Pothole Identification, Assessment and Repair Guidelines

Commissioned by: Communities of Tomorrow  
Leveraged Municipal Innovation Fund

Prepared by: Clifton Associates Ltd.

Sponsoring Municipalities: Prince Albert, Saskatoon
EXECUTIVE SUMMARY

These guidelines have been commissioned by the public-private partnership Communities of Tomorrow on behalf of a number of Saskatchewan urban communities. They include a full review of the existing flexible pavement pothole repair methods, materials and equipment, with focus on those most suitable for the Saskatchewan climate.

Two types of potholes – structural, involving the full thickness of the road structure, and non-structural, occurring in the top layers of the road only, are distinguished. In Saskatchewan, the majority of potholes occur due to water infiltrating the road structures, then freezing and thawing, causing loss of support in the road layers. Other factors contributing to pothole formation include structural deficiencies due to poor design or inadequate construction methods, deficient drainage, pervious or cracked road surface and poor joints. Both structural and non-structural potholes can be small or large in terms of affected road surface area.

Preventative maintenance aimed at early detection and remediation of defects or conditions which may cause potholes is cheaper in the long run than conventional pothole repairs of roads which have deteriorated to a condition below average.

Patching materials are bitumen, aggregate and various additive mixes intended to repair the top layers of a pothole. There are standard specification hot and cold mixes, locally produced mixes and proprietary mixes. The quality of the patching mix greatly affects the durability and quality of the patch; it is advisable to always use the best material available.

For non-structural potholes, patching materials can be applied using any of the cold mix repair methods or spray injection patching. For structural potholes, the road structure must be rebuilt before restoring the asphalt concrete or thin membrane surface. The choice of method to restore the road surface depends on the surface area of the failure, road use, original surface, costs and available equipment, and desirable level of patch durability.

There are five cold mix repair methods available today, listed in the general order of increased durability and cost. These are: throw and go, throw and roll, spray patch, edge seal and semi-permanent repair. The first two methods are quick emergency repairs. Spray injection is a hot mix repair method which has proven to produce good repairs lasting up to two years when quality patching materials are used. Permanent repairs are used for structural failures and are intended to rebuild the
road structure from the subgrade up to restore the structural support of the road.

While there is standard equipment used for the pothole repair methods listed above, some proprietary equipment developers have come up with unique equipment intended to repair potholes, offering, de-facto, proprietary methods for pothole repairs. These repair methods, as viewed by the guidelines authors, are generally suitable for non-structural potholes and shallow failures of large areas as they are intended to restore the integrity and imperviousness of the road surface.

Mention of any proprietary material or equipment in these guidelines does not constitute an endorsement of it by the authors.
# TABLE OF CONTENTS

1. Introduction 7  
   1.1 Pavement Types 7  
   1.2 Traffic Loading 7  
   1.3 Types and Sizes of Potholes 8  
2. Causes of Potholes 10  
   2.1 Mechanisms of Pothole Development 10  
      2.1.1 Asphalt Concrete and Base Mix Problems 12  
      2.1.2 Structural Failures 13  
      2.1.3 Construction Failures 13  
   2.2 Utilities 14  
   2.3 Failure of Existing Patches 14  
   2.4 Location of Potholes 14  
3. Preventative Maintenance 16  
4. Patching Materials 19  
   4.1 Standard Specification Repair Mixes 19  
      4.1.1 Aggregate-Binder Compatibility 20  
      4.1.2 Aggregate-Dominated and Matrix-Dominated 20  
   4.2 Locally Produced Mixes 21  
   4.3 Proprietary Mixes 23  
      4.3.1 Fines, Workability and Coating 24  
5. Pothole Patching Methods 25  
   5.1 Repair Methods 26  
      5.1.1 Throw and Go 26  
      5.1.2 Throw and Roll 26  
      5.1.3 Spray Patch 27  
      5.1.4 Edge Seal 27  
      5.1.5 Semi-Permanent 27  
   5.2 Hot Patching 28  
      5.2.1 Spray Injection 28  
   5.3 Permanent Repairs 28  
6. Equipment 30  
7. Assessment of Best Practices 32  
   7.1 Pothole Type 32  
   7.2 Pothole Preparation 32  
   7.3 Material Selection 32  
   7.4 Equipment 32  
   7.5 Timing of Repairs 32  
   7.6 Safety 33  
   7.7 Preventative Maintenance 33  
8. Areas of Future Research 35  
9. Training 37  
10. Conclusions and Recommendations 38  
References 39  
Photo Credits 42  
Definitions and Abbreviations 44  
Appendices 45  
   Material Specifications  
   Equipment  
   Survey Summary
1. INTRODUCTION

This report has been commissioned by the public-private partnership Communities of Tomorrow on behalf of a number of Saskatchewan urban communities with the goal of developing a set of guidelines reviewing existing pothole repair methods, materials and equipment. Only pothole repairs for asphalt concrete (AC) and thin membrane surface (TMS) pavement types are included in the scope of this report.

The anticipated end users of these guidelines comprise municipal road preservation administrators and supervisors, as well as municipal council in charge of road maintenance decision-making processes. While engineering input was necessary to develop the technical content of these guidelines, a significant effort was made to keep the information understandable and usable by the intended reader.

To provide the Saskatchewan municipalities with the best advice on how to address potholes, worldwide practices on the issue were reviewed, with special interest for places with similar climate.

1.1 PAVEMENT TYPES

Potholes form in all pavement types found in Saskatchewan – asphalt concrete, TMS, concrete and gravel roads. However, we differentiate pavement types in order to select the correct repair methods, materials and equipment. For the purpose of limiting the scope of these guidelines, only asphalt concrete and TMS surfaces are discussed here.

*Asphalt Concrete (AC)* is a flexible type of road surface made of a mix of aggregate and bitumen. AC usually consists of one or more lifts of asphalt mix over unbound granular layers.

*Thin Membrane Surface (TMS)* is a design structure intended to carry the traffic loading of a gravel road resulting in a dust-free surface. It consists of a layer of oil-treated aggregate as the top layer of the road.

Both AC and TMS belong to the group of flexible pavements, which are named this way because they flex, or bend, in response to wheel loading of passing traffic.

1.2 TRAFFIC LOADING

Pavement incurs damage for two major reasons: environment conditions and traffic loading. The latter consists of heavy trucks applying significant pressure on the pavement surface, causing it to flex, fatigue and crack. Traffic loading is an important contributing factor to pothole formation; it causes pavement breakage and collapse above the areas where the soil has diminished bearing capacity due to
According to the mechanistic approach to surfacing design used by the Saskatchewan Ministry of Highways and Infrastructure (MHI), the life of a pavement is measured in traffic loading, or the number of heavy vehicle loads (with the unit being the equivalent single axle loads, or ESALs) accumulated over the pavement’s life. Pavement structures with known AC and granular thicknesses have a finite number of accumulated ESALs that they can withstand before failing.

The table below provides examples of how much traffic loading, in ESALs, an AC pavement with a thickness of 100, 200 and 300 mm can withstand where a granular base and subbase thickness of 0, 300 and 600 mm exists. The example below is provided for a typical Saskatchewan subgrade made of highly plastic clay with a CBR of 2.5.

<table>
<thead>
<tr>
<th>Granular:</th>
<th>0 mm</th>
<th>300 mm</th>
<th>600 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC=100mm</td>
<td>$2.0 \times 10^5$</td>
<td>$1.2 \times 10^5$</td>
<td>$1.0 \times 10^5$</td>
</tr>
<tr>
<td>AC=200mm</td>
<td>$1.1 \times 10^6$</td>
<td>$7.0 \times 10^5$</td>
<td>$1.8 \times 10^5$</td>
</tr>
<tr>
<td>AC=300mm</td>
<td>$6.0 \times 10^6$</td>
<td>$1.2 \times 10^6$</td>
<td>$2.0 \times 10^6$</td>
</tr>
</tbody>
</table>

TMS surfaces are, in essence, gravel roads with a soft asphalt mat on top which is placed not to increase their bearing capacity, but to keep them dust-free and mud-free. MHI assigns no design life to such surfaces, and recommends them only for low volume roads where the annual average daily number of vehicles does not exceed 500.

For more information, refer to MHI’s Surfacing Manual.

Potholes can also result from repeated traffic loading wearing away or ravelling out of AC surfaces that are aged or stripped.

In assessing pothole-prone roads, the municipal road preservation authority should consider redirecting the truck traffic away from a road that is not designed to carry such loading. Seasonal weight restrictions are another option where permanently rerouting the traffic is not an option; these consist of restricting heavy truck traffic from using certain roads in springtime only (March to May), when the road structure is the weakest due to thawing and wet conditions. Seasonal weight restrictions are achieved by decreasing the legal limits of truck axle loads.

**1.3 TYPES AND SIZES OF POTHOLES**

Potholes range from small, shallow pick-out ravel of the road surface layer to large failures related to loss of strength in subgrade where total failure occurs. For the purpose of these guidelines, potholes are considered small if they have an area below 0.9 m², and shallow if they involve only the top layers of the road (up to 15 cm deep).

Shallow potholes are referred to as *non-structural potholes*. For these potholes, there hasn’t been a loss of compaction in the structure of the road, with the possible exception of the very top of the base layer immediately beneath the road surface.

Deep potholes which involve failures in the base, subbase and subgrade of the road, are referred to as *structural potholes*. They can also start as small-area failures, but can quickly evolve into large
isolated failures or generalized failures of the entire structure. Under extreme environmental conditions and with heavy truck traffic involved, such potholes have been known to progress from small to general failures in less than 24 hours.

It is important to distinguish the types of potholes in order to choose the most suitable treatment and assign the appropriate priority. Some jurisdictions classify the pothole severity and assign priority levels based solely on their depth (see discussion on the left).

A study performed under the Strategic Highway Research Program in US limits the maximum size of a surface pothole to an area of 0.93m$^2$ and a depth of 15 cm (Blaha), with larger areas being usually associated with multiple failures as opposed to isolated occurrences.

Pothole classification is often subjective, reflecting the level of funding and the priority that the community assigns to the problem. For example, the Haringey Council, UK, set an intervention standard for a pothole, corresponding to a 50 mm depth on major roads, 60 mm on unclassified roads, and 25 mm for locations where they may be a hazard to pedestrians or cyclists (Haringey Council).
2. CAUSES OF POTHOLES

There are several reasons why it is important to understand how potholes form:

- It makes it easier to identify potholes even before they are fully formed, or predict them before they even appear based on surrounding conditions.
- It helps determine the correct extent (especially depth) of the pothole.
- It helps explain the selection of repair materials – the importance of granular gradation and seal. It thus promotes a better selection of materials.
- It promotes general understanding of what a good road design is, and how to build roadways that are less susceptible to potholes.

2.1 MECHANISMS OF POTHOLE DEVELOPMENT

In flexible pavements, potholes begin forming where there is a weakened area beneath the pavement surface. Heavy traffic loading causes excessive flexing of the road surface, leading to cracking.

Water action is often the cause of weakening of the road subsurface. In Saskatchewan, potholes are commonly formed during freeze-thaw cycles. Following is a general scenario of how a pothole forms due to water:

1. Water seeps under the surface of the road.

Where a road surface is damaged, rutted or cracked, water can seep in directly from above. Where the road surface is in good condition, water can still seep in at the curb or through the sideslopes if the road embankment is not sufficiently high above surrounding ground (<1.2 m), and/or if the water table is high. The water that seeps into the road will often pool above the subgrade (local soils, often clayey) in the granular, sandy layers constituting the subbase and base of the road.

Water can also be drawn upward by frost action.

2. Water freezes and expands.

When frozen, the water increases in volume by about 9%. The forces causing this expansion are electrochemical in nature and are quite significant. As a result, the ice pushes the soil particles apart and upward. In the asphalt mat, trapped water can push out aggregate or separate lifts of mix. The road structure beneath the surface loses its...
compaction and cohesion. When it thaws, water can also be trapped in underlying frozen materials as thawing occurs. Traffic pressure can result in pore pressure build-up and pavement cracks may allow water to enter the pavement structure and subgrade. Under freezing conditions, water can be concentrated next to the cracks, resulting in bumps when frozen, and additional cracking of potholes during thawing.

3. The road traffic damages the road surface.

Where the soil particles are no longer keyed in place and well-compacted, even light traffic exerts enough pressure to cause the road surface to crumble and break away.

There are multiple ways the water seeps into the roadway structure:

- Through a pervious AC or TMS surface: See Section 2.1.1. Where the water is trapped immediately beneath the surface, a non-structural pothole will occur. This often happens in the winter months during short thawing periods. The road salt, due to its hydrophilic properties, additionally contributes to concentrating water near the surficial cracks, causing shallow failures. Where the water travels downward and pools in the lower layers of the road structures, a structural pothole may occur.
- Through the sideslopes: highways and other roadways built on embankments are normally well-above the surrounding ground (on average by about 1.2 m), and with free-draining ditches around. This is done to keep the water table low as compared to the road surface. If the road is not built high enough, or the ditches do not drain properly, water comes closer to the road surface, penetrating it, weakening it by (1) making it buoyant and (2) starting potholes. These potholes are generally structural.
• From below: even when the water table is sufficiently low, water will travel upward through capillary action, causing structural potholes. See Section 2.1.1.

Potholes on urban streets: Curbed roadways such as urban streets are somewhat different from highways built on embankments in the way they are exposed to conditions contributing to pothole formation. There are no sideslopes, drainage ditches and other elements comprising a surface drainage system, draining water away from the road surface, and the roadways commonly serve as stormwater conduits for water flowing from developments around using urban drainage systems comprised of gutters and curbs, as well as catchbasins, manholes, storm sewers and underground storage. Urban drainage systems normally have a lower conduit capacity than surface drainage systems and are discouraged where an option exists (Kenny). On roadway networks with urban drainage systems, the mechanism of water seepage into the road structure is most commonly through the road surface, at the curbline through cracks and joints, or behind the curb where water enters as it drains towards the street. The resulting potholes are often shallow, lying directly beneath the AC or TMS layers.

2.1.1 Asphalt Concrete and Base Mix Problems

Water commonly penetrates the road from above, through the asphalt concrete layer. If built properly, this layer is relatively impervious. The common causes why the AC layer is pervious are:

• Poor gradation: the gradation of the aggregate in the AC mix does not follow specs, causing gaps and pores in the surface for the water to seep through. Highly porous, open-graded mixes are not intended for AC use as they are designed to let water through.
• Segregation: the aggregate in the AC mix has good gradation, but segregation of the aggregate sizes occurred during mixing or placement.
• Poor joints: where construction joints or surface repairs were done and the new surface meets the old one, there is often low density at the joints, or a poor seal. These areas become entry points for the water.
• Low bituminous content: The bituminous content of the mix is too low, failing to create a continuous waterproof surface around the aggregate.

Porous asphalt pavement structures are AC hot mix layers with an open-graded (popcorn) aggregate. They are pervious by design, with the intent of letting the water drain through the road structure instead
of trapping it. Research has found these asphalts more durable and less prone to pothole formation (Cahill Assoc.). In Saskatchewan, the Ministry of Highways and Infrastructure has tested popcorn mix on a section of Highway 1 in the City of Regina with conflicting results: the surface has performed well for a while, but proved to be prone to ravelling. Part of the reason for failure may have been that conventional AC hot mix was placed on the shoulders and popcorn mix on the lanes, confining the water (Anderson).

In addition to a faulty AC mix, there could be issues with the subbase and base courses which contribute to water retention:

- "Dirty" base/subbase course: this term is used for crushed gravels that have fines (silt or clay particles) mixed in. In such mixes, the pores are much smaller and the water does not drain freely. To make matters worse, there is significant capillary action, causing the water to travel upward well above the water table in the road structure. This can lead to the formation of ice lenses well above the subgrade and sometimes directly beneath the AC or TMS. Good drainage in terms of cross-slope is key to performance.

2.1.2 Structural Failures

Structural failures are related to lack of support for AC or TMS. If the base or subbase (i) do not have adequate thickness, or (ii) have not been compacted densely enough, the road surface flexes, cracks and deteriorates as described in step 3 of Section 2.1, even when water is absent. These failures are different from structural potholes in the sense that they are caused not by water but by poor construction methods, but are similar to them in the way they are addressed.

2.1.3 Construction Failures

Commonly, potholes are caused by water freezing/thawing between the lifts of AC. This happens where the AC layers were separated due to a poor bond between lifts. This can happen when (i) laying a lift on a dirty or wet surface (dew or rain), or (ii) placing insufficient amounts of tack coat between lifts. The AC flexing in the separated layer causes fatigue cracking, creating a pathway for the water to seep in. The water is then trapped between layers, and causes a non-structural pothole or a generalized shallow failure by the mechanism described earlier.
2.2 UTILITIES

When utilities are installed under roadways using open cut or trenching methods, the roadways are commonly not properly rebuilt, and become potential pothole locations.

The following things often happen during utility installations:

- The road structure – clay subgrade, aggregate subbase and aggregate base – are not rebuilt to the existing structure’s height and compaction levels. Inconsistencies of boundary conditions can create various problems: fillcrete and other fill materials can create differential movement.
- Even where the road structure is properly rebuilt and compacted, the surrounding material may have been disturbed and has lost its compaction due to winter, high moisture or other conditions.
- Backfill materials may have different thermal or moisture sensitivity, resulting in concentration of water.

As a preventative measure, ensure that during utilities installation the road structure and disturbed material are properly rebuilt and recompacted.

2.3 FAILURE OF EXISTING PATCHES

If a repaired patch is failing, it is important to find out why: this will affect the choice of repair method. Following are some common reasons for premature patch failures:

- The patch did not seal the surface properly, letting the water seep through. Factors causing this type of failure are low density joints, low bituminous content, low quality patching mix, etc.
- The repair did not address the cause of the problem:
  - If the pothole was generated in the subgrade, subbase or base well below the road surface, a surface patch would not provide adequate support for the traffic.
  - If the pothole resulted from high water levels around the road, the drainage issues are continuously weakening the road and must be resolved first.

2.4 LOCATION OF POTHOLES

Even a simple assessment of a pothole location can help with choosing correct repair methods and developing preventative strategies. Typical pothole locations include:
• Wheel path ravel, or loss of aggregate in the wheel paths due to traffic action. This type of damage results in shallow, non-structural potholes.

• Wheel path rutting and shear: in these areas, the pavement flexes and develops ruts, fatigue cracking and eventually, potholes. These kinds of potholes are structural and may occur even in dry conditions or in the absence of water/ice lenses beneath.

• Pavement joints: where the road surface was built at different times and joints meet, there could be cracking, low density or pervious areas and other pavement deficiencies. These locations are entry points for water and traditional potholes are expected. They can also be starting points for ravel.

• Utility locations: if a pothole has occurred at a location where utilities have been recently installed, consider that deep damage at the depth of the utility, rather than surface damage, is causing it. Deep patching rather than temporary repairs are more suitable for these situations; consult with the utility for special work precautions.

• Drainage problems: if there is, or recently was, water ponding around the road, the road structure may be wet and weakened. Ponding areas around curbs can weaken and fail rapidly under heavy loading by vehicles such as buses which tend to operate in the curb lane.

• Paved back alleys: these roads are habitually under-designed due to their relatively low priority and profile; yet, these roads have truck traffic such as garbage trucks.

• Manholes and catchbasins: on roadways designed with urban drainage systems, manholes, catchbasins and other elements form a surface cave-in where snow, ice and water gather. In addition, these are locations where different materials (AC, concrete, metal, etc.) are jointed. These spots are known to be prone to pothole formation (CDOT, CVAM).

Unlike highways, urban roads often double as stormwater conduits. This service alley in the City of Edmonton (Cepas 1) has failed throughout. Note that the road does not have a well-defined drainage system (curbs, manholes, sideslopes, drainage ditches) while being the receptacle of the runoff from the adjacent lands.

Curbs, catchbasins and any other road features forming a depression in the roadway are potential pothole locations.

The picture below, reproduced from The Telegraph (UK), shows a pothole formed at the curb. There are two potential factors which probably contributed to its formation: the depressed shape and the AC-concrete joint.
3. PREVENTATIVE MAINTENANCE

By the time a pothole is developed, the road structure has failed. A pothole repair is, therefore, a form of reactive maintenance.

Preventative maintenance is a road management strategy that has been proven by many agencies to cost significantly less in the long run than reactive maintenance. Preventive maintenance is key to controlling long-term costs: it costs less in the long run to have good roads than bad roads—if one keeps up with preventive maintenance continuously (MTP 2035).

Practicing preventative maintenance often prevents the formation of potholes and improves the quality of road overall. In addition, the average quality of the infrastructure improves, better serving the community.

The main challenge to implementing preventative maintenance practices is monetary, as arguing for spending money now to prevent road failures which did not yet happen is a much harder sell than asking for funding to fix road failures which already exist.

Fortunately, many agencies have looked at the costs and other implications of preventative vs. reactive road maintenance. Their experience can be used to argue for the financial and other benefits of preventative road maintenance (Cepas 1).

Good road maintenance has implications that go far beyond direct road maintenance costs. Economic research (World Bank 1; Heggie) has concluded that:

- The costs of poor road maintenance are borne largely by the road users, both in increased vehicle operation costs and in decreased economic activity (Heggie, p.12); and
• Road maintenance and rehabilitation projects carry economic rates of return of over 35% (World Bank 1). See the example on the right about Africa’s roadway infrastructure.

Some simple preventative maintenance practices which avert roadway failures such as potholes are listed below:

• Ensure good drainage around roads by:
  o cleaning culverts every spring and whenever plugged, and installing additional culverts where necessary;
  o cleaning and maintaining manholes;
  o removing debris which impede water flow in the ditches or along sidewalks;
  o maintaining good drainage around curbs.

• Perform surface repairs which prevent water from seeping in:
  o Fill in ponding areas so they are flush with the rest of the road surface;
  o Seal segregated areas to prevent them from holding water;
  o Seal joints;
  o Seal cracks.

• Haul the snow from the high-traffic road sections prior to spring thaw (see discussion on the right).

Early identification: Potholes progress rapidly, so it is essential to repair them early. There are several strategies that road authorities are adopting around the world, intended to assist with early identification and location of potholes:

• There is an emerging trend joined by municipal road authorities around the world to enable pothole reporting online by private citizens. In Canada, the Cities of Edmonton and Toronto are among those who have successfully practiced this approach.

• To involve the young and “connected” segment of population, pothole reporting apps are being made available for IPhone and Android systems (Choney).

• There are emerging technologies intended to equip road maintenance authorities with tools of early pothole identification (see example on the next page, on the left). The intent of these technologies is to shift the reliance for timely pothole reporting from the public and roaming crews to a more consistent system, and to enable pothole detection at earlier stages.

The World Bank has studied the economic impact of various road maintenance strategies on the road user, using the example of roadways on the African continent. Several road maintenance strategies were considered, such as patching, surface-treated reconstruction for roads with IRI=7, and asphalt concrete overlay for roads with IRI=5, among others. The benefit to cost ratio ranged from 4 to 10 for roads in poor condition and from 6 to 12 for roads in fair condition. Even simple patching had a benefit to cost ratio of 4 and 6 respectively (Heggie, p.14).

The research has also quantified the impact of potholes on the cost of vehicle operation, determining that the latter increases by about 17% for roads with extensive potholes (Heggie, p.15). While the above numbers cannot readily be transferred to a North-American setting for reasons of differing socio-economic and climatic conditions, the general trend is still valid.

City of Yorkton, SK, actively practices hauling the snow piled on all medians situated on arterial and collector roads prior to spring thaw. In the City’s experience, this practice greatly reduces water runoff around the roadways, removing the potential for infiltration and hydraulic action caused by traffic. This ultimately reduces potholes in these locations.

The City of Yorkton has proven this practice to be a more cost effective option as compared to continuous patching with no snow haul (Mandzuk).

The picture below, courtesy City of Yorkton, shows such a spring cleaning operation.
The principles of preventative or early maintenance apply to pothole repairs. In most cases, repairing a pothole early, while it is small, will prevent it from growing or expanding from a surficial to structural failure. Even spot sealing over a failure in its early stages can delay or prevent further damage by keeping out the water.

A group of MIT computer scientists have recently designed and tested a prototype of a pothole identification device named “pothole patrol”. The device was mounted on taxi cabs and recorded vibration and GPS data. The results were found to be about 90% accurate, with some false negatives triggered by bridge joints and sunken manhole locations (Eriksson et al).

The picture above shows an example of a small pothole detected using the Pothole Patrol. The picture below shows a sunken manhole which triggered a false alarm. Both pictures are reproduced from Eriksson et al.
4. PATCHING MATERIALS

Patching materials, in most general terms, incorporate bitumen, aggregate and various additives to create a mix intended to repair the top layer of the road structure consisting of AC, TMS, and sometimes, the very top portion of the granular layer beneath the road surface. Used by themselves, these materials are intended to repair shallow, non-structural potholes with small or large areas. For structural failures, these materials may or may not be used to repair the road surface in the very last step of the repair, with prior steps involving the restoration of the road structure.

Patching materials designed for use in winter or cold conditions tend to use softer asphalts and slightly higher asphalt contents, so that it is easier to lay and compact them, and their adhesion to the pothole is improved. These mixes also tend to perform poorly once the temperatures rise and the asphalt softens. Patching materials with harder asphalts and lower asphalt content can be used in winter if hot boxes or other methods of heating the repair are used; this would provide the same short-term performance, but better long-term performance.

In the last decades, patching materials have improved significantly. Today, there are specs available that enable agencies to produce patching materials on their own, and proprietary mixes readily available for purchase. Some of these can be used in adverse weather for emergency works.

Choosing high-quality patching materials is the most important decision to ensure quality pothole repairs (Wilson). Research has shown that even traditional methods of pothole repair such as “throw-and-roll” are reasonably effective when quality materials are used.

4.1 STANDARD SPECIFICATION REPAIR MIXES

Standard specification patching materials are designed by transportation agencies. They describe the aggregate and binder parameters which ensure a good quality of the mix. Following these specifications, an agency can produce a patching material of a specified quality.

For Saskatchewan conditions, a good patching material must have the following properties:

- The workability of the mix is good in a wide range of temperatures;
• The mix must be compactable to design densities in a wide range of temperatures, including cold weather.

The table below summarizes the common patching materials which are most suitable for Saskatchewan conditions. The standard specifications are provided in the Appendices.

Some road authorities have less formal specifications for their patching mixes. For example, the City of Saskatoon defines its hot mix patching mix as Type 3 HMA that is placed with a self propelled hot box truck or with a tow-behind trailer; this is a 13 mm mix with a stability of 6 kN and a minimum asphalt content of 5.7% with 2 to 4% air voids.

<table>
<thead>
<tr>
<th>Mix name:</th>
<th>Used by:</th>
<th>Notes:</th>
<th>Appendix No.:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section 815 Bituminous Cold Mix</td>
<td>US, India</td>
<td>A cold mix patching material which is most commonly used in US.</td>
<td>1</td>
</tr>
<tr>
<td>Section 819 High Performance Bituminous Cold Mix</td>
<td>US</td>
<td>All-weather pre-packed cold mix patching material specification manual application. This material is known to have a fast curing time and thus is suitable for high-traffic areas which cannot be closed to traffic for a long period.</td>
<td>2</td>
</tr>
<tr>
<td>Standard Specs. 4140 &amp; 4150</td>
<td>SK, MHI</td>
<td>Typical cold mix using cutback or emulsion.</td>
<td>3</td>
</tr>
<tr>
<td>Specification 53.10 Asphalt Pavement Pothole Patching</td>
<td>Alberta Highways</td>
<td>Alberta Transportation specification for patching materials</td>
<td>4</td>
</tr>
<tr>
<td>OPSS 1152 Material Specification for SC800 Patching Material</td>
<td>Ontario Transp.</td>
<td>Cutback specification suitable as a patching material</td>
<td>5</td>
</tr>
<tr>
<td>PennDOT Colx Mix No. 485</td>
<td>US</td>
<td>This patching material was found to perform better than many proprietary mixes (SHRP report 1991)</td>
<td>6</td>
</tr>
<tr>
<td>Minnesota DOT Specification 2381 Bituminous Stockpile Patching Mixture</td>
<td>US</td>
<td>A number of US transportation agencies reported good performance by this material (Kuennen)</td>
<td>7</td>
</tr>
<tr>
<td>City of Regina Hot Patching Mix Specification</td>
<td>City of Regina, SK</td>
<td>A set of minimal requirements used by City of Regina for assessing purchased hot patching mixes</td>
<td>15</td>
</tr>
</tbody>
</table>

4.1.1 Aggregate-Binder Compatibility

Cold mix patching materials consist of aggregate (gravel and, optionally, recycled asphalt materials) and binder (bituminous material). To obtain a good patching material, the two must bind well (Wilson). When they do not, aggregate segregation (aggregate popping out) may happen.

To determine the aggregate-binder compatibility, a stripping test is conducted. A stripping test is designed to determine how much aggregate surface is not covered by bitumen in a mix, and it is expressed as a percentage of exposed vs. total area. Two stripping test standard specifications are found in Appendices 8 and 9.

Generally, stripping is not desirable at all, if possible. The Indian Roads Congress specifies a maximum stripping value of 5% (Mathew et al).

4.1.2 Aggregate-Dominated and Matrix-Dominated

Patching materials fall into two large classification groups: matrix-dominated (materials with higher binder content) and aggregate-
dominated (materials with lower binder content). Their performance is dependent on the properties of binder (commonly, bitumen) for matrix-dominated materials, and of aggregate interlocking properties for aggregate-dominated materials. Aggregate-dominated materials are unlikely to provide good service life unless all edges are supported by existing intact surrounding material (Atkins).

Matrix-dominated materials, otherwise known as hot rolled asphalts, tend to deteriorate through deformation (rutting). Aggregate-dominated materials usually deteriorate through segregation (aggregate separates and pops out).

Proprietary polymer-modified repair mixes, as well as proprietary repair materials using warm mix technology, are becoming available on the market.

4.2 LOCALLY PRODUCED MIXES

Locally produced mixes fall into three general groups: hot mixes, cold mixes with cutbacks, and emulsions.

Hot mixes are a conventional mix of aggregate and bitumen. They are heated before being placed on the road surface as the increase in the temperature of the mix results in a decrease of the bitumen viscosity. As a result, the mix is workable while hot, and hardens as soon as it cools down. The temperature of the hot mix is not fixed, but depends on the bitumen used. Generally, the heavier the bitumen is, the higher the mixing temperature it requires to be workable.

For Saskatchewan, the asphalt mixing temperatures are appropriately specified by MHI’s construction specifications. See Table 4100.3.T3 on page 14, Appendix 10. Another source of information for mixing temperatures of the hot mix asphalt is NCHRP Report 648 (Appendix 11, Table 1, p.10).

If the type of asphalt used does not fall into the range of those specified by MHI, one can test it to determine the correct mixing and compaction temperatures. The National Cooperative Highway Research Program has determined that (i) the High Shear Rate Viscosity and (ii) the Steady Shear Flow methods, both described in Report 648 (West et al, see Appendix 11) can be used for this purpose. Typically, the asphalt producer or supplier can produce the required tests and determine the necessary temperature values for mixing and compaction. It is important not to overheat the mix by an excess of 10°C over the specified mixing temperature, or over the maximum temperature of 190°C (Serafin) as it will result in the aging and degradation of the asphalt binder.
The compaction temperature of the hot mix asphalt depends on (i) ambient and existing surface temperatures and (ii) lift thickness. Hot mix temperatures that are too low affect the workability of the mix and result in poor compaction. Examples of compaction minimum temperatures are found in Appendix 11, Table 2, page 12.

The hot mixes are generally thought to be the best patching materials. The drawback is that (i) they require equipment such as mixing plants and on-site tanks, (ii) the energy use is quite high, increasing the cost of the material, and (iii), in cold temperatures, it can be a challenge to maintain the compaction temperature in the field. In addition, one cannot prepare a small amount of hot mix for one or a few small repairs; the scope of the work should be commensurate with the minimum amount of hot mix a plant can produce.

New warm mix technology relies on additives to allow mixing and laying at lower temperatures. This technology may provide some advantages for patching materials.

*Cold mixes with cutback* consist of aggregate, asphalt binder, and cutback asphalt. The cutback fraction is a petroleum solvent, usually diesel or gasoline, which has the purpose of decreasing the viscosity of the asphalt binder so that it can be worked. The cutback eventually evaporates, leaving the harder asphalt fraction behind.

The SK MHI material specifications for cutback asphalts are found in Appendix 12. During laying and working the material, the cutter is released, allowing the mix to harden. There are significant emissions associated with this material, as virtually all cutback is expected to evaporate into the atmosphere. Cold mixes are difficult to work and compact in cold conditions, needing to be heated and stored indoors. Laying in cold conditions does not remove the cutter, so the mix could remain unstable in the patches.

*Emulsions* are another variety of cold mix material, where the workability of the asphalt and aggregate mix is attained by the addition of water and an emulsifying agent (such as soap) to the asphalt fraction. Water does not normally mix with asphalt, but when an emulsifier is added, they do. Like cutback, the water eventually evaporates during working, leaving hardened asphalt in the road surface. Emulsion mixes are not workable in very cold conditions; the mix can be stored inside a heated shop in order to be workable.

The SK MHI material specifications for emulsions are found in Appendix 13. The mixing grade specification is suitable for the patching material itself while the high float high residue specification is suitable for joint and crack sealing.
Emulsions are safer than cutbacks as they have very low emissions; consequently, they can be stored indoors.

4.3 PROPRIETARY MIXES

The very large number of proprietary mixes for pothole patching available on the market may make it difficult to choose a product. Generally, a material is considered appropriate if it can remain in place for 1 year after installation (Oregon DOT).

A number of studies have compared the relative performance of a number of patching materials, providing some guidance in their selection. In addition, many larger transportation agencies test proprietary materials and publish lists of approved products. Following is a list of various products, assembled based on these studies.

<table>
<thead>
<tr>
<th>Product:</th>
<th>Notes:</th>
<th>Contact:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquaphalt (also known as Raphalt)</td>
<td>Patching material produced by Vialit Asphalt (Austria). In 2007-08, it was successfully tested by Virginia DOT and introduced on the list of approved products (VDOT).</td>
<td><a href="http://www.aquaphalt.com">www.aquaphalt.com</a> 1.866.784.5031</td>
</tr>
<tr>
<td>Bond-X</td>
<td>Tested by Oregon DOT, rated “fair” at 1 year, “poor” at 2 years.</td>
<td><a href="http://www.nugentec.com/">http://www.nugentec.com/</a> 1.888.996.8436</td>
</tr>
<tr>
<td>Elasti-Patch</td>
<td>Tested by Oregon DOT, rated “fair” through 2 years.</td>
<td><a href="http://www.kochind.com/">http://www.kochind.com/</a></td>
</tr>
<tr>
<td>EZ Street Cold Asphalt</td>
<td>Approved by ON Transport, City of Edmonton. The latter prefers this product to others on the market because it sticks to potholes in wet conditions and repels water very well. Also used as overlay material, with test sections in Edmonton, Calgary, BC and ON. Prepared as warm mix through a double mixing cycle (Cepas 3).</td>
<td><a href="http://www.ezstreetasphalt.com">www.ezstreetasphalt.com</a> 1.800.734.1476</td>
</tr>
<tr>
<td>HFMS-2SP/HFE-300S</td>
<td>Tested by Oregon DOT, rated “fair” through 2 years.</td>
<td><a href="http://www.albina.com">www.albina.com</a> 1.360.816.8016</td>
</tr>
<tr>
<td>IAR</td>
<td>This cold mix was tested by FHWA and found to have performed in line with other tested patching materials. No particular recommendation for using this material was made (Maher).</td>
<td><a href="http://www.zbco.org/">http://www.zbco.org/</a></td>
</tr>
<tr>
<td>Instant Road Repair</td>
<td>Tested by Oregon DOT, rated “fair” through 2 years.</td>
<td><a href="http://www.roadwayresearch.com/">www.roadwayresearch.com/</a> 1.281.441.3558</td>
</tr>
<tr>
<td>King Patch</td>
<td>Tested by Oregon DOT, rated “poor” at 6 months, “overlaid” at 1 year.</td>
<td>Pacific Asphalt Marketing 1.801.785.1560</td>
</tr>
<tr>
<td>PermaPatch</td>
<td>This cold mix was tested by FHWA and found to have performed in line with other tested patching materials. No particular recommendation for using this material was made (Maher). Tested by Oregon DOT, rated “fair” through 24 months after use.</td>
<td><a href="http://www.permapatch.com/">www.permapatch.com/</a> 1.800.847.5744</td>
</tr>
<tr>
<td>ProPatch</td>
<td>A ready-to-use out of the bag cold mix. Approved by ON Transport.</td>
<td>1.800.387.5777</td>
</tr>
<tr>
<td>QPR</td>
<td>Used by Calgary, Battleford. A competent cold mix. One issue is that the one-size aggregate is prone to holding water and segregating (Cepas 3). Tested by FHWA, performing in line with other products; no particular recommendation for using this material was made (Maher). Tested by Oregon DOT, rated “good” at 6 months, “fair” after 2 years. Same study found it less susceptible to pavement distress than other products.</td>
<td><a href="http://www.qprcoldpatch.com/">www.qprcoldpatch.com/</a> 1.800.388.4338</td>
</tr>
<tr>
<td>Sylvax UPM</td>
<td>Product was in the past used by City of Edmonton, but has been replaced by EZ Street due to the criticism for uniform-graded aggregate which does not compact well and holds moisture. The mix was found to hold no advantage over locally prepared patching materials (Cepas 3).</td>
<td></td>
</tr>
<tr>
<td>Tag 8000</td>
<td>Tested by Oregon DOT, rated “good” at 6 months, “fair” at 2 years. Same study found it less susceptible to pavement distress than other products.</td>
<td><a href="http://www.infratech.com/">www.infratech.com/</a> 1.604.888.8808</td>
</tr>
<tr>
<td>Wespro</td>
<td>This cold mix was tested by FHWA and found to have performed in line with other tested patching materials. No particular recommendation for using this material was made (Maher).</td>
<td><a href="http://www.wesproasphalt.com">www.wesproasphalt.com</a> 1.559.281.1032</td>
</tr>
<tr>
<td>1170 High Performance Road Repair-Regular Grade</td>
<td>Regular sized aggregate, all-weather application. Suitable for deep repairs.</td>
<td><a href="http://www.northlandconstruction.com">http://www.northlandconstruction.com</a></td>
</tr>
<tr>
<td>1175 High Performance Road Repair-Fine Grade</td>
<td>Small sized aggregate, all-weather application. Suitable for shallow repairs. Used in North Battleford.</td>
<td></td>
</tr>
<tr>
<td>Cold Applied 1100 Rubberized Crack Filler</td>
<td>Crack sealant, suitable for warm (10°+) application. May be used for joints.</td>
<td></td>
</tr>
</tbody>
</table>

There are trade-offs between durability and rutting resistance requiring a thorough evaluation and balancing of performance requirements. The evaluation of proprietary patching products is a continuous task, as proprietary products may change in their formulation, be rebranded,
and new products may be released. For these reasons, it is advisable to develop and maintain an inter-agency database or list of evaluated products.

### 4.3.1 Fines, Workability and Coating

In reality, it is not always feasible, especially for a smaller agency, to field-test various patching products. However, it is possible to assess a patching product’s quality by checking its three key qualities.

**Fines:** The quality of a patching mix is greatly affected by aggregate gradation. Finer aggregates create mixes that are less pliable. It is important that dust, or particles passing sieve no. 200, constitute less than 5% of the aggregate (Berlin).

Patching materials with finer aggregate are more suitable for shallow potholes as they can be laid thin and are less susceptible to ravelling. Coarser aggregate (75% larger than 3 mm) is more suitable for deep potholes as they provide for better support (Berlin).

**Workability** in all-weather conditions is a primary concern, especially in Saskatchewan climate. The patching material stockpile is expected to be pliable and workable for several months or years after preparation, and in the expected ambient temperatures.

Workability has to last, e.g. the coating agent in the mix should not dry and harden fast. This is necessary so that the material can be stockpiled before use (Berlin).

**Coating:** The binder must coat over 90% of all aggregate surface (Berlin). Also, a water-repelling binder is superior to one that does not repel water well, and it is more suitable for use in wet and winter conditions.

Some mixes are suitable only for specified seasonal operation. When storing such a material off-season, drain down (the draining of bitumen from the mix) must be considered. Drain down often occurs when the coating agent in the mix is not thick enough, or it is too runny. It then collects at the bottom of the stockpile, creating storage and usage problems (Berlin).

There are trade-offs associated with the selection of materials, generally concerning durability vs. the ease of use.
5. POTHOLE PATCHING METHODS

Generally, there are two classes of pothole repairs: temporary and permanent.

Temporary pothole repairs consist of rebuilding the road surface with a suitable patching material, and are intended to last for up to 1 year. When done with quality materials, most temporary repairs will last up to and beyond 18 months (Wilson). These types of repairs are covered in Sections 5.1 and 5.2.

Permanent pothole repairs address the road’s weakened structure by excavating the softened subsurface, recompacting it, and rebuilding the road surface by any of the methods described in Sections 5.1 and 5.2, or by reapplying the AC or TMS surface through traditional construction methods. Permanent pothole repairs are discussed in Section 5.3.

Preparation is key to a good repair, regardless of method used. Even the best patch will not perform if the preparation work is not performed well (Atkins). Preparation generally consists of cleaning the debris, water and loose material from the pothole, compacting the subgrade, and drying the hole if possible. Some repair methods include the additional step of cutting edges of the pothole with a saw so that a more uniform joint with neat vertical edges is created, and all the failure area is treated.

For small potholes (area <0.9 m²), both cold and hot mix patching materials can be successfully used to rebuild the top of the road surface. Repairs of shallow (<15 cm) potholes can be done using patching materials only, when an appropriate repair process is used.

For small but deeper potholes, where a softening of the base and subbase layers has occurred, prior to placing the patching material in the hole, the softened material must be recompacted back in place with the addition of more base aggregate if necessary.

For large shallow potholes (>0.9 m², <15 cm deep), resurfacing the road using a variety of approaches like hot mix, cold mix, cold-in-place recycle, or similar proprietary processes work best (see Bagela® BR series and Battle River Asphalt 448I equipment in the equipment table, Section 6).

For large and deep potholes where there is a loss of strength in the entire structure (surface, base, subbase and subgrade), deep patching is the only repair approach which will produce satisfactory results. Short
term repairs would consist of filling the pothole with base or reclaim aggregate until permanent repairs can be completed.

Prior to all deep patch type pothole repairs in Saskatchewan, utility locates must be done.

5.1 REPAIR METHODS

5.1.1 Throw and Go

This is the simplest method used to patch a pothole, consisting of filling the pothole with a patching material. Often, the pothole is not cleaned or prepared in any way.

This is the least advisable method for pothole repairs, and is suitable only for small, non-structural potholes. It is important to note that this repair method is temporary and very short-lived, and can only be applied in dry conditions. The benefit of this repair approach is that it is cheap and easy to apply, not requiring any specialized equipment; the resulting temporary patch reduces the extent of pavement deterioration and addresses the public safety issue until a more permanent repair can be performed.

The improved version of this repair method is throw-and-roll, which produces satisfactory temporary pothole repairs.

5.1.2 Throw and Roll

The throw-and-roll procedure consists of placing a cold mix patching material directly into the pothole (which may or may not be filled with water and debris). A compressed air lance can be used to partially clean and dry the hole to improve the patch performance. Then, the patching material is compacted using truck tires. The compacted materials should have a slight (3 to 6 mm) crown. The road is open to traffic as soon as the equipment and crew leaves the roadway.

When using quality materials, the properly applied throw-and-roll method is as effective as the semi-permanent procedure while having a lower cost. This operation is advisable for repairs in adverse weather because it can be done quickly. Only quality materials should be used (Wilson). If the repair is more than 100 mm deep, the patching material should be placed and compacted in lifts not exceeding 80 mm each.

To improve performance under very cold conditions, the pothole patching material must be stored indoors and/or in heated truck boxes (where the exhaust from the truck is used for heating).
This pothole repair method is suitable for small, shallow potholes, and is expected to last for up to 1 year when implemented properly. This pothole repair method is recommended as a temporary measure and for safety reasons.

5.1.3 Spray Patch

This method is somewhat similar to the throw-and-roll approach. The main difference is that instead of out-of-the-bag patching material, a material that is cold-blended as it is sprayed into the hole is used. Normally, the spray patching materials use emulsified or cutback asphalts. The material is then compacted, and the road is open to traffic as soon as the equipment and workers have left the roadway.

The materials used for this type of repair are local aggregates and local or proprietary asphalts, emulsions or cutbacks. The repair should not be performed in cold temperatures below 5°C (Alberta Spec. 53.7, see Appendix 14). Reclaimed asphalt or concrete can be used at the bottom of deeper holes since these materials are easily compacted. The top surface can then be sprayed to seal.

5.1.4 Edge Seal

Edge seal method is an improved “throw-and-roll” method, implemented in two steps:

1. Cold-mix patching material is placed in the pothole without prior preparation. The material is compacted using truck tires and checked for levelness. If there is a depression, more material is added and the procedure is repeated until the surface is level. The patch is then left to dry for 24 hours.
2. A 10-15 cm band of bituminous material such as a tack coat is placed around the patch perimeter. A layer of aggregate is placed on the tack coat.

The edge seal method helps prevent the potholes from expanding.

5.1.5 Semi-Permanent

A semi-permanent repair is done as follows (Atkins):

1. The edges of the hole are prepared by cutting a circular (preferred) or rectangular shape in the asphalt surface. The final edges should be vertical.
2. The pothole is prepared by removing all water, debris and loose material. The hole is dried if possible.
3. A tack coat is applied to the hole bottom and edges. The preferred tack coat type should be cationic emulsion with minimum 60% bitumen.
4. The hole is filled in lifts not exceeding 80 mm with patching material of the agency’s choice, compacted. Compaction is done with a vibrating plate or a tamper.

5.2 HOT PATCHING

5.2.1 Spray Injection

Spray injection uses special equipment (see Section 6) to heat asphalt emulsion, mix it with aggregate, and spray the mix into the pothole. The steps for spray injection are as follows:

1. Blow the water and loose material from the pothole.  
2. Apply a tack coat to the bottom and sides of the pothole.  
3. Spray the aggregate-asphalt mix into the pothole and compact.  
4. Cover the pothole area with a layer of uncoated aggregate.

Generally, the road is ready for traffic use immediately after the workers and equipment have left the roadway.

The benefits of spray injection include fast repair and ability to repair potholes in adverse weather. The drawbacks include higher cost of patching for low quantities used (Griffith). The patches generally last up to two years, but are known to perform poorly where moist conditions persist (Prang). Deeper patches tend to consolidate or displace during hot summer conditions.

5.3 PERMANENT REPAIRS

The intent of permanent repairs for both isolated failures and larger areas is to restore the road structure to its original state. This is done as follows:

1. The AC or TMS surface is stripped off over the pothole length (which can vary from 5 to 20 m) and over the full road width.  
2. The softened road subsurface is excavated until compacted, cohesive soil is found. The soils are left to dry or replaced.  
3. Each of the clay subgrade, aggregate subbase and base are rebuilt in lifts to their original height and recom pacted to the original specified compaction levels.  
4. The AC or TMS surface is rebuilt.

The intent of repairing the full width of the road is to provide a drainage path for the water to the side of the roadway. Where the full roadway width cannot be excavated due to curbs, the pothole area is
cleared and excavated to the extent of softened material, and the material is replaced or recompacted back into place. The road surface is then rebuilt by conventional methods described earlier.

Permanent repairs last much longer than temporary repairs. Other factors improving the durability of repairs are dry holes and warm ambient temperatures (Road Management & Engineering Journal).

According to the Strategic Highway Research Program, the spray injection method of pothole repairs is often more efficient and productive than other methods, requiring fewer people and no compaction. Rosco Manufacturing was the first manufacturer to develop a spray injection system (Purdue).

Spray Injection Equipment Examples:
Photo 1: DuraPatcher Trailer Type

Photo 2: Rosco RA-400 Self-Contained Unit
6. EQUIPMENT

Spray Injection Equipment includes (Griffith):

- Trailer type units: these are the most common piece of equipment and are suitable for smaller agencies due to lower price and simpler maintenance.
- Modified truck units.
- Self-contained units.

The table on the next page summarizes some of the common types of equipment, their applicability to repair methods, and provides equipment examples with manufacturer information and additional comments.
<table>
<thead>
<tr>
<th>Equipment:</th>
<th>Type:</th>
<th>Repair Method(s):</th>
<th>Examples:</th>
<th>Comments:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circular Saw</td>
<td></td>
<td>Semi-Permanent Repairs</td>
<td></td>
<td>Used to create a clean vertical edge in asphalt concrete pavement to reduce further AC deterioration. See Section 5.1.5 and graphic insert on page 26.</td>
</tr>
<tr>
<td>Compactor</td>
<td>Plate</td>
<td>All repair methods discussed in Sections 5.1 to 5.2</td>
<td></td>
<td>Either of these pieces of equipment may be used to compact the patching material. This equipment can be used for compacting when using any of the repair methods listed in Sections 5.1 and 5.2.</td>
</tr>
<tr>
<td>Plate</td>
<td>Roller</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patcher</td>
<td>Trailer Type</td>
<td>Spray Injection</td>
<td>DuraPatcher Trailer Duraco Industries <a href="http://www.durapatcher.com">www.durapatcher.com</a></td>
<td>Air is used to feed and propel aggregate and emulsion to the nozzle at up to 61 kg per minute. No moving parts are involved in the spray injection process. Aggregate feed system can pass up to 64 mm rock and is regulated by engine rpm providing infinite adjustment for job-site conditions. This unit is used by Humboldt. See a picture of the unit on page 29.</td>
</tr>
<tr>
<td>Truck-Mounted Unit</td>
<td></td>
<td></td>
<td>Rosco RA-2000 Rosco Manufacturing <a href="http://www.leeboy.com">http://www.leeboy.com</a></td>
<td>Trailer-mounted, two-crew spray patcher. The producer claims that repairs can be conducted at ambient temperatures as low as -17.8°C, and that maintenance is reduced due to only one moving part (leeboy.com)</td>
</tr>
<tr>
<td>Self-Contained Unit</td>
<td>Automated preparation, filling and compaction</td>
<td></td>
<td>Thermo-Lay Northwest Manufacturing &amp; Distribution Co.</td>
<td>City of Regina currently has five units. All units are used on a daily basis around the year (cold mix in the winter and hot mix in the summer). In a 10 hour day, they are capable of placing 5 – 10 tonnes of asphalt in the Regina environment (Kosoloński).</td>
</tr>
<tr>
<td>Heated Truck Box</td>
<td>Trailer Type</td>
<td>All except spray-patching</td>
<td>FPS Flameless Pothole Patcher Bergkap Inc. <a href="http://www.bergkampinc.com">www.bergkampinc.com</a></td>
<td>The electrically heated box keeps the patching material warm. See Appendix E6.</td>
</tr>
<tr>
<td>Hot In-Place Repair Unit</td>
<td></td>
<td></td>
<td>Stepp Mfg. SPH-OJ Hot Box stepmpfg.us</td>
<td>Used by the City of Saskatoon. See page 30 for picture and discussion. Note that the company also produces a range of other equipment for pothole patching.</td>
</tr>
<tr>
<td>Other In-Place RAP Hot Mixing Unit</td>
<td>Other</td>
<td>All repair methods discussed in Sections 5.1 to 5.2</td>
<td>Battle River Asphalt Equipment Ltd. <a href="http://www.goodroads.ca">www.goodroads.ca</a> 1.306.398.2060</td>
<td>Hot in-place repairs unit; functions by heating up and softening the distressed road surface (which may be a pothole, crack, rut or other type of road distress) and recompacting it. The addition of new material is possible. Demonstrated to City of Regina and MHI.</td>
</tr>
<tr>
<td>Other Other</td>
<td></td>
<td></td>
<td>Bagela® BA Series <a href="http://www.pavementrecycler">www.pavementrecycler</a> s.com</td>
<td>Portable mixing plants. Producer claims that 100% RAP hot mixes can be prepared without additives to use for pothole patching and other small to medium pavement repairs. See Appendices E3-E5.</td>
</tr>
</tbody>
</table>
7. ASSESSMENT OF BEST PRACTICES

7.1 POTHOLE TYPES

Recognize the pavement type and likely cause of the pothole and select appropriate repair materials and methods.

7.2 POTHOLE PREPARATION

Generally, an improved preparation of the repair area will improve the performance of the patch. Clean the area using a broom and air (preferably hot) lance. Dry the hole using the air lance. Compact the material at the bottom of the hole.

7.3 MATERIAL SELECTION

Select the best quality material available that is suitable for the failure condition. Use fine mix for shallow repairs and coarse mix for deeper repairs. Deep holes can have coarser mix placed at the bottom for added strength, and finer mix towards the surface for better sealing.

The warmer the patching material is, the easier it is to work and compact it, resulting in improved performance. Whenever possible, heat up repair materials by storing them in a heated shop (even overnight), or using heated truck boxes. Use hot emulsions for tacking or sealing.

7.4 EQUIPMENT

Use the equipment that best suits the repair requirements. Pots and kettles can be used to heat liquid products. Equipment that heats or maintains the mix at a warm temperature will improve the performance of the patch. The compaction of the patch will improve its performance; use multiple passes of truck tires or hard compactors for this purpose. Specialized equipment may provide good performance under the right conditions.

7.5 TIMING OF REPAIRS

Shallow failures within the surfacing structure (mat or base) should generally be repaired as soon as possible, while they are small. Base material loses density if unconfined, so potholes will grow rapidly. Sealing to prevent penetration of water is important.

Deep frost and water-related failures should be left as long as traffic and safety conditions permit, to allow the frost to disappear and the water to drain. Repairs can be temporary (blading and filling). Once the water conditions have stabilized, permanent repairs can take place. In many cases, once the water that has been concentrated and trapped...
by frost has stabilized, the subgrade and granular materials can be recompacted and the surface can be restored.

7.6 SAFETY

Material and equipment must be selected to meet storage, handling and site conditions.

7.7 PREVENTATIVE MAINTENANCE

Water and drainage issues around roadways must be addressed early. Repairing and sealing minor road surface damage prevents potholes from appearing or progressing. Hauling snow away from roadways before the spring thaw diminishes the number of potholes and is more cost-effective than repairing potholes.

A process flowchart showing the pavement maintenance cycle, including the pothole assessment and repair selection process, is provided on page 34.
Pothole Identification:
- Small Non-Structural Pothole
  - Area < 0.9m², Depth < 15 cm
  - Base, subbase layers well-compacted
- Large Structural Pothole or Generalized Structural Failure
  - Area > 0.9m², Depth > 15 cm
  - Multiple small, deep potholes could be present in one area
  - Loss of compaction in base, subbase, and/or subgrade layers
- Large Non-Structural Pothole or Generalized Surface Failure
  - Area > 0.9m², Depth < 15 cm
  - Multiple small, shallow potholes could be present in one area
  - Base, subbase layers well-compacted
- Small Structural Pothole
  - Area < 0.9m², Depth > 15 cm
  - Loss of compaction in base, subbase, and/or subgrade layers

Pothole Repair:
- Subgrade, Subbase and Base Excavation, Reconstruction and Recompaction
  - Longevity: up to 2 years
  - Season: All-Season
  - Cost: Decrease
  - Durability Increase: Larger Size
- Throw & Roll
  - Longevity: 3-12 months
  - Season: All-Season
- Spray Patch
  - Longevity: 1 year
  - Season: Summer
- Edge Seal
  - Longevity: 1+ year
  - Season: All-Season
- Semi-Permanent
  - Longevity: up to 2 years
  - Season: All-Season
- Spray Injection
  - Longevity: up to 2 years
  - Season: Summer

Asset Management:
- Document Repair
  - Location, method, photos (before, after and process)
- Routine and Preventative Maintenance

Planning, Design and Construction:
- Plan:
  - Comprehensive drainage
  - Acceptable pavement failure risk levels
  - Maintenance funding
- Design:
  - Adequate drainage, road grade and road structure
  - Surface pavement:
    - Impervious
    - Porous
- Construction:
  - Design mix, gradation and mixing controls
  - Humidity, moisture considerations:
    - Prevent lift separation

Moisture & Drainage Management
- Hole Preparation
  - Clean up, remove debris & loose material, dry cut edges (optional)

Monitoring and Assessment
- Periodic patch performance assessment
- Detection strategies:
  - Public & internal reporting strategies
  - Early detection strategies
8. AREAS OF FUTURE RESEARCH

- The National Research Centres in Partnership, EU, are currently developing a study titled “Durable Pothole Repairs”, intended to summarize the best practices of European Union with regard to pothole patching. The report is due to be released in 2012 (Kubanek) and should be evaluated for Saskatchewan conditions.

- Communities of Tomorrow are currently in the process of developing a set of guidelines on utility cuts as part of the Trench Reinstatement Project.” These guidelines, with the working title “Improve Trench Reinstatement Programs and Practices for Municipalities” have the potential to become a useful resource for developing best practices for trench backfilling, resulting in an approved product list.

- Proprietary patching products may change in their formulation or be rebranded, and new products may be released. For these reasons, it is recommended that an interagency database be developed to track and evaluate proprietary patching products. By extension, a database of any patching materials, methods and equipment may be developed for the purpose of their continuous evaluation and sharing.

- Research emerging technologies assisting with early pothole detection and reporting:
  - Emerging technologies assisting with early electronic pothole detection can potentially help shift maintenance practices from reactive to preventative.
  - Reporting of potholes by public via sites or applets is becoming mainstream and proactively involves the public in the issue. Beside the direct benefit of earlier detection, this approach may promote public awareness and positive involvement.

- Pervious pavement design is being currently extensively researched and continuously improved. This road surface design approach may help increase the road durability and decrease the frequency of occurrence of potholes.

- The use of warm mixes as applied to pothole patching materials may provide an alternative solution to winter patching. It is recommended to investigate warm mix technologies to determine if additives improve the workability of patching materials.

- It is recommended to investigate recycled products such as reclaimed asphalt or concrete as stable fill materials for deeper potholes.
• Training to recognize the failure causes and types could allow for better selection of materials and methods.
9. TRAINING

The relevant competencies and respective training needs regarding pothole patching materials, equipment and processes are dependent on the individual’s role in the municipal organization. Three distinct functions can be identified within a municipal authority, which have impact on the correct implementation of these:

- Planning: persons involved with strategic planning and development, and participate in financing and budgeting processes, should be knowledgeable in matters of maintenance strategies and their comparative costs. Decision makers should be especially informed in matters of preventative maintenance and the costs of maintaining a road infrastructure at various service levels. Drainage types and implications of these on the road performance should be another area of competence, especially for individuals involved in long-term urban planning. Matters of public communication, such as implementing public feedback systems for early pothole identification, are also decided on this level, requiring awareness about these issues.

- The construction and maintenance authority must be competent in matters of implementation and requirements for various repair methods. Understanding the difference between different pavement types, pothole types and knowing how to properly select the repair types is of special importance. At this level, repair result and performance feedback collection and assessment is done, requiring competencies in the area of asset management. Individuals assuming this role should also determine detailed training requirements for their crews, technicians and operators.

- Construction and maintenance crews, lab technicians and equipment operators must be adequately trained in matters of implementing specific processes assigned to them. For example, lab technicians should be trained in all pertinent testing and mix design procedures. Maintenance crews should understand pavement types and material performance, as well as be able to identify failure types in order to determine the correct repair techniques and materials.

It is advisable to hold on a periodic basis, in addition to specialized training for each of the identified functions, general workshops with the purpose of reviewing the entire process.
10. CONCLUSIONS AND RECOMMENDATIONS

- Use the best materials available to reduce repatching. The quality of patching materials is the most important property affecting the patch performance. For best performance, it is recommended to use the best materials available.

- Use high-productivity operations in adverse weather. Throw-and-roll and spray injections are the methods of choice for efficient pothole patching.

- Factor in the safety and delay costs when evaluating the cost of a patch.

- Repair failures when they are small, then seal the area around to reduce pothole growth. Use temporary repair methods if permanent repairs cannot be scheduled immediately.

- Before selecting spray injection equipment, request demonstrations and orientations on maintenance and personnel requirements from producers.

- Trailer type units are most suitable spray injection equipment type for smaller agencies, as they are simple to use and significantly lower in price than self-contained units.
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Cover page: Saskatchewan Provincial Highway No. 6-08 pavement failure; courtesy of Saskatchewan Ministry of Highways and Infrastructure, 2012.

Section 2.1: 3 graphics on pothole formation, Virginia Department of Transportation http://www.virginiadot.org/info/faq-potholes.asp accessed 05 March 2012.

Section 2.1: 2 pictures of pothole excavation on Saskatchewan Provincial Highway No. 11; courtesy of Saskatchewan Ministry of Highways and Infrastructure, 2012.

Section 2.4: picture of a service road with potholes throughout. Reproduced from Cepas, A. “We’ve got the data – now what?”, City of Edmonton, presented at 7th International Conference on Managing Pavement Assets, 2008 (1).

Section 2.4: picture of a back alley with pothole failures in the wheel path. Reproduced from Cepas, A. “We’ve got the data – now what?”, City of Edmonton, presented at 7th International Conference on Managing Pavement Assets, 2008 (1).


Section 3: 2 graphs from Cepas, A. “Challenges in Road Maintenance”, City of Edmonton, presented at Annual Western Canada Pavement Workshop, February 1, 2012.


Section 5.1.5: Semi-permanent repair images from the Vale of Glamorgan Council site:

Section 5.2.1: picture of Koyl Avenue in the City of Saskatoon, courtesy City of Saskatoon 2012.


Section 6: picture of Rosco RA-300 spray patcher, courtesy of City of Saskatoon, 2012.

Section 6: picture of Stepp Mfg. SPH-OJ Hot Box, courtesy of City of Saskatoon, 2012.
## DEFINITIONS AND ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AC</td>
<td>see Asphalt Concrete</td>
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<tr>
<td>CBR</td>
<td>California Bearing Ratio, a measure of soil strength with values of 0-10 for soils with low bearing strength such as clays and silts. The standard test for CBR is made on crushed California limestone, with a value of 100 assigned to it.</td>
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<tr>
<td>Asphalt Concrete</td>
<td>A flexible type of road surface made of a mix of aggregate (usually, gravel and recycled asphalt pavement mills) and bitumen</td>
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<tr>
<td>IRI</td>
<td>International Roughness Index</td>
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<tr>
<td>TMS</td>
<td>see Thin Membrane Surface</td>
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<tr>
<td>Thin Membrane Surface</td>
<td>A treatment of a gravel road resulting in a dust-free surface; consists of a layer of bitumen-treated aggregate as the top layer</td>
</tr>
<tr>
<td>MHI</td>
<td>Saskatchewan Ministry of Highways and Infrastructure</td>
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APPENDICES

Appendix 6 accessed online only: PennDOT Cold Mix No. 485 material specifications can be found at