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Alleviating the Effects of Pavement Growth on Structures

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1. Introduction

Failures of concrete pavements as a result of Pavement Growth (PG) are pronounced and easily identified. When PG occurs at a contraction joint it is often referred to as a “blow-up”. The damage from PG on structures is not as easily identified since much of it occurs beneath the deck. Effects of pavement stresses are not well understood, nor are they often noticed until environmental deterioration reduces the bond of protective joint fillers. Performing biennial preventive maintenance to the vast quantity of concrete roads is impractical due to a finite amount of maintenance funding and staff. However, expensive and irreversible damage to structures caused by pavement stresses may be reduced if bridge engineers, inspectors, and maintenance workers identify the signs of PG early, and initiate corrective action through the installation of a Pressure Relief Joint (PRJ) in a timely manner.

Sources of Growth

There are many contributing factors that lead to the PG that causes catastrophic damage to bridge components. These sources are interconnected and work to complement one another. The average daily traffic (ADT) a roadway experiences and joint seal maintenance are one such example. It is often difficult to justify lane closures for joint sealing in a metropolitan area, but joint seals wear and deteriorate faster where there is more traffic. Open contraction joints allow debris buildup and thus reduce the amount pavement can expand during increasing temperatures.

The length of concrete pavement and joint spacing adjacent to a bridge also determines the rate and extent of PG. It is believed that growth leading to detrimental stress will happen faster for long portions of pavement with a limited number of joints compared to a short section of pavement with multiple joints. In part, this is due to the fact that with additional contraction joints the space between slabs will be reduced during initial shrinkage, and large Incompressible Particles (IP) will not be collected as quickly. The practice of installing additional joints may reduce the rate of pressure generation; however, it will not eliminate it. Traditional pavement maintenance practices of placing emulsion and stone in and over joints also accelerates PG due to the intentional introduction of IP.

Other intertwined variables that lead to pavement distress or bridge damage are temperature, age, and the use of sand during winter maintenance operations. If temperatures frequently fluctuate, as they do in Michigan’s climate, there is an increased opportunity for the introduction of IP into joints. Hot poured rubber and other joint sealants take time to break down and deteriorate, and a series of cycles over several years are often required for pronounced effects. Obviously the deliberate introduction of sand leads to an acceleration of PG caused by IP.

In various combinations these sources cause pressures to generate in excess of 1,000 psi at structures. Joint sealant maintenance and short longitudinal spacing between contraction joints extends the amount of time before bridge damage occurs. Understanding the pressure generation cycles in Figures 1 through 10, and the process used to alleviate it will reduce the need for temporary supports and/or expensive rehabilitation projects.

Pressure Generation Cycles

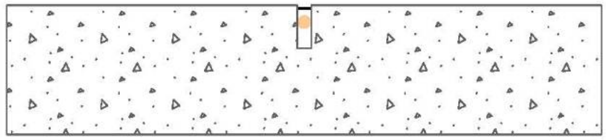

Figure 1. Saw cut and sealed green concrete pavement

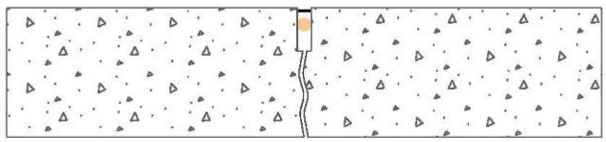

Figure 2. Shrinkage crack forms at contraction joint

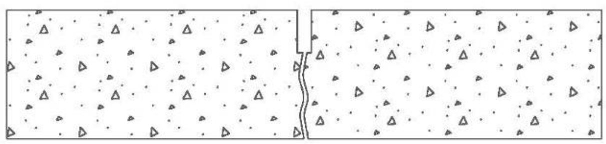

Figure 3. Joint seal lost

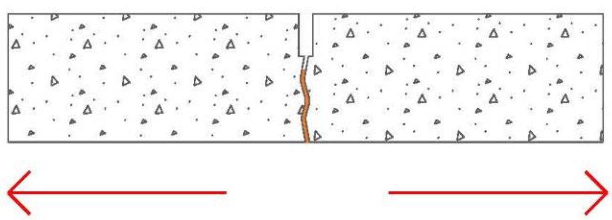

Figure 4. Fine particles infiltrate joint and expansion occurs

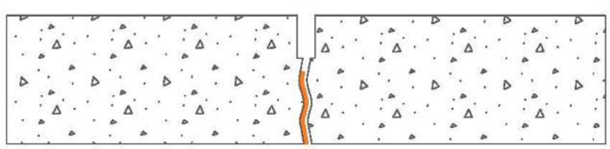

Figure 5. Concrete contracts

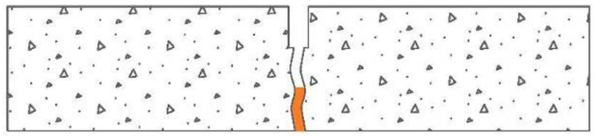

Figure 6. Incompressible particles settle

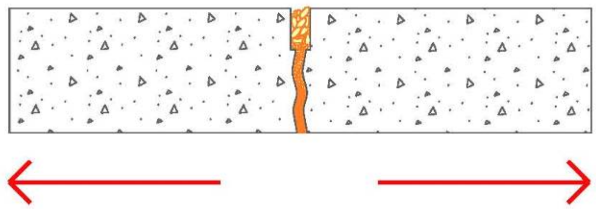

Figure 7. Coarse particles begin to infiltrate joint and expansion occurs

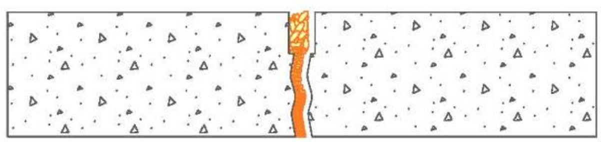

Figure 8. Concrete contracts

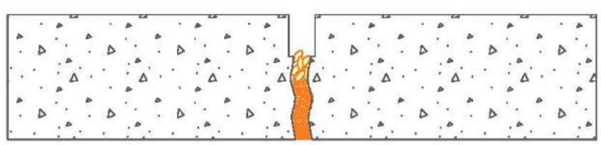

Figure 9. Incompressible particles settle

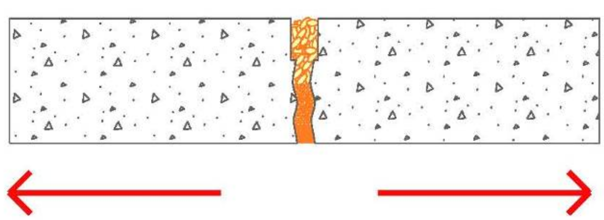

Figure 10. Coarse particles infiltrate joint and expansion occurs

Symptoms of Pavement Growth

There are common signs that PG is occurring at a structure. Before detailing each one it is important to first visualize the problem, which often helps differentiate PG symptoms from elements constructed poorly. In order for PG to cause damage to a bridge, concrete pavement must be adjacent to one or both sides of the structure. Usually a significant amount of concrete roadway, 1,000 feet or more are required to generate excessive pressures. Although the 1,000 feet rule is applicable in most cases, damaging PG has been noticed where there is less than the prescribed amount of pavement. These uncommon cases are especially true if another structure is located nearby.

Imagine if a bridge and the adjoining approach pavement was placed in a vise and compressed slowly. You may first notice concrete "blow-ups" at the approach, or bridge approach curb and gutter separating from the end-wall. If all of the longitudinal stress generated from the road is transferred through the slab without any noticeable effects, damage may only be seen along the backwall and expansion joints.

Expansion joints are often the first vital component to be affected by PG. They allow the bridge to freely expand and contract during temperature cycles, and if there is no space available for expansion damage will occur to the deck and beams beneath.

Figures 11 & 12. Expansion joints permanently closed

Damaged railing is often readily noticeable and may be the first element damaged. If the space separating two sections of railing at an expansion joint is less than the joint throat the railing will be tight or crushed first. The damage may also occur along the approach if the expansion joints are not on the bridge.

Figures 13 & 14. Crushed concrete railings

Many older structures have single and double tube railing, and tube separation is a visual sign pressure from the roadway is being applied. Look for separated sections near each end of the deck where tube railing attached to a wing wall meets railing joined to the tailspan.

Figures 15 & 16. Aluminum tube rail separation

A series of cracks that propagate near the approach end of a tailspan are a feature of pavement pressure. The cracks are measurable in some cases, but are most often hairline. If more than two cracks at a forty-five degree angle to the reference line can be seen, look for other symptoms beneath the deck.

Figures 17 & 18. Diagonal deck cracks in tailspans

Pin and hangers are easy to see while driving, and closed ones during winter months should be investigated. Although corrosion is often blamed, a closer examination should be conducted.

Figures 19 & 20. Pin & Hangers closed during cold weather

Severely tilted rockers may be an indication of PG. Taking action by only realigning the tilted rocker bearings to accommodate for thermal expansion is not a remedy. Installing a PRJ prior to beam end contact will eliminate damage to beam ends.

Figures 21 & 22. Tilted rocker bearings during cold weather

Beam end contact occurs when the effects of PG have gone untreated and the resulting damage will lead to stress cracks near the bottom flange and web interface. A hands-on inspection should be performed to determine if a crack is present that will require a bolted repair.

Figures 23 & 24. Examples of damage from beam end contact

An independent backwall that is not vertically plumb may have been constructed correctly, but has since been pushed by PG. This action results in a void forming behind it causing the approach to crack. In many cases both vertical construction joints between the backwall and wing walls will open and a significant amount of subbase material may be lost.

Figures 25 & 26. Tilted independent backwalls

When sounding of the abutment stub reveals delaminations beneath the beams PG is present and corrective action through the installation of a PRJ must be performed. Significant spalling or exposed positioning dowels are signs of reduced bearing and will require substructure repair and temporary supports.

Figures 27 & 28. Dependent backwall delamination and spalling

A bridge approach that has settled or been raised by PG creates additional impact force on the deck. A void beneath the pavement presents an unneeded hazard and further inspection is required to determine if it is a result of PG or poor construction.

Figures 29 & 30. Approach settlement and void behind backwall

If the previous signs are ignored tailspan beams may buckle from longitudinal pavement stress. A buckled beam could possibly be heatstraightend. Retrofitting a heatstraightened beam with a bolted repair is a temporary fix, and would require attentive monitoring until replacement.

Figure 31. Buckling tailspan beam

Pressure Relief Joint Materials

Three approved materials were listed on the recently revised PRJ special provision. All of the products are composed of proprietary blends of closed cell foam, and are UV resistant as well. The joints all perform well when PG is occurring, but our field monitoring has revealed that the cost of these materials do relate to durability.

Watson Bowman Evazote is available in multiple widths and lengths, and a chart provided on the technical data sheet lists recommended widths according to various joint openings. A two part epoxy adhesive is used to bond the edges of the Evazote to the vertical concrete surfaces. Since it is semi-rigid and not very compressible with the use of one's hands, it is very important to maintain a 4" wide joint opening during saw cutting. Evazote is the preferred product in those instances when immediate PG and joint compression is NOT imminent. The two part epoxy provides exceptional adhesion to the adjacent concrete and greatly reduces failures.

CMC Construction Services Flex-Lok brand is furnished in 8' lengths and is 4.75" wide. The material is forgiving as it compresses easily and slight variations during saw cutting will not prevent installation. It is glued in place by using a one component lubricant adhesive such as D.S Brown 1520.

W.R. Meadows Ceramar is produced in 12' sections 4.5" wide. It is comprised of multiple laminated sheets glued together. The average cost per foot ranges from 25% to 33% of the other two options. Although the material does perform well it is recommended for use in areas of low to moderate traffic, and at those locations where the joint will be placed into immediate compression.

Installing Pressure Relief Joints

Pressure Relief Joints are installed into 4" wide full depth joint openings. The saw cutting is often contracted because two parallel cuts must be made accurately which is often better performed by a sawing professional. The joint must be continuous extending across the entire road, and any adjoined curb and gutter or concrete barrier wall must be cut as well. Cuts in concrete barrier wall require the use of a concrete cutting chainsaw. Be mindful of electrical conduit locations whenever saw cutting through barrier wall containing lighting.

Figure 32. Saw cutting concrete barrier wall to relieve pressure

The joints should be located approximately 50' away from the structure, but not placed at an existing joint or load transfer device. After saw cutting, the concrete and any mesh reinforcement should be removed completely and the aggregate base must be visible. This may be accomplished using either 60 pound jackhammers or a skid steer with mounted hydraulic hammer attachment.

Once removed, the vertical surfaces must be dried with air and sandblasted to aid the bonding ability of the lubricant adhesive. A vacuum truck is helpful to remove slurry located in the bottom of the joint that is generated during saw cutting.

Figure 33. Sandblasting the exposed edges of pavement

Each contacting edge of closed cell relief joint material must be coated with lubricant adhesive. Inexpensive disposable rollers or steel trowels may be used to spread the material conservatively. Once the sides are coated, the material should be pressed in place by hand working from one end to the other without stretching it. Press the foam into the void so it is recessed approximately one half inch. Tools may be cleaned with xylol or acetone to remove any lubricant adhesive residue.

Figure 34. Applying lubricant adhesive to both contacting edges

Any irregularly saw cut areas that are wider than 4” require the use of spacers. Spacers are simply pieces of the same material and act as wedges to hold the material in place until it is in a state of compression. Provide spacers a maximum of every 6” or as needed to maintain the joint elevation. Allow any excess lubricant adhesive lying on the road surface to cure or place blasting sand on it to prevent tracking. Do not reopen lanes to traffic if the material will be picked up by vehicular traffic.

Scheduling Installation

Installations should only be scheduled prior to peak seasonal temperatures. Placing the material during the summer or fall usually results in loss of the material. The foam does not react well under tension. The Region Bridge Support Unit recommends scheduling installations during the months of March, April, May, and June. Each location has its own unique obstacles to contend with such as traffic volume, layout, and other coinciding conditions. In many cases the experience of the maintenance crew workers, saw cutting contractor, and even weather can determine if the tasks will be completed earlier or later than expected. To increase awareness and aid Region personnel scheduling crews and lane closures a typical project timeline for a common three lane freeway in an urban area has been included. The durations listed are for an average project with a maintenance crew consisting of five to six people, as well as two additional support persons from Central Maintenance.

Activity 1. Maintaining Traffic – Initial Setup 1 to 2 Hours

Once arriving at the site with the devices loaded it may take one to two hours to close the right or left and center lane. Closing ramps, placing detours, and loading signs and channelizing devices are not included in the duration for this activity.

Activity 2. Saw Cutting Pavement – Phase 1 0.75 Hours

This activity includes the time required to mark the joint location(s) and perform full depth saw cutting of the roadway and any adjoining curb and gutter. The saw cutting of concrete barrier wall or raised median will significantly increase the duration of this activity. A sixty pound hammer and air compressor should be on site to provide assistance if the cutting blade becomes wedged in the pavement.

Activity 3. Concrete Removal – Phase 1 0.75 to 1.25 Hours

The removal of concrete utilizing a skid-steer mounted jackhammer substantially reduces the amount of time and effort to open a void for the insertion of material. Sections of the saw cut material are usually broken into eighteen inch lengths, pried loose using the equipment, and then loaded by hand into a stake truck.

Activity 4. Installing Relief Joint – Phase 1 0.75 to 1.0 Hours

Flex-Lok, Evazote, and Ceramar are three commonly used relief joint products. While each has its own unique advantages, the placement of Evazote requires mixing a two-part epoxy and additional placement effort.

Activity 5. Maintaining Traffic – Switch Setup 1.5 to 3 Hours

A wide variance in the amount of time for the activity is used because many variables are unknown until the location is determined. Ramps and heavy traffic flow in the influence area usually increases the amount of time needed.

Activity 6. Saw Cutting Pavement – Phase 2 0.75 Hours

Again, this activity includes the time required to mark the joint location(s) and perform full depth saw cutting of the roadway and any adjoining curb and gutter. It is important to expedite the previous activities so additional stand-by charges are not incurred from the contractor.

Activity 7. Concrete Removal – Phase 2 0.75 to 1.25 Hours

The removal of concrete utilizing a skid-steer mounted jackhammer substantially reduces the amount of time and effort to open a void for the insertion of material. An increase in crew size and duration is needed if sixty pound hammers are used to remove the concrete.

Activity 8. Installing Relief Joint – Phase 2 0.75 to 1.0 Hours

The installation of the relief joint is a simple process that may go much faster than the expected duration. When preparing to press it into place it is necessary to examine the void and make sure all rebar and IP have been removed otherwise the material may never become compressed.

Activity 9. Maintaining Traffic – Removal 1 to 2 Hours

Once the joint has been installed there is no "cure time" requirement for the adhesive and lanes may be opened at once if there is no excess material that may be tracked onto vehicles.

Activity 10. Monitoring Life of Relief Joint

It is important to pay close attention to the joint; annual inspections will allow the joint to be replaced prior to pavement growth distress.

Figure 35. PRJ installations also work well during night time hours

Monitoring

Once a PRJ has been installed work is not finished. It is very important for bridge inspectors to monitor the width of the joint and communicate to maintenance staff when a replacement is required. If the joint measures 1” to 2” a replacement should be added to the list of annual maintenance work crew recommendations. When a PRJ measures less than 1” it should be replaced immediately to eliminate the opportunity for damage.

Figure 36. Inspectors should measure the joint to prevent future damage

The amount of time required before performing a replacement will vary for each PRJ. A concrete repair project or bituminous overlay on the concrete roadway will significantly reduce the rate at which pavement stresses form. However, if no changes occur and the factors that cause PG are plentiful, replacements will often occur after only 4 years of service.

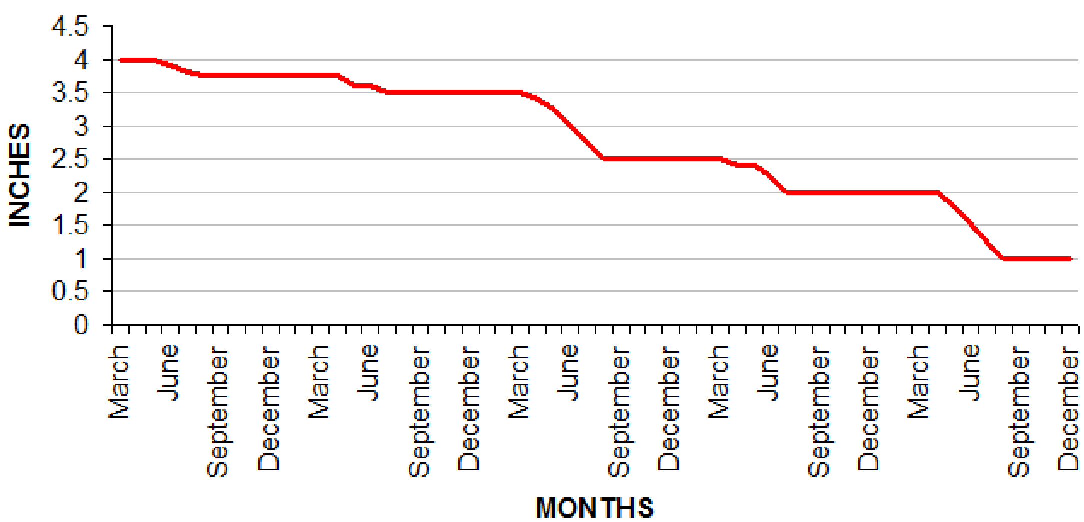

Figure 37. Characteristic monthly PRJ measurements

Preventing Structural Damage

As previously mentioned, it is currently impossible to eliminate the infiltration of IP in all jointed concrete pavements. Preventing expensive bridge damage, however, is possible and steps to ensure pavement stresses are identified and alleviated should be executed through continual communication and awareness. Bridge inspectors can identify the symptoms of PG early, during biennial routine inspections without extra time and effort. Corrective action through the installation of a PRJ may be initiated by including it in annual maintenance work crew recommendations and flagging it as a high priority.

Construction and maintenance practices may also be improved as well. Engineers assembling pavement repair projects (concrete patch jobs) can incorporate additional expansion joints in aging pavements. Continued emphasis to enforce current standards for joint sealing, investments in equipment and materials that provide long term joint seals, and the use of joint sealing material that does not incorporate IP are all initiatives that could reduce the effects of PG on structures throughout the state.