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CIE 822

Graduate Project Paper

May 4, 2017

Paper Title:

Review of Current Standards and Patching Products for Rapid Setting Partial Depth Repairs used on Concrete Pavements and Bridge Decks

Abstract:

Partial depth concrete repairs are an extremely common way to fix only parts of deteriorating concrete infrastructure. Concrete pavements and bridge decks are in need of quick fixes that are durable and long-lasting so more time and effort can be put into replacing or rebuilding our country’s main method of transportation. This literature review examines the current standards of practice for partial depth concrete repairs through current agency specifications. The details and laboratory testing specifications of the products used in concrete repairs are investigated to see how well they have performed and what they are lacking. New materials and combinations of products and materials are explored to see what they have to offer the concrete partial depth repair industry.

Generalized Paper Outline:

1. Current agency specifications for concrete repairs
   1. FHWA partial depth repairs for pavements
      1. What is a partial depth repair?
      2. Types of partial depth repairs
      3. Review the process of material selection
      4. What are the recommended repair materials and what are their characteristics?
   2. ACPA (American Concrete Pavement Association) partial depth repairs for pavements
      1. What is a partial depth repair?
      2. Types of partial depth repairs
      3. Review the process of material selection
      4. What are the recommended repair materials and what are their characteristics?
   3. NCPTC (National Concrete Pavement Technology Center) with Iowa State University Institute for Transportation, partial depth repairs for pavements
      1. What is a partial depth repair?
      2. Types of partial depth repairs
      3. Review the process of material selection
      4. What are the recommended repair materials and what are their characteristics?
2. Approved products review
   1. FHWA 2005
      1. QPL Products
      2. Specifications for Product Approval
   2. Caltrans (California)
      1. QPL Products
      2. Specifications for Product Approval
   3. IDOT (Illinois)
      1. QPL Products
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   4. IOWADOT (Iowa)
      1. QPL Products
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   5. MnDOT (Minnesota)
      1. QPL Products
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      1. QPL Products
      2. Specifications for Product Approval
3. ASTM specification review to determine properties of these partial depth repair materials
   1. C39/C39M
      1. Review of the testing procedure and how the results are used
   2. C157/C157M
      1. Review of the testing procedure and how the results are used
   3. C469/C469M
      1. Review of the testing procedure and how the results are used
   4. C531/C531M
      1. Review of the testing procedure and how the results are used
   5. C666/C666M
      1. Review of the testing procedure and how the results are used
   6. C882/C882M
      1. Review of the testing procedure and how the results are used
   7. C928/C928M
      1. Review of the testing procedure and how the results are used
   8. C1581/C1581M
      1. Review of the testing procedure and how the results are used
   9. C1583/C1583M
      1. Review of the testing procedure and how the results are used
4. Analysis of the more common partial depth repair methods and products and how they could be used in different ways or combined with others methods/products
   1. Which products have proven to be more successful and why?
   2. Could a combination of methods or products be developed to produce a product that performs better than the already approved products?
   3. What other types of bonding materials have not been analyzed yet? Could these materials be incorporated into existing materials or used on their own?

Detailed Paper Outline:

1. Current agency specifications for concrete repairs
   1. FHWA partial depth repairs for pavements
      1. What is a partial depth repair?
         1. The removal of concrete and replacement of a repair material on a shallow, deteriorated area of a concrete structure (Smith and Harrington 2014)
         2. They extend the service life of the concrete structure (Smith and Harrington 2014)
         3. Are used as repairs where the deterioration of the pavement is at a depth of less than 1/3 to 1/2 of the total depth of the pavement structure (Smith and Harrington 2014)
         4. In a partial depth repair, any load transfer devices are not affected at all (Smith and Harrington 2014)
         5. Costs of partial depth repairs are dependent on size (Smith and Harrington 2014); meaning they are dependent on how much work needs to be put into them and how much of the repair material must be used
         6. They are used for deteriorated concrete only because the repair materials cannot handle the flexibility of joints with high stresses (Smith and Harrington 2014)
         7. Example of areas where partial depth repairs have been successful are (Smith and Harrington 2014):
            1. Spalling caused by the intrusion of incompressible materials into the joints
            2. Spalling caused by poor consolidation, inadequate curing, or improper finishing practices
            3. Spalling caused by weak concrete, clay balls, or mesh reinforcing steel locate too close to the surface
            4. Spalling caused by an inadequate air void system
            5. Other localized areas of deterioration or scaling that are limited to the upper one-third to one-half of the slab thickness and are of sufficient size and depth to warrant repair
         8. Areas where partial depth repairs should not be used are (Smith and Harrington 2014):
            1. Spalling caused by dowel bar misalignment or lock-up
            2. Spalling of transverse or longitudinal cracks caused by shrinkage, fatigue, or foundation movement
            3. Spalling caused by MRD (materials-related distress), such as D-cracking or reactive aggregate
         9. The performance of the partial depth repair depends on the existing condition of the pavement, the materials used, and the equipment and construction techniques used (Smith and Harrington 2014)
         10. They can last for 15 years or more when done properly, and can fail in as little as 2-3 years when done poorly (Smith and Harrington 2014)
      2. Types of partial depth repairs
         1. Type 1: Spot Repairs of Cracks, Joints, and Spalls (Smith and Harrington 2014)
            1. Can be Joint “V” Milled and Spot Repair Saw and Chip (Smith and Harrington 2014)
            2. Repairs to address small areas of failure, not for repairs of large lengths (Smith and Harrington 2014)
            3. Good for the following types of repairs (Smith and Harrington 2014):

Joint spalling

Mid-slab surface spalling or cracking

Severe surface scaling

Joint reservoir issues

* + - * 1. The failed concrete can be removed by sawing the area and then jackhammering it out or it can be milled with a milling machine (Smith and Harrington 2014)
      1. Type 2: Joint Crack Repairs (Smith and Harrington 2014)
         1. Can be Crack “V” Milled, Longitudinal Joint “V” Milled, and Transverse Joint “V” Milled (Smith and Harrington 2014)
         2. Done on longitudinal or transverse joints where the crack is longer than six feet (1.8 m) and where the maximum depth is 1/2 of the slab (Smith and Harrington 2014)
         3. For transverse joints the joint needs to be sawed to recreate the joint at its full depth with an additional 0.25 to 1 inch (6-25 mm), and for longitudinal joints the repair material is only installed at the surface of the crack (Smith and Harrington 2014)
      2. Type 3: Bottom Half Repairs
         1. Basically the same as full-depth corner repairs to fix the edges of the slab that have failure that is more than 1/2 of the slab thickness. To be a partial depth repair, the bottom half repair must be shorter in length because of its thicker depth (Smith and Harrington 2014)
         2. When done at the outer edge of a slab, the length of the repair shall not be greater than 18 inches (460 mm) at the bottom of the repair (Smith and Harrington 2014)
         3. Full-depth repairs are highly recommended when the transverse length of the repair is longer than 18 inches (460 mm) into lanes on either side of the longitudinal joint (Smith and Harrington 2014)
    1. Review the process of material selection
       1. The following factors need to be considered when choosing a repair material (Smith and Harrington 2014)
          1. Available curing time
          2. Placement conditions (ambient temperatures and moisture levels)
          3. Material properties (particularly shrinkage, coefficient of thermal expansion, and bond strength)
          4. Material and placement costs
          5. Compatibilities between the repair material and existing pavement
          6. Size and depth of the repair
          7. Performance capabilities and performance requirements of project
          8. Project size
       2. Other considerations are climatic conditions, urgency, and rehabilitation schedules (Wilson et al. 1999)
       3. It may be most cost-effective to choose a more expensive repair material with better performance for a repair that will not be covered in any way and that will be exposed to traffic and climate (Wilson et al. 1999)
       4. When comparing cost in choosing a repair material, the material cost, installation cost, equipment cost, labor cost, and time must all be contributing factors (Wilson et al. 1999)
          1. Table 1. Properties of some rapid-setting partial depth spall repair materials (Wilson et al. 1999)
       5. Table 2. Initial material selection criteria for some rapid-setting materials
       6. The available curing time should be the main priority for material selection based upon the required reopening time of the roadway (Smith and Harrington 2014)
       7. The drying shrinkage of the material must also be taken into serious consideration because most repair materials have greater drying shrinkage than normal concrete (Smith and Harrington 2014)
       8. Drying shrinkage of repair materials can induce a tensile stress of up to 1,000 pounds per square foot (6,900 kPa) compared to normal concrete (Smith et al. 2008)
       9. Differences in the coefficient of thermal expansion between the repair material and the existing concrete can lead weakened bonds from expansion movement of the repair material and existing concrete (Smith and Harrington 2014)
       10. Table 5.1 Example of Opening Strength Requirements for PDRs (Smith and Harrington 2014)
       11. Premature deterioration of partial depth repairs can happen because of material-related factors (Smith and Harrington 2014):
           1. Incompatibilities between the climatic conditions during repair replacement and the materials or procedures used
           2. Thermal incompatibility between the repair material and the pavement
           3. Extreme climatic conditions during the life of the repairs that are beyond the capabilities of the repair material
           4. Inadequate cure time prior to opening repairs to traffic
           5. Incompatibility between the joint bond breaker and the joint sealant material
       12. Use of bonding agents
           1. Most of the materials used in concrete repairs will require the addition of a bonding agent between the existing concrete and repair material (Smith and Harrington 2014)
           2. The most common bonding agent is a sand-cement grout. This sand-cement grout is compromised is 2 parts of Type I cement, 1 part of water, and 1 part of sand (Smith and Harrington 2014)
           3. The sand-cement grout fits into all the small void spaces still remaining on the existing concrete (Smith and Harrington 2014)
           4. Epoxy bonding agents have shown to minimize traffic closure time to 6 hours or less when used with Portland cement concrete and proprietary repair materials (Smith et al. 2008)
           5. Bonding agents should not be left too long to dry before the placement of the repair material as this will prevent the purpose of the bonding agent (Smith and Harrington 2014)
       13. The location of the nearest ready-mix plant must also be considered when selecting the repair material. In some instances, it may be best to bring the materials and a small portable mixer to the repair site for smaller repairs (Johnson et al. 1980)
       14. The material needs to be verified that it is obtained from an approved source off of the Qualified Products List from the contract documents (FHWA 2005)
       15. The repair material needs to be sampled and tested prior to installation as written in the contract documents (FHWA 2005)
       16. The bonding agent to be used with the repair material also needs to be verified that it meets specifications in the contract documents (FHWA 2005)
    2. What are the recommended repair materials and what are their characteristics?
       1. Concrete Materials
          1. Portland Cement Concrete

High quality concrete is typically the most used type of concrete for partial depth repairs (Smith and Harrington 2014)

Can use Types I, II, and III Portland cement with coarse aggregate not larger than 1/2 the repair thickness (0.375 inches, or 9.5 mm is often used) (Smith et al. 2008)

Type III is more finely ground than Type I which speeds up the hydration rate, strength development, and heat release of the concrete during the first 7 days (Wilson et al. 1999)

It is possible that the repair concrete will provide sufficient durability to the patch area even if the aggregates of the repair material are of a lesser quality than the aggregates of the existing concrete (Johnson et al. 1980)

The concrete should be air entrained and of a low slump with a maximum water-cement ratio of 0.44 (Smith and Harrington 2014)

If a faster setting time is needed, patches with Type III (HE) cement can be opened right when the material can endure loads without plastic deformation (Smith et al. 2008)

Because of its low cost, abundant availability, and ease of use, Type I cement is the most commonly used in concrete as a repair material (Smith and Harrington 2014)

Minimum compressive strength values are typically between 1,600 and 1,800 pounds per square inch (11-12.5 MPa) for repairs able to support traffic loading without any deterioration (Smith and Harrington 2014)

* + - * 1. Gypsum-Based Cement Concrete

Setting times can be as low as 20-40 minutes can open to traffic in as little as an hour with gypsum based cements because of their calcium sulfate content (Smith and Harrington 2014)

Should only be used in temperatures above freezing, and they require dry conditions during placement (Smith and Harrington 2014)

Should not be used with reinforced pavements for prevention of steel corrosion from free sulfates in the gypsum (Smith et al. 2008)

* + - * 1. Calcium Aluminate Concrete

Have low shrinkage during curing, good bonding properties, they gain strength rapidly, and have good resistance to freeze thaw cycles and deicing chemicals (Smith and Harrington 2014)

This makes them good in low temperature pavement repairs with still contributing early strength (Smith and Harrington 2014)

At high temperatures, strength loss is likely to occur over the time of curing, so this cement is not recommended as a repair material at high ambient temperatures (Smith et al. 2008)

* + - * 1. Magnesium Phosphate Concrete

Can come as a one- or two-component system. The one-component system is a magnesium and phosphate mixed as a powdered form and added to water. The two-component system is magnesium powder and aggregate combined with a phosphate liquid solution (Smith and Harrington 2014)

This mixture sets very quickly and yields high early strength. It is an impermeable material that will bond with clean and dry surfaces (Smith and Harrington 2014)

Can set in as little as 10 to 15 minutes in hot weather where the temperature is above 90 °F (32 °C) (Smith et al. 2008)

Sensitive to water and aggregate type (Smith and Harrington 2014)

Excess water can decrease strength severely (Wilson et al. 1999)

* + - 1. Polymer-Based Concrete Materials
         1. General Information

These concretes are made of a polymer resin, an initiator, and aggregates. The aggregates make the resin more “thermally compatible” with the concrete, provides a wearing surface, and makes the mixture more cost-effective (Smith and Harrington 2014)

The polymers make the mix set quicker, however they are sensitive to moisture and temperature conditions, and can be costly (Smith and Harrington 2014)

Four categories of polymer concretes are epoxies, methacrylates, polyester-styrenes, and urethanes (Smith et al. 2008)

* + - * 1. Polyurethane-Based Concrete

Consist of a two-part polyurethane resin combined with aggregate (Wilson et al. 1999)

They are typically flexible and quick setting (90 seconds), however they display substantial initial shrinkage and have a high coefficient of thermal expansion (Smith and Harrington 2014)

Some are moisture-tolerant, meaning they can be placed on wet existing concrete without creating any adverse effects (Smith et al. 2008)

* + - * 1. Epoxy Polymer Concrete

A two component system of a liquid epoxy resin mixed with a curing agent (Smith and Harrington 2014)

They have great impermeability and adhesive properties, however the range of setting times, application temperatures, and bonding conditions is very extensive (Smith and Harrington 2014)

The epoxy concrete mix must be compatible with the existing concrete pavement due to the high coefficient of thermal expansion of the epoxy concrete (Smith and Harrington 2014). The use of larger aggregates mitigates this problem by creating an increase in the volume stability which in turn reduces the chance of the bonds coming apart (Smith et al. 2008)

For deep epoxy repairs, the material must be placed in multiple lefts to control the heat build-up (Smith et al. 2008)

* + - * 1. Methyl Methacrylate Concrete

Can also be high molecular weight methacrylate (HMWM) (Smith et al. 2008)

They are volatile and can be a health hazard to those placing it who are exposed to the fumes for an extended period of time (Smith et al. 2008) However, they have high compressive strengths, long working times, and good adhesion (Smith et al. 2008)

They can be placed in a wide range of temperatures from 40 to 130 °F (4 to 54 °C) (Smith et al. 2008)

Can also be classified as cementitious materials (Wilson et al. 1999)

* + - * 1. Polyester-Styrene Concrete

Have many of the same properties of methyl methacrylates, however their strength gain rate is much slower, which limits the reopening time for the pavement slab (Smith et al. 2008)

Generally used more than methyl methacrylates because they are more cost-effective (Smith et al. 2008)

* + - 1. Bituminous Materials
         1. Conventional Bituminous Materials

Considered only as temporary or emergency repair materials (Smith and Harrington 2014)

They are low in cost, available, easy to handle, and have very low cure times (Smith and Harrington 2014)

Most effective and well performing are the hot-mix asphalt concretes (Wilson et al. 1999)

Can be used anywhere and in all climates (Wilson et al. 1999)

* + - * 1. Proprietary and Modified Bituminous Materials

More expensive than conventional bituminous materials, but perform better (Smith and Harrington 2014)

They can be placed along transverse joints without having to reform the joint, which speeds up the replacement process (Smith and Harrington 2014)

* 1. ACPA (American Concrete Pavement Association) partial depth repairs for pavements
     1. What is a partial depth repair?
        1. It is a rehabilitation technique to restore areas of spalling, deterioration, and distresses around area of joints and cracks in the upper 1/2 to 1/3 of a pavement slab (ACPA 1998)
        2. Once surface spalls are created, the constant loading on that area of the pavement slab will continue to develop into having more problems (ACPA 1998)
        3. The repairs themselves are relatively small, only covering about 1.2 square yards (1 sq. m) and only reaching about 2-3 inches (50-75mm) into the pavement slab (ACPA 1998)
        4. The steps of the repair include removing and examining the area of the repair, cleaning the existing concrete, placing the repair material and any other additional materials, and reestablishing the joints (ACPA 1998)
     2. Types of partial depth repairs
        1. Repairs from Spalling
           1. Spalling is the complete breaking of the concrete (ACPA 1998)
           2. Transverse joint spalling can also occur along a joint where the joint is prevented from closing due to blockages between the joints. These blockages can be rocks, sand, and other material fragments that fit between the joints when they are open in cooler weather (ACPA 1998)
           3. Plastic inserts that help form joints can also be the cause of spalling. These inserts bring water to the surface, which alters the water-cement ratio, causing the paste at the top of the slab to become susceptible to spalling and scaling (ACPA 1998)
           4. This similarly happens with metal inserts because the metal inserts react with the increased water at the surface of the slab to create corrosion. The corrosion breaks down and becomes small fragments that lodge between the joints to cause spalling and breaking (ACPA 1998)

If a partial depth repair is to be used within an area using metal inserts, the metal inserts must be removed before performing the partial depth repair (ACPA 1998)

* + - * 1. If a spall is smaller than about 2 inches (50 mm) it is considered too small to affect the riding quality of the concrete pavement, and therefore does not need to be considered for a partial depth repair (ACPA 1998)
      1. Repairs from Cracking
         1. Cracking is the chipping and fraying of concrete at joints and edges that is within about 2 inches (50 mm) (ACPA 1998)
         2. Cracking typically runs as a fracture through most if not all of the concrete slab (ACPA 1998)
         3. Because cracks typically run through the entire slab, most of the time a full-depth repair is necessary, but is still dependent on the condition of the crack (ACPA 1998)
         4. A combination of spalling a cracking would be the most likely case where a partial depth repair would be suitable for cracking as long as the crack is sealed after the spall is repaired (ACPA 1998)
    1. Review the process of material selection
       1. Factors of material selection depend on (ACPA 1998):
          1. Time available before opening to traffic
          2. Air temperature during construction
          3. Funding
          4. Desired service life
          5. The size and depth of the patches
       2. Ideal repair material would have (ACPA 1998):
          1. Good workability
          2. Quick mixing time
          3. Fast setting time
          4. Rapid strength development
          5. Low shrinkage
          6. Strong bind capability
          7. Good long-term strength and durability
          8. Thermal compatibility with existing concrete
          9. Reasonable cost
       3. Material properties to be considered (ACPA 1998):
          1. Strength gain
          2. Modulus of elasticity
          3. Bond strength
          4. Freeze-thaw resistance
          5. Scaling resistance
          6. Sulfate resistance
          7. Abrasion resistance
          8. Coefficient of thermal expansion
          9. Shrinkage (volume changes)
       4. Strength development of the repair material must be rapid when considering that down time needs to be minimized. This is influenced by not just the material properties, but also by the ambient conditions of the site and the curing methods (ACPA 1998)
       5. Serious consideration should be given to cost, which includes labor costs, equipment costs, curing costs, and costs associated with closure time (ACPA 1998)
    2. What are the recommended repair materials and what are their characteristics?
       1. Cementitious Repair Materials
          1. Normal concrete

When the concrete slab can be closed to traffic for 24 hours or more, it is best to use normal concrete mixes with Type I cement (ACPA 1998)

The selection of aggregate has to follow that the aggregate size cannot be greater than 1/2 of the depth of the repair (ACPA 1998)

Grout with a 1:1 ratio of sand to cement by volume added to water can be used as a bond between the existing concrete and the repair concrete (ACPA 1998)

The grout must still be workable when the repair concrete is replaced or the grout will need to be sand blasted out, and placed again (ACPA 1998)

At temperatures below 55 °F (13 °C), a longer curing period or insulation of the repair may be required. Normal concrete should not ever be placed when the temperature is below 40 °F (4 °C) (ACPA 1998)

* + - * 1. High-early strength PCC

High-early strength PCC uses Type III cement so the repair can be open to traffic in as little as 4 hours. This early strength gain can be as much 3000 psi (21 MPa) in about 24 hours (ACPA 1998)

The most common bonding agent to use with high-early strength PCC is an epoxy bonding agent (ACPA 1998)

* + - * 1. Gypsum-based (calcium sulfate) cement

Best when used in temperatures above freezing up to 110 °F (43 °C) (ACPA 1998)

* + - * 1. Magnesium phosphate and magnesium ammonium phosphate cement

Can be classified with three setting times: normal (fast), intermediate, and retarded (ACPA 1998)

The normal mixes should be made in small batches and mixed rapidly because their short setting time (ACPA 1998)

The retarded mixes are made of magnesium ammonium phosphate cement, which was originally developed for hot summer days with temperatures above 85 °F (29 °C) (ACPA 1998)

The intermediate mix is also made od magnesium ammonium phosphate cement with a setting time between the normal and retarded mixes

All of these mixes are sensitive to the moisture content of the existing concrete and cannot be used in pavements with limestone aggregates. However they have low permeability and good bond strength to any clean and dry surface (ACPA 1998)

* + - * 1. High-alumina cement mixtures

Recommended not to use because of their calcium aluminate hydrate components contributing to strength loss (ACPA 1998)

* + - * 1. Alumina powder

Alumina powder can be used with Type I and Type III cements that have higher shrinkage than other repair materials. However the alumina powder can decrease the bond strength and repair abrasion resistance from the decreased density of the paste (ACPA 1998)

* + - 1. Polymer concretes
         1. Epoxy-resin mortars or epoxy concretes

Epoxy resins are good repair materials when considering their great adhesive properties and low permeability, however, they have a wide range of setting times, placement temperatures, strengths, bonding capabilities, and abrasion resistance (ACPA 1998)

Their biggest downfall is that they are not thermally compatible with a lot of existing concrete, which can result in early failure (ACPA 1998)

They are recommended to not be used in spalling repairs with reinforcing steel because the epoxy will speed up the corrosion in the steel

* + - * 1. Methyl-methacrylate concrete

Methyl-methacrylate concretes can be placed anywhere from 40 to 130 °F (4 to 54 °C), however, they are hazardous in nature and pose a threat to those working with it because it can easily ignite when exposed to a spark (ACPA 1998)

They do have high compressive strengths, working times between 30 and 60 minutes, and can adhere to any clean and dry concrete surface (ACPA 1998)

* + - * 1. Polyester-styrene concretes

Polyester-styrene concretes are extremely similar to methyl-methacrylate concretes except that they have slower strength gain, which means they may not be an effective repair material for a short closure period (ACPA 1998)

* + - * 1. Polyurethane concretes

Polyurethane concretes are a combination of aggregates and a two-part polyurethane resin which sets quickly (ACPA 1998)

There are currently two forms of polyurethane available as repair materials. One is moisture sensitive and will foam when in contact with water, and the other is moisture resistant so it can be placed on wet surfaces (ACPA 1998)

* + - 1. Bituminous materials
         1. Bituminous materials deteriorate rapidly, and are most commonly considered for temporary repairs (ACPA 1998)
  1. NCPTC (National Concrete Pavement Technology Center) with Iowa State University Institute for Transportation, partial depth repairs for pavements
     1. What is a partial depth repair?
        1. The removal and replacement of small areas of deteriorated concrete pavement (Frentress and Harrington 2012)
        2. Partial depth repairs either slow down or remove the spreading of spalling and distresses caused by spalling from traffic loading and weather conditions (Frentress and Harrington 2012)
        3. Partial depth repairs improve the quality of riding on the road surface, restore the structural integrity of the pavement slab, and extend the service life of the entire concrete pavement (Frentress and Harrington 2012)
        4. When the repair materials are chosen carefully, the life of a partial depth repair can last 10-15 years (Frentress and Harrington 2012)
        5. Originally believed that partial depth repairs should be limited to the top 1/3 of the slab, and that anything deeper than that should be taken care of with a full-depth repair (Frentress and Harrington 2012)
        6. Since several cold-weather states started using partial depth repairs as deep as 1/2 of the slab thickness, most states have adopted this rule because of the success of these partial depth repairs (Frentress and Harrington 2012)
     2. Types of partial depth repairs
        1. Type 1: Spot Repairs of Joints, Cracks, and Spalls
           1. They are used for small, isolated areas of failure that are not intended to be long and continuous (Frentress and Harrington 2012)
           2. Can be used to repair joint spalling, mid-slab surface spalling or cracking, severe scaling, and to restore joint reservoirs (Frentress and Harrington 2012)
           3. Typically used for pavements where existing load transferring devices are still function (Frentress and Harrington 2012)
           4. When spot repair areas are closer than 2 feet, they are recommended to be combined into one spot repair (Frentress and Harrington 2012)
        2. Type 2: Extended Length Repairs
           1. There are two types of extended length repairs: longitudinal or transverse joints (Type 2A) or cracks (Type 2B) (Frentress and Harrington 2012)

Use Figures 7 and 8 (Frentress and Harrington 2012)

* + - * 1. These repairs are typically longer than 6 feet in length and can be as deep as 1/2 of the thickness of the slab (Frentress and Harrington 2012)

Use Figures 9 and 10 (Frentress and Harrington 2012)

* + - * 1. For longitudinal and transverse repairs, the joint needs to be reconstructed usually be sawing the joint. For crack repairs, a preformed joint is added as a compression material in the crack (Frentress and Harrington 2012)
      1. Type 3: Bottom-Half Spot Repairs
         1. Bottom-half repairs are used in locations where the failure of the concrete is at a depth of more than 1/2 the slab thickness, which would require a full-depth repair. However, these types of repairs occur along the outside edges of the slabs, therefore not needing a full-depth repair (Frentress and Harrington 2012)
         2. These repairs cannot be wider than 18 inches at the bottom of the repair, but can be longer than 18 inches along the centerline, however they cannot transversely extend more than 18 inches, which would warrant a full-depth repair (Frentress and Harrington 2012)

Use Figures 11 and 12 (Frentress and Harrington 2012)

* + 1. Review the process of material selection
       1. Mixture selection depends on the following factors (Frentress and Harrington (2012):
          1. Allowable lane closure time / strength of repair mixture required for opening
          2. Shrinkage characteristics
          3. Coefficient of thermal expansion
          4. Ambient temperature
          5. Cost
          6. Size of repair
          7. Estimated performance
       2. The most widely used parameter when selecting the repair material is the strength of the mixture at any given time during the life of the repair Frentress and Harrington 2012)
       3. In the partial depth repair, it is common to base the repair on compressive strength only because the repair material only carries compression stresses rather than the existing concrete, which carries tensile stresses (Frentress and Harrington 2012)
       4. The minimum strength of the repair should be around 1,600 to 1,800 psi in order to not experience any damage to the concrete (Frentress and Harrington 2012)
          1. Use Table 1 (Frentress and Harrington 2012)
       5. The shrinkage and coefficient of thermal expansion of the repair material are important factors that need to compare closely with the existing concrete or the repair will experience early failure (Frentress and Harrington 2012)
       6. Freeze-thaw durability must be considered because repair materials with rapid strength gain are susceptible to durability problems because of their reduced curing times (Frentress and Harrington 2012)
          1. This may be remedied by using high quality materials, reducing the water-cement ratio and by increasing the aggregate volume, but keeping the workability the same (Frentress and Harrington 2012)
       7. Premature failures of partial depth repairs are cause by many material-related failures such as (Frentress and Harrington 2012):
          1. Thermal incompatibility between the repair material and the pavement
          2. Incompatibility between the joint bond breaker and the joint sealant
          3. Inadequate cure time prior to opening repairs to traffic
          4. Incompatibilities between the climatic conditions during repair replacement and the materials or procedures used
          5. Extreme climatic conditions during the life of the repairs that are beyond the capabilities of the repair material
    2. What are the recommended repair materials and what are their characteristics?
       1. Conventional PCC with Types I, II, and III cement is the most commonly used and generally most accepted material (Frentress and Harrington 2012)
       2. Type I without any admixtures is best because of its low coat, availability and ease of use. This mix uses smaller size (no greater than 1/2 inch) aggregate size with low slump, air entrainment, and a maximum water-cement ratio of 0.44 (Frentress and Harrington 2012)
       3. When using Type III (HE) cement, the repair can be opened to traffic faster than Type I cement, however this cement can be more difficult to place (Frentress and Harrington 2012)
       4. If the repair needs to be opened to traffic sooner than usual, generally mixes can be used where the strength of the repair is strong enough to be opened within 4 to 12 hours after placement. These mixtures can be designed with accelerating admixtures so that they are not giving up long term durability (Frentress and Harrington 2012)
          1. The higher early strength and use of admixtures does pose a higher risk of failure however (Frentress and Harrington 2012)
       5. For lower early strength mixtures, it is important to determine the equivalent single axle loads (ESALs) that the repair will carry to help define the total closure time for the pavement slab (Frentress and Harrington 2012)
       6. Can also use rapid-setting, high early-strength proprietary materials. These products are “flexible” and “semi-rigid” (Frentress and Harrington 2012)
       7. Bonding agents
          1. Bonding agents are required to be used with any PCC material to enhance the strength of the bond of the repair material and the existing concrete structure (Frentress and Harrington 2012)
          2. Sand-cement grouts are the most common and successful bonding agent. This grout is made of 2 parts of cement, 1 part of water, and 1 part of sand, which produces a creamy consistency that’s good for filling small areas left after the milling and sand blasting processes (Frentress and Harrington 2012)
          3. Not all materials will need a bonding agent, and manufacturers of specific repair materials will specify the required bonding agent for that material (Frentress and Harrington 2012)

1. Approved products review
   1. Caltrans (California)
      1. QPL Products (Caltrans 2017 Materials List)
         1. Category 3: Dry, Rapid-Hardening Cementitious Materials for Concrete Repairs (ASTM C928) – Surface Spalls, Honeycomb and Minor Defects (Caltrans 2017 Materials List)
            1. 10-60 Mortar, BASF Construction Chemicals/Master Builders, Horizontal Application
            2. 10-61 Mortar, BASF Construction Chemicals/Master Builders, Horizontal Application
            3. Elephant Armor DOT Industrial Grade Mortar, GST International, Horizontal Vertical and Overhead Application
            4. SikaQuick 1000, Sika Corporation, Horizontal Application
            5. SikaQuick 2500, Sika Corporation, Horizontal Application
            6. Express Repair, The Euclid Chemical Company, Horizontal Application
         2. Category 4: Dry, Rapid-Hardening Cementitious Materials for Concrete Repairs (ASTM C928) – In Depth Repair (Caltrans 2017 Materials List)
            1. EMACO T415, BASF Construction Chemicals/Master Builders, Horizontal Application
            2. Elephant Armor DOT Industrial Grade Mortar, GST International, Horizontal Vertical and Overhead Application
            3. SikaCrete 321FS, Sika Corporation, Horizontal Application
      2. Specifications for Product Approval
         1. Provide the following documents/materials (Caltrans 2017 Authorization)
            1. Company’s name, address, and contact information
            2. Name of the repair product
            3. Certificate of compliance stating proposed material complies with the tests on the material data sheet
            4. Material safety data sheet
            5. Material data sheet that at a minimum contains tests results for compliance requirements

Minimum 7-day compressive strength of 4000 psi (ASTM C39 or C 109)

Minimum 28-day bond strength of 1500 psi (ASTM C882 as modified by ASTM C928)

Maximum 28-day length change of -0.15% (ASTM C157)

Maximum soluble chlorides by weight of 0.05% (AASHTO T260)

OR submit a material data sheet stating conformance with ASTN C928

* + - * 1. List of project where product has been used successfully (bridge project, transportation project, etc.). Include reports or pictures of application, if possible.
        2. Manufacturer’s recommended procedures for use
        3. Limitation on use (e.g. environmental, overhead and vertical application, horizontal application, etc.)
        4. Shelf life of the product
        5. Storage requirements
        6. Supply two prepackaged bags (approximately 100 lbs) of sample taken from the same batch of material that was supplied for Certificated of Compliance testing. Sample provided must be within the shelf life of the product for Department testing and verification.
      1. Caltrans will then evaluate the product as follows (Caltrans 2017 Authorization):
         1. Ensure all required documentations and samples are received
         2. Review the technical information provided
         3. Perform testing of the concrete repair sample to verify compliance with the requirements listed
         4. Inform manufacturers/supplier in writing of the evaluation results
         5. Allow one retest if the initial specimen fails, if requested by manufacturer/supplier. Retest sample will be selected by a Caltrans representative
         6. Update the Precast and Cast-In-Place Concrete Cementitious Based Repair Material Authorized Material List, as necessary
      2. With Caltrans, the authorization of any product will only last 5 years before it must be renewed (Caltrans 2017 Authorization)
      3. Caltrans specifies that manufacturers and suppliers must submit documentation for renewal 6 months before the product expires (Caltrans 2017 Authorization)
      4. Caltrans also states that they reserve the right to remove a product or material from their list at any time (Caltrans 2017 Authorization)
  1. IDOT (Illinois)
     1. QPL Products
        1. Packaged, dry formed concrete repair mixtures (IDOT 2017 Formed)
           1. Formflo P-51, JE Tomes & Associates

Slump is designated to be 7-10 inches when using 3 quarts of water per pound of bag material, and 5-7 inches as specified in the Guide Bridge Special Provision for Structural Repair of Concrete (IDOT 2017 Formed)

* + - 1. Packaged, dry, rapid hardening cementitious materials for concrete repairs (IDOT 2017 Rapid Hardening)
         1. Rapid Hardening Cement (IDOT 2017 Rapid Hardening)

No materials approved at this time

* + - * 1. R1 Mortar (IDOT 2017 Rapid Hardening)

Quikrete Quick-Setting Cement, Quikrete

* + - * 1. R2 Mortar (IDOT 2017 Rapid Hardening)

HD-50 Heavy Duty Concrete Patch, Dayton Superior Corporation

Quikrete Commercial Grade Fastest Repair Mortar, Quikrete

Speccopatch RS, Specco Industries

SikaQuick 1000, Sika Corporation

SikaQuick 2500, Sika Corporation

Utilibond, Utilicor Technologies, Inc.

* + - * 1. R3 Mortar (IDOT 2017 Rapid Hardening)

Masteremaco T 545, BASF Corporation-Building Systems

Rapid Set Mortar Mix, CTS Cement Mfg. Co. / Rapid Set Products

Rapid Set DOT Repair Mix, CTS Cement Mfg. Co. / Rapid Set Products

Rapid Set Cement All, CTS Cement Mfg. Co. / Rapid Set Products

Chemspeed 65, ChemMasters

Pave Patch 3000, Dayton Superior

Express Repair, The Euclid Chemical Company

Planitop 18, MAPEI Corporation

Planitop 18 ES, MAPEI Corporation

Futura – 15, W.R. Meadows

Quikrete Commercial Grade Fastest Nonshrink Grout, The Quikrete Companies

Repcon 928, SpecChem

Speccrete Highway Repair 928, Specco Industries, Inc.

Speccrete Phastpatch D.O.T., Specco Industries, Inc.

* + - * 1. R1 Concrete (IDOT 2017 Rapid Hardening)

No materials approved at this time

* + - * 1. R2 Concrete (IDOT 2017 Rapid Hardening)

No materials approved at this time

* + - * 1. R3 Concrete (IDOT 2017 Rapid Hardening)

Rapid Set Concrete Mix, CTS Cement Mfg. Co. / Rapid Set Products

* + 1. Specifications for Product Approval
       1. The following documentation need to be provided when submitting a packaged, dry, formed concrete repair mixture (IDOT 2017 Formed)
          1. The specific product brand name
          2. Safety Data Sheet
          3. Technical Data Sheet
          4. Manufacturers recommended mixing instructions
          5. Contact person’s name, title, address, email address, and phone number
          6. A signed letter stating that the subject material will not be changed without written notification to the Department
          7. A signed letter certifying the following:

Individual weight of cement and finely divided minerals (hundredweight per cubic yard)

Type of cement, Class of fly ash or Grade of ground granulated blast-furnace slag

Maximum size of coarse aggregate

Brand and name of ASTM C494, Type F admixture used

Recommended water dosage for 5-7 inch slump (w/c ratio shall not exceed 0.46)

* + - * 1. Independent laboratory test results showing the water soluble chloride ion content, in pounds per cubic yard, resubmitted every 2 years (during recertification for even numbered calendar years; for example, 2018, 2020, etc)
        2. Acknowledgement by Company
      1. The manufacturer must submit a sufficient amount of the subject material to mix 1 cubic foot for testing purposes (IDOT 2017 Formed)
      2. IDOT states that any product that is submitted without the required information will not be tested and that any changes to the formulation outside of the original specifications will need to be resent as a new sample submittal (IDOT 2017 Formed)
      3. Recertification of products will happen within the last quarter of the calendar year (IDOT 2017 Formed)
  1. IOWADOT (Iowa)
     1. QPL Products
        1. Elastomeric Concrete for Concrete Repair (IOWADOT 2017 MAPLE)
           1. Delpatch, D.S. Brown
        2. Fast-Setting Repair Mortars for Structural Components (IOWADOT 2017 MAPLE)
           1. Blendcrete, Bonsal American
           2. Fastrac 220 FQ, Western Material and Design LLC
           3. Fastrac 300, Western Material and Design LLC
           4. FlexKrete, FlexKrete
           5. HD 50, Dyton Superior
           6. MasterEmaco T 415, BASF Construction Chemicals – Building Systems
           7. MasterEmaco T 430, BASF Construction Chemicals – Building Systems
           8. Meadow – Crete GPS, W.R. Meadows, Inc
           9. Pavemend 15.0, Ceratech Inc.
           10. Pavemend TR, Ceratech Inc.
           11. Pavemend VR, Ceratech Inc.
           12. Phoscrete Four Season, Phoscrete Corporation
           13. Phoscrete VO-Plus, Phoscrete Corporation
           14. Planitop 15, Mapei Americas
           15. Planitop 18 ES, Mapei Americas
           16. Planitop XS, Mapei Americas
           17. Precast Patch, SpecChem
           18. Precast Patch 5, SpecChem
           19. RM800PC, Hilti, Inc.
           20. RepCon V/O, SpecChem
           21. Sika Repair SHB, Sika Corporation
           22. SikaQuick VOH, Sika Corporation
           23. Speed repair, Right Pointe
           24. US Spec Quickset, US Mix Co.
           25. US Spec Quickset V/O Patch, US Mix Co.
           26. Ulti-Grout, Buzi Unicem USA
        3. Inspection & Acceptance – Rapid-Setting Concrete Patching Materials for Pavements (IOWADOT 2017 Inspection)
           1. DOT Line, Ceratech Inc.
           2. Durapatch Hiway, L&M Construction Chemicals, Inc
           3. Durapatch Hiway, L&M Construction Chemicals, Inc
           4. Euco Speed MP, Euclid Chemical Company
           5. Fastrac 220 FQ, Western Material and Design LLC
           6. Fastrac 246, Western Material and Design LLC
           7. Fastrac 300, Western Material and Design LLC
           8. Fastrac 220 FQ, Western Material and Design LLC
           9. Futura 15, W.R. Meadows, Inc
           10. HD 15, Dayton Superior
           11. MG Krete, IMCO Technologies, Inc
           12. MasterEmaco T 1060, BASF Construction Chemicals – Building Systems
           13. MasterEmaco T 1060, BASF Construction Chemicals – Building Systems
           14. Pave Patch 3000, Dayton Superior
           15. Pavemend SL, Ceratech Inc
           16. Pro Traffic Patch, Ash Grove Packaging Corp.
           17. RM800PC, Hilti, Inc
           18. Rapid Set Concrete Mix, CTS Cement Manufacturing Corp.
           19. Rapid Set Concrete Mix, CTS Cement Manufacturing Corp.
           20. Rapid Set DOT Concrete Mix, CTS Cement Manufacturing Corp.
           21. RepCon 928, SpecChem
           22. RepCon 928 DBR, SpecChem
           23. SikaQuick 2500, Sika Corporation
           24. SikaQuick 2500, Sika Corporation
           25. Speccrete Highway Repair 928, Specco Industries, Inc
           26. Superior Pave Patch 3000, Dayton Superior
     2. Specifications for Product Approval
        1. Elastomeric Concrete For Concrete Repair (IOWADOT 2017 Elastomeric)
           1. Submittal of the following items to the Office of Construction and Materials in Ames, Iowa:

Product identification including brand name and product number

Complete manufacturer recommendations for usage

A current Material Safety Data Sheet (MSDS)

A sample consisting sufficient material for laboratory evaluation

* + - * 1. Has to meet the following criteria for ASTM C109/C579, Method B:

Three 2 inch cubes cured for 24 hours at 73 ± 4 °F before testing, minimum strength of 2000 psi

* + - * 1. Has to meet the following criteria for ASTM C882

Soak in dummy section for 24 hours

Allow dummy section to air dry for 15 minutes then air blast surface

Apply primer to dry surface of dummy section

Allow to cure 30 minutes

Mix elastomeric concrete according to manufacturer’s recommendation

Cast the material against dummy section

Cure at 73 ± 4 °F before testing at 24 hours

Minimum strength of 300 psi

* + - * 1. Manufacturer has to provide the ASTM C882 tested shear strength by independent laboratory for the evaluation
      1. Fast-Setting Repair Mortars For Structural Components (IOWADOT 2017 Fast-Setting)
         1. Submittal of the following items to the Office of Construction and Materials in Ames, Iowa

Product identification including brand name and product number

Complete manufacturer recommendations for usage

Current Safety Data Sheet (SDS)

A copy of test report for the submitted product from the National Transportation Product Evaluation Program (NTPEP)

* + - * 1. Approval of the product is based upon satisfactory evaluation of the NTPEP test report. The minimum requirements for approval are listed in the table below

Provide this table in the review

* + - * 1. Magnesium phosphate materials will not be allowed due to its poor freeze-thaw durability
        2. The Office of Construction and Materials may sample and test fast-setting repair mortars to verify their capability of meeting the approval requirements
      1. Inspection & Acceptance – Rapid Setting Concrete Patching Materials for Pavements (IOWADOT 2017 Inspection)
         1. Acceptance of rapid setting concrete patching materials will be on the basis of approved brands and satisfactory test results
         2. These materials are approved for use when the plans and/or specifications permit their use for surface patching purposes
         3. Brand names must be in identifiable packages
         4. Material shall be packaged in a multi-wall moisture resistance paper bag
         5. Shelf life shall be indicated on each packaged bag (by expiration date)
         6. Mixing sequence and addition of mixing water for each material shall be as directed and recommended by each manufacturer
         7. When coarse aggregate is used, its type and quantity shall follow manufacturer recommendations and a minimum of Class 2 durability rating
         8. Submittal of the following items to the Office of Construction and Materials in Ames, Iowa

Product identification including brand name

Complete manufacturer’s recommendation for usage

A copy of test report for the submitted product from the National Transportation Product Evaluation Program (NTPEP)

A current Materials Safety Data Sheet (MSDS)

* + - * 1. Magnesium phosphate-based patching materials will not be allowed due to its poor freeze-thaw durability
        2. Manufacturer shall provide the acid-soluble chloride result from an independent test agency for review

Provide the table in the document for review

* 1. MnDOT (Minnesota)
     1. QPL Products
        1. Example of one standard concrete mixture that has had success in Minnesota (Smith and Harrington 2014)
           1. This cementitious mixture gives an 18 hour opening strength of 3,000 pounds per square inch (20.7 MPa)

850 lbs of Type I cement

295 lbs of water

1,328 lbs of coarse aggregate

1,328 lbs of sand

Target water-cement ratio of 0.35

Type E water reducing and accelerator

6.5 percent air

* + - 1. Packaged, dry rapid hardening cementitious material (MnDOT 2017)
         1. Renupave Ultra, ABC Cement LLC
         2. Rapid Patch Concrete Surface Repair, Akona Manufacturing LLC
         3. ProSpec Rapid Patch Commercial DOT Repair, Akona Manufacturing LLC
         4. ProSpec Rapid Patch Horizontal Repair, Akona Manufacturing LLC
         5. Ardex TRM, Ardex Engineered Cements
         6. 10-60 Rapid Mortar, BASF Construction Chemical
         7. 10-61 Rapid Mortar, BASF Construction Chemical
         8. Set 45 HW, BASF Construction Chemical
         9. Rapid Patch – VR , Bonsal
         10. Fast Set Cement Mix, Bonsal
         11. Fast Patch 928, Burke
         12. Pavemend SL, Ceratech Inc
         13. DOTLine, Ceratech Inc
         14. MainLine, Ceratech Inc
         15. Pavemend SLQ (Low temp.), Ceratech Inc
         16. ChemSpeed 65, ChemMasters
         17. Tectonite, CFB
         18. Pave Patch 3000, Dayton Superior
         19. HD 50, Dayton Superior
         20. Rapid Set Cement All, CTS Cement Manufacturing
         21. Rapid Set Mortar Mix, CTS Cement Manufacturing
         22. Rapid Set Cement Mix, CTS Cement Manufacturing
         23. Rapid Set DOT Repair Mix, CTS Cement Manufacturing
         24. Re-Crete 20 Minute Set, Dayton Superior
         25. Five Star Highway Patch, Five Star Products
         26. Phoscrete VO, Phoscrete Corporation
         27. Phoscrete HC, Phoscrete Corporation
         28. SikaQuick 1000, Sika Corporation
         29. SikaQuick 2500, Sika Corporation
         30. Sikacrete 321FS, Sika Corporation
         31. Rep Con 928, SpecChem
         32. Highway Patch 928, Specco Industries Inc
         33. Speccopatch RS, Specco Industries Inc
         34. Speed Crete 2028, Tamms Industries
         35. Speed Crete Greenline, Tamms Industries
         36. Speed Crete Express Repair, Tamms Industries
         37. Uni Road Repair DOT, Universal Form Clamp
         38. Polypatch, US. Mix Products
         39. Transpatch, US. Mix Products
         40. Transpatch Concrete, US. Mix Products
         41. Transpatch EXT, US. Mix Products
         42. Polypatch FR, US. Mix Products
         43. STR Mortar, US. Mix Products
         44. Futura, W.R. Meadows
         45. Fastrac 220 FQ, Western Materials and Design LLC
         46. Fastrac 246, Western Materials and Design LLC
    1. Specifications for Product Approval (MnDOT 2008)
       1. Any material submitted for approval must be received by the Concrete Engineering Unit a minimum of 30 days prior to the start of work. Any material submitted after that time will not be evaluated (MnDOT 2008)
       2. Reference Materials
          1. Manufacturer shall submit a material sample for approval to the Mn/DOT Materials Lab. Also include a Materials Safety Data Sheet (MSDS) and a Technical Data Information Sheet
       3. Testing
          1. Manufacturer shall provide independent testing from an Independent Laboratory for each material. Tests will be performed according to ASTM Standard C928
       4. Field Acceptance
          1. If the above criteria are met successfully, the dry, rapid-hardening cementitious material will be given tentative approval, contingent upon satisfactory performance in the field
       5. Non-Compliance
          1. If future samples of these materials do not meet MN/DOT specifications, the product may be removed from the approved product list and subject to other failing material procedures
       6. It is the manufacturer’s responsibility to immediately notify MN/DOT if the chemical formulation of any product is changed or modified, or if the product is no longer being produced (MnDOT 2008)
  1. MoDOT (Missouri)
     1. QPL Products
        1. Rapid Set Concrete Patching Material (Horizontal) (MoDOT 2016 Concrete)
           1. Conspec Pave Patch 3000, Dayton Superior
           2. DOT Patch HD, Symons Corporation
           3. EcoFix, United States Gypsum Co.
           4. Fastrac 246 Rapid Setting Concrete, Western Material and Design LLC
           5. Fastrac 300 Rapid Setting Cement, Western Material and Design LLC
           6. HD-50, Dayton Superior
           7. MasterEmaco T 1060, BASF Corporation Construction Systems
           8. Mono-Patch, Bindan Corporation
           9. Quikrete Commercial Grade Fast Set DOT Mix, The Quikrete Companies
           10. Phoscrete HC, Phoscrete Corp.
           11. Rapid Set Concrete Mix, CTS Cement Manufacturing Corp.
           12. Rapid Set DOT Concrete Mix, CTS Manufacturing Corp.
           13. Rapid Set DOT Repair Mix, CTS Manufacturing Corp.
           14. RepCOn 928, SpecChem
           15. Road Pacth, Degussa Building Systems
           16. Sika Set Roadway Patch, Sika Chemical Corp.
           17. SikaTop 122 Plus, Sika Chemical Corp.
           18. Speedcrete 2028, Tamms Industries
        2. Rapid Set Concrete Patching Material (Vertical & Overhead) (MoDOT 2015)
           1. MasterEmaco N 424, BASF Building Systems
           2. SikaTop 122, Sika Chemical Corporation
           3. SikaTop 122 Plus, Sika Chemical Corporation
           4. SikaTop 123 Plus, Sika Chemical Corporation
     2. Specifications for Product Approval
        1. The current procedure to file for an approved product through the MoDOT is by filling out the New Product Evaluation Form for all pre-established product lists (MoDOT 2016 New)
        2. The additional items to submit with the form include (MnDOT 2016 New):
           1. Product specification (MoDOT specifications where compliant
           2. Installation instructions, preferably with pictures or drawings
           3. Material Safety Data Sheet (MSDS)
           4. Product Literature
           5. Product Certification
           6. Product Test Data
           7. Product Warranty
           8. Product Sample

1. ASTM specification review to determine properties of these partial depth repair materials
   1. C39/C39M
      1. Review of the testing procedure and how the results are used
   2. C157/C157M
      1. Review of the testing procedure and how the results are used
   3. C469/C469M
      1. Review of the testing procedure and how the results are used
   4. C531/C531M
      1. Review of the testing procedure and how the results are used
   5. C666/C666M
      1. Review of the testing procedure and how the results are used
   6. C882/C882M
      1. Review of the testing procedure and how the results are used
   7. C928/C928M
      1. Review of the testing procedure and how the results are used
         1. Determines the bond strength between repair materials and existing concrete through the use of the slant-shear bond strength test (Smith and Harrington 2014)
   8. C1581/C1581M
      1. Review of the testing procedure and how the results are used
   9. C1583/C1583M
      1. Review of the testing procedure and how the results are used
2. Analysis of the more common partial depth repair methods and products and how they could be used in different ways or combined with others methods/products
   1. See “Repair of Concrete Pavement Joints” document
   2. Which products have proven to be more successful and why?
   3. Could a combination of methods or products be developed to produce a product that performs better than the already approved products?
   4. What other types of bonding materials have not been analyzed yet? Could these materials be incorporated into existing materials or used on their own?