Pothole Patching: A Review on Materials and Methods

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Introduction

Potholes are an annoyance to drivers and potentially a dangerous hazard on the roadways. The repair of pothole distresses in asphalt pavement is often considered low on a road agency's agenda; however their repair consumes a large portion of time and funds. Many road crews are ill-informed on the proper materials and methods for pothole repair. Correct selection of pothole patching materials and proper application of repair procedures can greatly increase the longevity of pothole repairs, lead to fewer driver frustrations, and lower road maintenance budgets.

Pothole Background

A pothole can be defined as "Localized distress in an asphalt-surfaced pavement resulting from the breakup of the asphalt surface and possibly the asphalt base course. Pieces of asphalt pavement created by the action of climate and traffic on the weakened pavement are then removed under the action of traffic, leaving a pothole." (Wilson and Romine 1994). To be considered a pothole, the distress must be a bowl-shaped hole with a minimum plan dimension of six inches. Low severity potholes are less than one inch deep, moderate severity are one to two inches deep, and high severity potholes are more than two inches deep (Johnson and Snopl 2000).

Potholes are commonly caused from water seeping into cracks in the roadway during wet and freezing conditions. The water weakens the underlying support of the road surface, and when it freezes, it pushes up on the asphalt layer and down on the underlying material. When traffic passes over the weakened and stressed portion of asphalt, the loads and vibration cause the weak underlying material to sink and the surface layer to crack and break up. Under the

vibration of the passing traffic, the material will work its way lose and come out of the surrounding pavement, forming a pothole.

Other ways potholes are formed are through poor workmanship, poor mix design, or natural deterioration of the pavement. As traffic passes over the stressed area of the asphalt, the asphalt weakens and material is removed from the surface, leaving behind a pothole.

Figure 1: An example pothole (Photo NMDOT 2007)

A patch is defined as, "an area of pavement where part of the original pavement has been replaced or covered with new material to repair the existing pavement. A patch is considered a defect no matter how well it performs." (NMDOT 2007).

As asphalt concrete pavement ages and is exposed to the effects of weathering, it begins to break down and has a likelihood of developing potholes. Potholes are an annoyance and a danger to the public and their patching consumes time from state department of transportation and local department of public works agencies that could be spent elsewhere. Therefore,

correctly patching potholes the first time is extremely important to reduce long-term costs associated with repeated patching. In addition, correct patching techniques prolong the life of the pavement and prevent further degradation, which can lead to an accelerated rate of decay of the pavement. Potholes can be dangerous to the traveling public, and "on principal roadways potholes are considered dangerous if they are vertically sided, are more than 1 inch deep and have an area of greater than one sq. foot." (NMDOT 2007). Additionally, potholes reported on interstate highways should be repaired within 24 hours (NMDOT 2007).

Pothole patching can be done in response to emergency situations, or it can be a scheduled maintenance item. Cold-mix asphalt pothole patching can be performed in temperatures ranging from 100 °F to 0 °F (Wilson and Romine 1994). Oftentimes, pothole patching has been an afterthought, with highway agencies spending the majority of their time on new road construction and mill and overlay work. However, with many agencies facing tough economic conditions, pothole patching has become one of the most utilized maintenance procedures.

Potholes are typically caused by traffic stresses, poor underlying support, the presence of moisture, and freeze-thaw cycles. The potential safety and reliability hazards that could result from an unrepaired pothole should always be considered when an agency is determining whether or not to patch a pothole. Patching can take place during the spring period, when the base material is soft and wet and there are few, if any, freeze-thaw cycles expected, or during the winter period, when potholes are typically formed and the temperatures are low, the base material is frozen, and additional moisture and freeze-thaw cycles are expected. (Wilson and Romine 1994).

Quality pothole patching is achieved through a combination of material selection and repair procedures. Although hot mix asphalt is the best type of patching material, cold mix asphalt is typically used by agencies due to its low cost and readily availability. Three types of cold mix asphalt are usually available: cold mix produced by a nearby asphalt plant without considerations to a specification, cold mix produced that adheres to specifications put in place by the agency, and proprietary cold mix designs, which are usually available in tubs or bags. Both proprietary cold mix designs and cold mix designs produced to an agency's specification are tested for binder and aggregate compatibility to ensure the mix is well suited to cold patching. In addition, the optimum binder content is determined. Cold mix asphalts used for spray-injection are usually tested for both compatibility and acceptance criteria.

Cold-mix asphalt can be used for a variety of patching, including potholes, utility cuts, failed patches, depressions, and to repair alligator cracking, corrugations, washboarding, shoving, slippage cracks, and rutting. Cold mix patching materials tend to contain a lot of binder so that the material bonds well with the existing asphalt layer. Additionally, cold mix asphalts have been shown to push, shove, and remove from potholes more readily than hot mix asphalt. (NMDOT 2007). The benefit of cold mix asphalt is that it can easily be stockpiled and transported long distances to its needed location on demand without much change in performance.

Although pothole repairs can last for many years if repaired correctly the first time, there are several problems that can develop if the patch is placed incorrectly, including loss of material through raveling, lack of adhesion, and dishing. (NMDOT 2007).

Three Types of Maintenance

Preventive Maintenance

Asphalt pavement maintenance can be categorized as preventive maintenance, corrective maintenance, or emergency maintenance. Preventive maintenance is used to extend the life of a pavement before catastrophic distresses occur. Usually surface treatments are used in preventive maintenance to repair a road surface so that it will not continue to degrade and require regular maintenance in the future. If preventive maintenance is the focus of an agency, corrective maintenance may rarely need to be applied. In fact, "studies show that preventive maintenance is six to ten times more cost-efficient than a 'do nothing' maintenance strategy" (Johnson and Snopl 2000). By planning preventive maintenance, a road agency can greatly extend the life of the pavement and better plan a long term yearly budget.

Figure 2: A fog seal operation is one type of preventive maintenance (Photo NMDOT 2007)

Historically, preventive maintenance has been ignored due to a lack of federal aid for maintenance, thereby causing agencies to allow pavement to deteriorate to a condition where it

would be eligible for federal aid for replacement. Additionally, winter snow and ice maintenance is budgeted with other maintenance activities, and because winter maintenance involves driver safety, agencies will spend more money on winter maintenance, resulting in little funding left for regular maintenance. Lastly, the public expects road agencies to fix poor roads with lots of pothole repairs first, before applying preventive maintenance to roads that are in good condition.

The key to pavement preservation methods is to apply the right method at the right time. These methods have been demonstrated to be more sustainable than traditional rehabilitative methods, such as mill and overlay. Not only are they more cost effective if applied at a correct time in the pavement's life, but "the treatments are thinner, placed faster, less disruptive, and they involve less contract administration, produce less [greenhouse gas] emissions, and consume less energy." (Chan et al. 2011). Utilizing pavement preservation methods will help solve the shortage of available funds for infrastructure investment and at the same time reduce our impact on the environment.

Corrective Maintenance

Corrective, or reactive maintenance, is performed after "a deficiency occurs in the pavement, such as loss of friction, moderate to severe rutting, or extensive cracking" takes place (Johnson and Snopl 2000). Pothole patching, mill and overlays, and crack repair fall into the corrective maintenance category.

Figure 3: Milling must take place before the overlay of new asphalt pavement (Photo NMDOT 2007)

Emergency Maintenance

Emergency maintenance is performed after a serious or dangerous failure has happened to the asphalt pavement, such as a blowout or large pothole. Usually, emergency maintenance is only designed to correct the issue as quickly and safely as possible, without considerations to cost or long-term effectiveness.

Repair Techniques

Throw-and-Go

The four most commonly used techniques for pothole patching are throw-and-go, throw-and-roll, semi-permanent, and spray-injection. Throw-and-go is the most commonly used method for pothole patching because the material can be quickly applied and the cost is low. Using the throw-and-go method, material is shoveled into an unprepared pothole, which may or may not contain water and debris, until the pothole is filled. Compaction is left up to traffic, or occasionally the material is lightly compacted using a shovel.

Throw-and-Roll

A superior alternative to the throw-and-go technique is the throw-and-roll method. Using the throw-and-roll method, material is shoveled into an unprepared pothole and compacted using the maintenance truck tires. After the material has been compacted, it should be verified that a visible crown of about 0.125 in. to 0.25 in. is present on the patch (Wilson and Romine 1994). The compaction that takes place using this method leads to a tighter patch and increased longevity of the patch. The time to compact the patch is typically only one to two minutes, and therefore, there is little loss to productivity in the short run. In the long run, the pothole will need to be patched less often, leading to an increase in productivity and cost savings for the agency.

Figure 4: Demonstration of patching material being properly compacted with truck tires (Photo NCHRP 2014)

Semi-Permanent

The semi-permanent procedure for repairing potholes is often considered the best procedure besides full-depth replacement of the affected area. Using the semi-permanent method, the pothole is first cleared of water and debris and the sides of the pothole are squared to a depth where the pavement is sound. Next, the material is placed in the patch area and compacted with equipment smaller than the patch area, such as vibratory plate compactors or single-drum vibratory rollers. Using the semi-permanent repair method, the patch is very tightly compacted and provides exceptional longevity. The drawbacks of this method are increased labor and equipment costs and lower productivity compared with throw-and-roll and spray-injection. (Wilson and Romine 1994).

When preparing the pothole for cold mix, care should be taken so that oncoming traffic does not get hit with rocks blown from the pothole. The loose gravel that composes cold mix should be swept away from the patch site after completion so that it does not chip or damage passing traffic and the binder does not stick to cars.

Figure 5: A finished semi-permanent patch (Photo NCHRP 2014)

Spray-Injection

The final pothole patching procedure is spray-injection. Spray-injection is most useful for repairing transverse cracks and potholes. The pothole is first prepared by removing all water and debris before a tack coat of binder is sprayed on the sides and bottom of the pothole. Next, asphalt and aggregate are sprayed into the pothole before being covered with another layer of aggregate. No compaction is needed using the spray-injection technique and higher productivity can be achieved at the cost of increased equipment costs.

Figure 6: A trailer-mounted spray-injection patching operation (Photo NCHRP 2014)

Costs

The costs associated with pothole patching can be broken into three distinct categories: materials, labor and equipment. Material costs of purchasing the cold mix patching material are the most common costs, although not necessarily the largest costs. Higher upfront costs associated with purchasing better quality material will pay out over the lifespan of the patch, as the patch is more likely to last longer, requiring less attention and materials. The average price for cold mix asphalt was $55/ton in 2000 and the average lifespan of the patch was only one year, while spray-injection had an average lifespan of 1-3 years (Johnson and Snopl 2000).

Labor costs directly correspond with the size of the crew performing patching. As little as one laborer can be used for the throw-and-go technique, a common method for small department of public works. Larger agencies utilizing the throw-and-roll method will commonly use two workers—one to drive the truck and another to shovel material into the potholes. Semi-permanent patching methods have found four workers to be the most efficient and optimum number for productivity (Wilson and Romine 1994). Using four workers, two will prepare the

pothole by removing debris and squaring the edges and two will follow behind and fill and compact the hole. Spray-injection will require one to two laborers, depending on the type of equipment used. Of course, all methods will require labor costs for traffic control, when necessary. Potholes that are repaired correctly the first time will minimize the laborer's exposure to traffic over the lifetime of the patch.

Equipment costs for the throw-and-go, throw-and-roll, and semi-permanent methods will be the shovels, rakes, and other hand tools, in addition to trucks and any needed traffic control devices and equipment. The semi-permanent method will also require saws or jackhammer to square the edges, an air compressor to remove water and debris, and a compactor. Spray-injection will require either a self-contained or trailer-mounted spray-injection device.

Figure 7: A properly repaired pothole. Note the sealing around the edges. (Photo NMDOT 2007)

Improving Patch Performance

Winter Period

Patching is typically broken up into two periods of the year: winter patching and spring patching. Winter patching is done during periods where there is no snow present on the asphalt and maintenance crews are not expected to plow and apply salt. The warmer periods during the winter are also favorable to pothole development, as the pavement is still expected to undergo freeze-thaw cycles and the base materials of the pavement are soft, resulting in less support. Therefore, once patched, the patch will experience heightened levels of stress when compared to spring patching.

Due to the likelihood that water will be present in the hole before being patched, an anti-stripping agent is strongly recommended. High quality crushed stone aggregates should be used during the winter months should contain little fine material. Binders should be emulsified asphalt. Workability is especially important during the winter so that the material is easily handled and compacted by the crew. (Wilson and Romine 1994).

Because of the high presence of potholes during the winter months, oftentimes the semi-permanent patching technique is not productive enough to patch all potholes. Additionally, road crews are busy plowing. Therefore, the throw-and-roll method is most commonly employed during the winter because the throw-and-go method will lead to premature patch failure. "The goal of winter patching is to restore rideability and safety as quickly as possible (not to repair the distress permanently)" and therefore, "patches placed under winter conditions have a shorter life expectancy than patches placed in the spring." (Wilson and Romine 1994).

Spring Period

Spring patching takes place after much of the underlying support has already softened and no freeze-thaw cycles are expected to occur. Because of the better weather conditions and reduced stresses, patches applied in the spring have a much longer life expectancy.

Materials used during winter patching are still acceptable for spring patching; however, due to the binder selection for winter cold mix patching materials, the workability of the material in the spring may be difficult and the material may be very sticky. As with winter patching, crushed aggregate with few fines, mixed with an emulsifying asphalt should be used and an anti-stripping agent should still be considered. All methods of application of the cold-mix patching material can be used during spring patching.

Because of the improved weather conditions and the increased availability of road crews dedicated to patching, patches completed in the spring generally last longer than patches placed in the winter. In fact, it has been observed that, "patches in place after the initial setting period (2 to 4 weeks) were likely to remain in place until the surrounding pavement begins to deteriorate." (Wilson and Romine 1994). If slightly larger up-front costs are used to place the patch correctly utilizing a method other than throw-and-go, and if the patch lasts longer than one year, there will be reduced costs in following years to replace the patch.

Summary

Potholes are typically caused by traffic stresses, poor underlying support, the presence of moisture, and freeze-thaw cycles. Asphalt pavement maintenance can be categorized as preventive maintenance, corrective maintenance, or emergency maintenance. Preventive maintenance is used to extend the life of a pavement before catastrophic distresses occur. Corrective, or reactive maintenance, is performed after "a deficiency occurs in the pavement,

such as loss of friction, moderate to severe rutting, or extensive cracking" takes place (Johnson and Snopl 2000). Emergency maintenance is performed after a serious or dangerous failure has happened to the asphalt pavement, such as a blowout or large pothole.

The four most commonly used techniques for pothole patching are throw-and-go, throw-and-roll, semi-permanent, and spray-injection and the costs associated with each type of pothole patching can be broken into materials, labor and equipment.

Patching can take place during the spring period, when the base material is soft and wet and there are few, if any, freeze-thaw cycles expected, or during the winter period, when potholes are typically formed and the temperatures are low, the base material is frozen, and additional moisture and freeze-thaw cycles are expected. (Wilson and Romine 1994). Because of the better weather conditions and reduced stresses, patches applied in the spring have a much longer life expectancy.

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