ASTM D 4263 " Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method." This test is simple to perform. It involves taping a polyethylene sheet to the bridge deck for a period of time and then visually inspecting the underside of the sheet and the concrete surface for the presence of water. The ASTM standard requires leaving the plastic sheet in place for 16 hours, however Michigan specs require a minimum of two hours. It is highly recommended that this test be included in the MoDOT specifications to verify that the deck is completely dry. The presence of water in the deck will prevent an adequate bond between the concrete and EPO. This could be behind some of the failures on I-29 in District 1. Unlike many of the failures observed, in this area the epoxy appeared to "flake" off the bridge deck. See Figure 2.

Figure 2. Epoxy "flaking" off the bridge deck

Initially no patterns could be found between the epoxy failures and the background information that was gathered on each bridge. We eventually determined that MoDOT EPOs were experiencing two different problems, pitting and all other defects. Once pitting was removed from the other defects, we began to see patterns between those bridges with failing overlays and characteristics of the bridge deck itself. We also examined each factor looking at all of the epoxy bridges as a whole and then at only the newer overlays placed in 2000 or later. We picked the year 2000 as a cutoff of "newer overlays" so that we could verify that the patterns we were seeing were not due to the varying ages of the bridges. For example, certain products were used on the earlier overlays and other products were used on the newer overlays. Looking at the bridges as a whole would show inferior performance for the older type of epoxy even if it was due to the age differences as opposed to the product itself.

Pitting

An unexpected observation during the study was the presence of pitting on a majority of the bridge decks. Sixty-two out of ninety eight bridges had pitting of some degree. (The epoxy polymer overlay on two of the bridge decks, K108 placed in 1990 and A1944 placed in 1984, had worn to the point that determining failure mechanisms was impossible.) The degree of pitting ranged from pinprick sized pits to quarter inch sized pits. Pitting has been noted in many literature reports; however most sources claim that the pits will never line up between the two layers of overlay and should not be of concern. In the course of the investigation we found areas where the pits DID line up which create a funnel for water and chlorides to enter the deck. We also found that once the pitting became larger the EPO began to show signs of cracking between the pits, which eventually became block cracking. One source of pitting is the presence of air bubbles in the epoxy component of the overlay. In discussions with epoxy suppliers it was noted that the use of certain types of paddles for mixing can lead to air bubbles within the epoxy. The proper type of paddle to be used is called a "jiffy paddle" or a "Sika paddle." Most epoxies have a maximum speed for the paddle, mixing any quicker can introduce air. Inspectors should verify that the contractor is using the correct type of paddle for mixing the epoxy and that the correct speed is being used. It was also noted that an increase in temperature leads to an increased chance of pitting. See Figure 3. During higher temperatures, extra care should be given to working out any remaining air bubbles during placement. The likelihood of pitting also increased with the number of freeze/thaw cycles. See Figure 4.

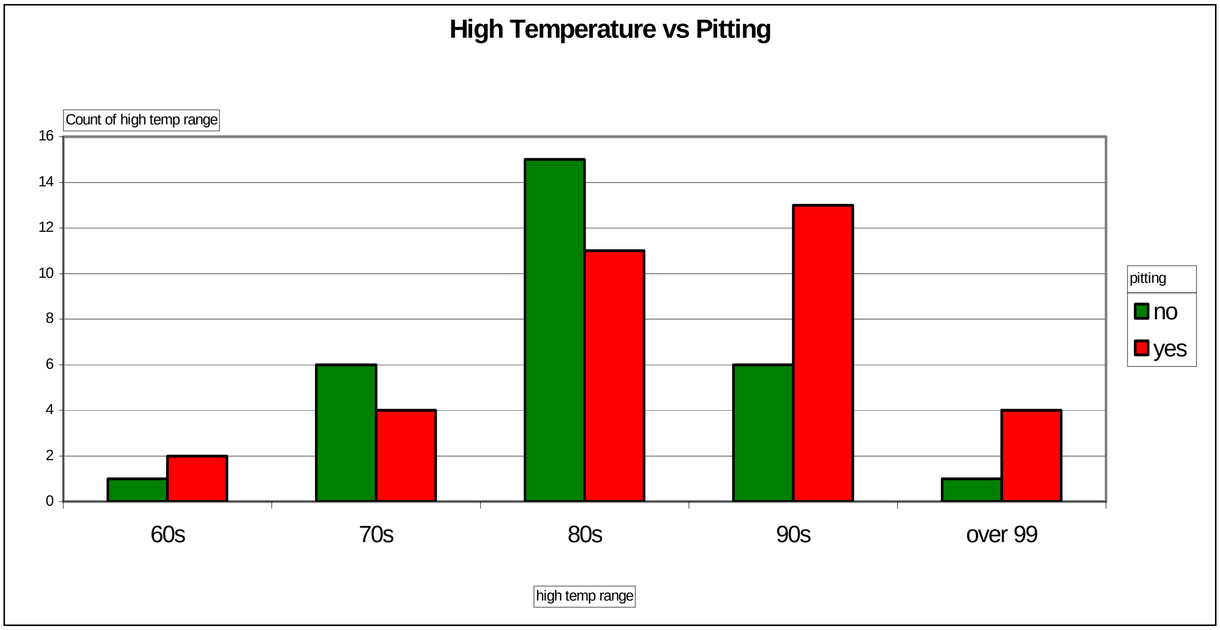


Figure 3. High Temperature at Placement vs. Pitting

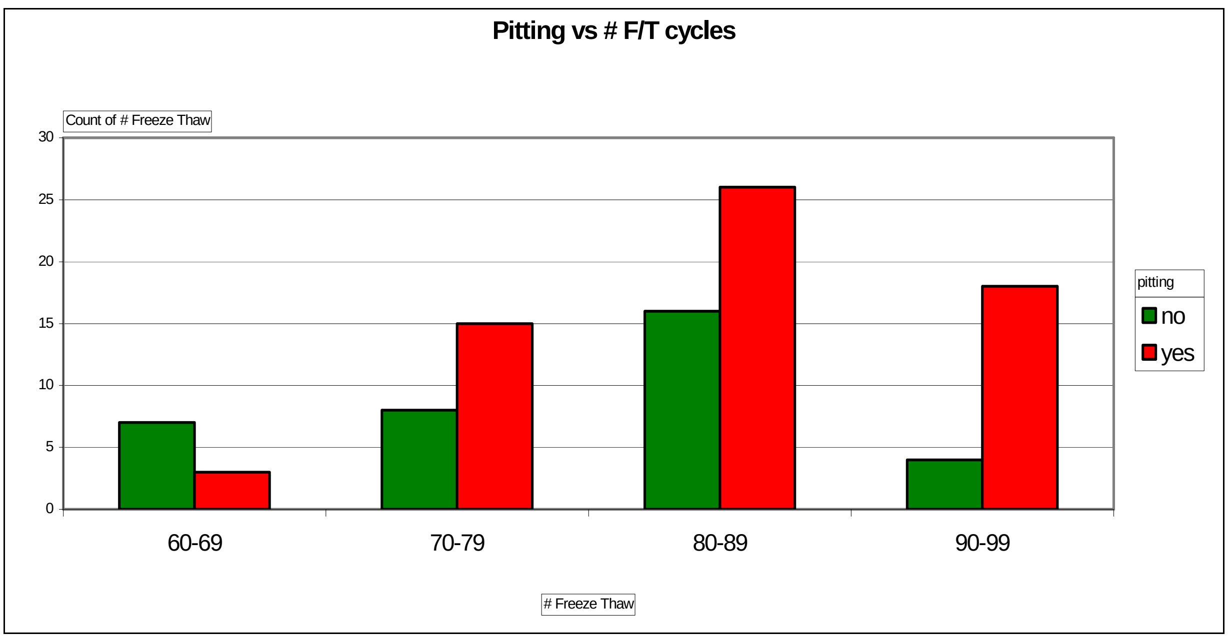


Figure 4. Freeze/Thaw Cycles vs. Pitting

Previous Deck Rating

The condition of a bridge deck should be the most important consideration when determining if a bridge is a good candidate for an epoxy polymer overlay. An EPO can provide good protection for a deck that is in decent condition. Once a significant portion of the bridge deck has deteriorated, it is past the point that an EPO can help. In conversations with the district personnel the decision to place and EPO on a bridge is made anywhere from the design engineer to the district bridge engineer. The decision has been based on a number of different factors including the appearance of an epoxy polymer overlay. It is important to involve someone who is familiar with the deck and its present condition. While the deck rating can be helpful information it can be several years between a deck rating and actual placement of the overlay. A deck rating can also be based on visual inspection only; any areas that are beginning to delaminate can be missed without a full deck survey. It is important that a deck be revisited close to the placement of the overlay to determine that there has not been a significant change in the deck condition since the initial decision to place the overlay.

For those bridges that we were able to gather background information, we collected the previous deck survey prior to placement. Most bridges had either a rating of 6 or 7. There were a few decks that were previously rated an 8 however there were only five. Four out of the five had overlays that ranged in age from 12-14 years old so there is not enough data to draw any conclusions for those bridges. In order to quantify the EPO rating, each bridge was given a number of the EPO rating of 4 for excellent down to 1 for poor. The average rating for the overlay on the bridges with a previous deck rating of 6 was a 2.4 whereas the average rating for the overlay on the bridges with a previous deck rating of 7 was a 3.14. See Figure 5. The bridge decks with a higher deck rating prior to placement are more likely to have an excellent or good rated overlay.

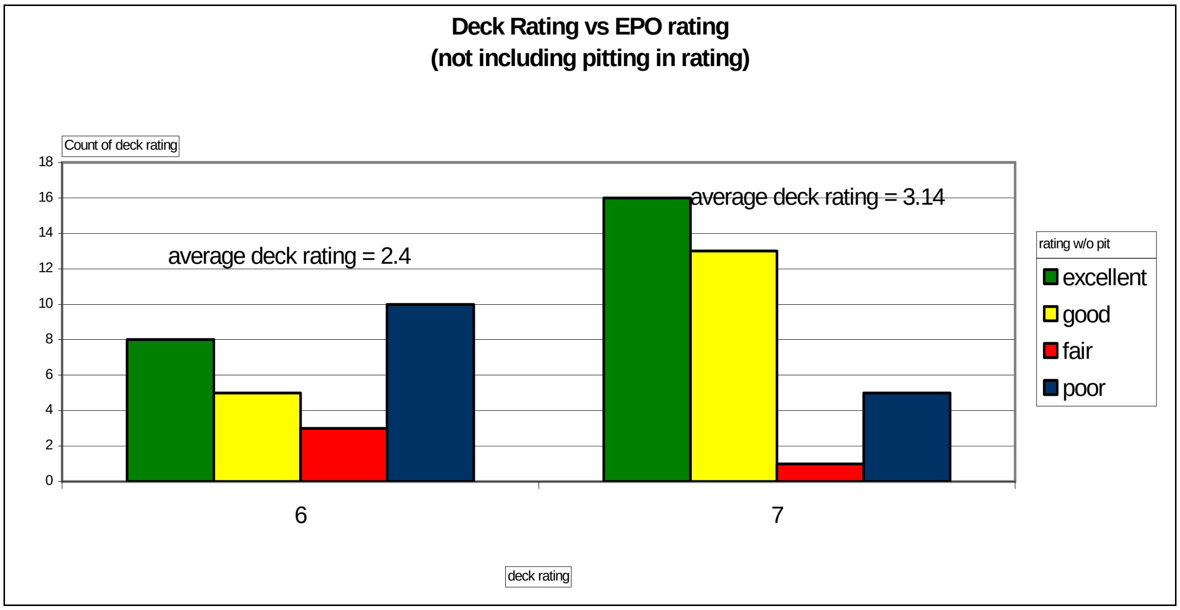


Figure 5. Previous Deck Rating vs. EPO Rating

While deck rating can be an important tool for screening possible candidates, it does not take the place of a full deck evaluation. A bridge deck may be rated a 7 yet still have up to 10% delaminations, in which case it is not a good candidate for an EPO. Likewise a deck may have no delaminations but be rated a 6 because of transverse cracking and efflorescence. An EPO might perform very well on this deck. It is suggested that as well as a determination of delaminations and chloride testing, a pull-off test be performed on the bare deck. This will give the engineer an idea of the strength of the deck itself. If the deck has a low tensile strength, it is likely the EPO will pull off the top layer of paste.

Product Type

An effort was made to relate product type to overlay performance. We were able to get the product information for fifty-five of the bridges. Sikadur 22 and Unitex Pro Poxy III were almost exclusively used. Those two products accounted for forty-seven of the placements. Unfortunately an accurate comparison could not be made because the Sikadur overlays had an average age of 8.5 years whereas the Unitex decks had an average age of 3.5 years.

Freeze/Thaw Cycles

The number of freeze/thaw cycles greatly impacts a bridge deck. When water infiltrates the surface then freezes it can cause fractures in the concrete. The same can be said for epoxy polymer overlays, especially if the overlay has pitting. We gathered climatological data for each bridge deck. The Midwest Regional Climate Center provides the average values for temperatures from 1971 to 2000. By looking at the number of days below freezing and above freezing we estimated the number of freeze/thaw cycles at the nearest weather station to each bridge. As expected as the number of freeze/thaw cycles increases the average rating of the overlays decreased. See Figure 6.

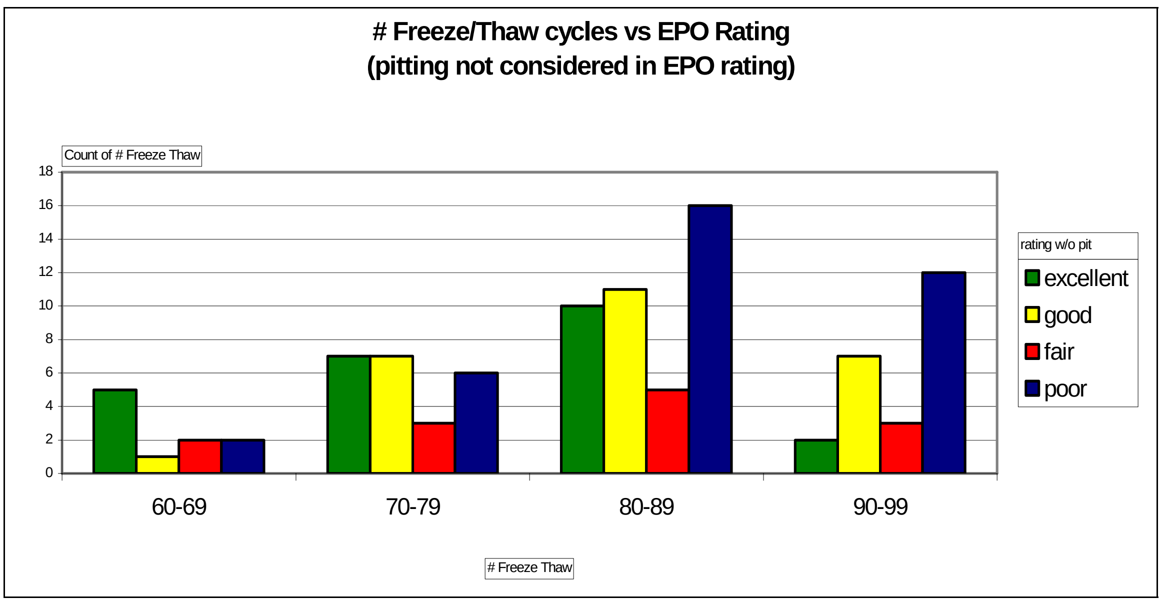


Figure 6. Freeze/Thaw Cycles vs. EPO rating

Temperature at Placement

The temperature at placement was retrieved from the National Climatic Weather Center. There is a loose correlation between temperature and overlay performance. Epoxies that were placed when the high temperature was in the 80s appear to have the best performance. See Figure 8. Temperature variations will affect the viscosity of the epoxy. For decks that have steep grades or are superelevated this can be a concern in high temperatures. When the temperature is too high the epoxy can run and cause it to be too thick at the lowest elevation. MoDOT specifications require that the temperature of the bridge deck at placement be in accordance with the manufacturer's recommendation. For decks with a superelevation or with a steep grade, it is recommended that an upper temperature limit be set. When the epoxy becomes too thick it can put the top layer of deck in tension as the deck moves causing fractures in the deck surface. If the temperature is too low the epoxy can thicken causing placement problems with the aggregate not embedding in the epoxy.

Span Length/Girder type

The span lengths of the bridge had an effect on the performance of the overlays. We compared the longest span length and overlay rating which indicated that the longer span bridges were more likely to have problems with their overlays. See Figure 7 and 8. This is not surprising since the longer spans will be more flexible, increasing the chance of the epoxy and/or deck cracking. Some of the newer epoxies are more flexible than the older epoxies, which should help with this problem. For bridges with long spans it would be more cost effective to look for an epoxy that is more flexible as opposed to going with the cheapest product. Transpo-T48 is a more flexible epoxy that might provide better protection on flexible decks. The girder type is related to the span length so the same pattern was found. Bridges with steel wide-flange sections and P/S I girders had higher EPO ratings than steel plate girders. See Figure 9.

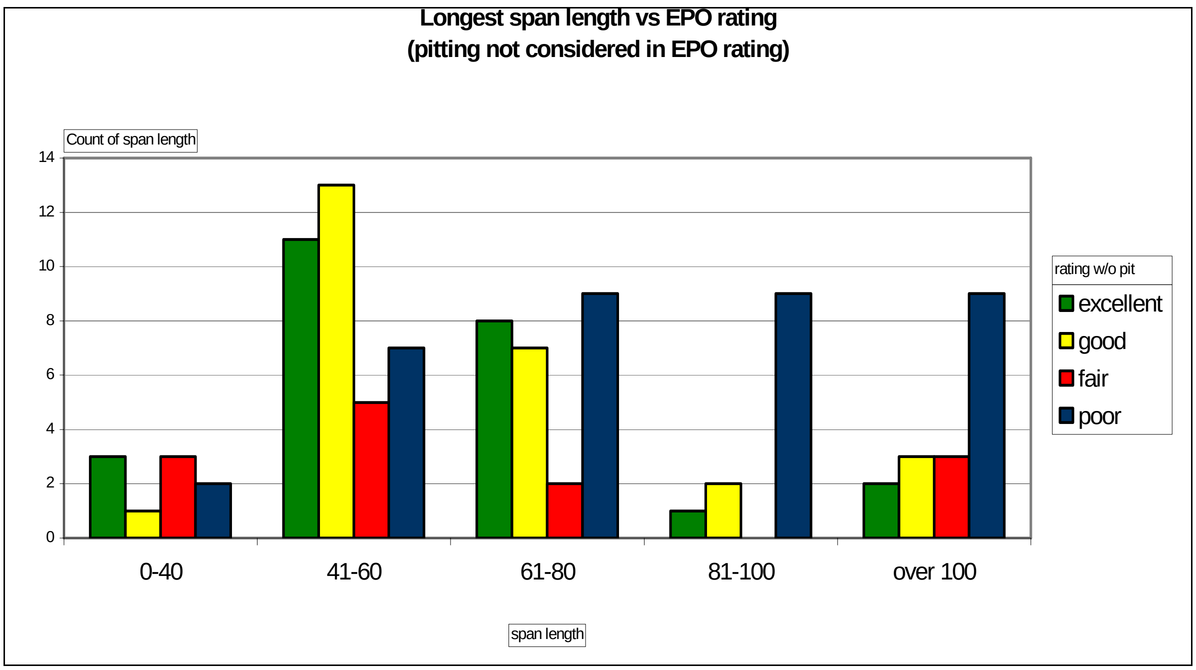


Figure 7. Longest Span vs. EPO rating