MITIGATING PAVEMENT RUTTING AT INTERSECTIONS

City of Lethbridge - circa 1989

Submitted To:

Centre for Transportation Engineering and Planning

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EXECUTIVE SUMMARY

Pavement rutting at urban intersection locations is a significant issue, and a challenge for those responsible for municipal pavement infrastructure. Balancing the costs associated with the rehabilitation of intersections, while maintaining an adequate level of safety for the traveling public, requires that a collective effort and a made-in-Alberta approach be developed. There is generally consensus amongst those practitioners in pavements technology (agencies, contractors, consultants, and suppliers alike) that there is significant value to the sharing of these experiences with others in the industry.

A review of the literature describing research aimed at mitigating intersection rutting reinforces that this problem is prevalent in many jurisdictions. Much can be learned from the experience of others, but it is also recognized that some conditions with respect to the performance of intersection pavements are specific to Alberta. The need to provide materials which will meet performance expectations over a wide range of climatic conditions, particularly with respect to the high and low service temperatures, has led to the use of relatively soft asphalt cements. The nature of Alberta’s aggregate sources (sand and gravel versus quarried aggregate) may result in characteristics of HMA aggregate that provide lesser rutting resistance, and in some cases agencies are faced with significant cost implications to improve aggregate quality. These factors, along with the continuing increase of truck hauled goods and resources associated with Alberta’s strong economy, has resulted in asphalt concrete pavements (the predominant pavement type in Alberta) being particularly susceptible to instability rutting at intersections.

In recent years Alberta agencies have installed several types of intersection treatments with the objective of assessing and improving performance under in-service conditions. These strategies have included polymer modified asphalt binders, stone matrix asphalt, Superpave mix types, asphalt rubber mixes, Portland cement concrete pavement, roller compacted concrete, and ultra-thin white topping. Although some of these installations have not met performance expectations, many have shown promise in the initial service period, and in many cases longer term monitoring has been planned. Presented in this report is a Summary Project Template, which has been developed and completed for recent projects. It is envisioned that these documents will provide not only the details of intersection treatment installations, but be maintained with ongoing monitoring information. A system by which this information is shared amongst agencies will have future benefits for the selection, design and construction of intersection pavements.
The design of a pavement system for high traffic signalized intersections, simply has to address two issues:

- What is the extent of the pavement, in terms or area and depth, that requires special attention?
- What type of materials should be selected for that area and depth that will satisfy performance expectations?

To date, limited efforts have been focused on understanding the “rutting characteristic” at signalized intersections. A case study has been presented which aids in linking the extent and severity of rutting with vehicle movements. In doing this, “Traffic Condition Zones” have been identified which can be used in the design of intersection pavement systems. In addition, guidance has been provided with respect to the basis for rut measurements with the objective of implementing consistency amongst jurisdictions.

Based on information obtained from a literature review, experiences and practices of Alberta agencies, and the outcomes of an Expert Group Workshop, a guideline methodology for the design of treatments to mitigate urban intersection rutting has been developed. The guidelines provide a rational approach for the selection of a pavement strategy at intersections. The guidelines are generic in that they apply to flexible, rigid or composite pavement systems for both the construction of new intersections and the rehabilitation of existing intersection pavements.

Primary to the guidelines is the establishment of performance criteria specific to the pavement application. This requires that the agency define the performance level expected, and these criteria become the basis for evaluation of various options. Recommended evaluation and design activities include traffic analysis, structural evaluation and assessment of the limits of the intersection treatment (area and depth). Based on this information alternative materials and/or designs are identified. Life cycle cost analysis is carried out for the various alternatives using the typical service lives provided, supplemented by local experience. In addition to life cycle costs, other evaluation criteria (initial costs, risk, industry capability, traffic accommodation etc.) should be assessed and prioritized. Using the weighted evaluation criteria, the design alternatives are ranked and the most appropriate strategy can be selected.

It is envisioned that the guidelines developed will provide agencies and pavement design practitioners with a systematic approach to the design and selection of strategies to mitigate intersection rutting. A system to monitor the ongoing performance of various in-service treatments will enhance the design methodology and optimize the selection of rut mitigating treatments.
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Staff from the Cities of Edmonton, Calgary and Lethbridge, Strathcona County and Alberta Transportation were very cooperative and open with providing information and data, and sharing experiences.

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1.0 INTRODUCTION

Rutting of asphalt concrete pavements due to slow moving and accelerating and decelerating traffic at signalized intersections is a common pavement distress and maintenance problem for many urban centers. The impacts of rutting at intersections is two fold:

1. Safety - of cars, trucks, motorcycles, bikes and other vehicles traveling down the road, and of pedestrians, bikes, wheelchairs/scooters and other vehicles traveling across the road at intersections.

2. Cost to agencies of maintenance and rehabilitation.

Pavements technology has advanced over the last several years in better defining the mechanisms of asphalt concrete pavement rutting and in providing better design solutions to mitigate rutting, e.g. polymer modified and engineered binders, use of aggregates with higher fractures and manufactured sands, Stone Matrix Asphalt (SMA) mixtures, and Superpave mix design methodology and binder selection. However, the mitigation of rutting at intersections has proved to be a significant challenge, more so in northern climates where asphalt concrete mix and pavement design and asphalt binder selection is a balancing act between optimizing high temperature (rutting), low temperature (cracking) and durability performance parameters.

Recognizing there is a strong need to have a more cohesive "made-in-Alberta" approach to solving this problem, the Centre for Transportation Engineering & Planning (C-TEP) commissioned EBA Engineering Consultants Ltd. and the University of Alberta to develop a synthesis of best practices and a common set of research protocols for partnering agencies to continue with their own pavement research.

This project is to focus on the mitigation of instability rutting at intersections in the Alberta context.

What makes intersections special?

- High traffic means significant user disruption and inconvenience during rehabilitation and maintenance.
- Truck traffic is concentrated and channelized with much less wheelpath wander.
• Loading times are very long due to slow vehicle speeds, and the resulting reduction in binder and mixture stiffnesses.
• Additional shear stresses are imposed due to acceleration and deceleration of vehicles.
• Relatively small quantities of specialty or higher cost mixes are required at intersections; therefore special construction management processes are necessary.

![Photo 1.1: Severe Rutting at a Signalized Intersection](image)

This report provides the final deliverable for this research project and includes the following:

• Identification of conditions or factors considered unique to Alberta urban municipalities (Chapter 2).
• Summaries of published literature and other information sources reviewed (Chapter 3).
• Detailed project summaries of special rutting resistance materials used in Alberta municipalities (Chapter 4 and Appendices A and B).
• A case study of a detailed rut survey of an existing major intersection in Alberta (Chapter 5).
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- The introduction of Traffic Condition Zones to describe the combined effects and interaction of traffic speed and braking/acceleration/deceleration effects at urban intersections (Chapter 5).
- A proposed design methodology for mitigating rutting for both the construction of new intersections and the rehabilitation of existing intersections (Chapter 6).

An Expert Workshop, with participants from the Cities of Edmonton, Calgary and Lethbridge, Strathcona County, Alberta Transportation, the University of Alberta and EBA, was held to assess current practices and future needs. The outcomes and discussions of the workshop have been captured and are reflected throughout this report.

It was found that significant developments in the application of new materials and technologies have been implemented by Alberta agencies as experiments, trials or demonstration projects. It is anticipated as longer term performance data is collected, performance and design criteria can be established to refine and fine-tune the findings presented in this report.
2.0 ALBERTA CONDITIONS

Limited research into the high temperature performance of asphalt pavements at urban intersections has been carried out in Canada and the United States. Truck types and configurations, tire pressures and load limits may be similar across jurisdictions in North America; however climatic/environmental conditions, materials properties and pavement design practices may be significantly different. We can learn from the experiences of others in North America and abroad, but need to consider the conditions in Alberta that differ from other jurisdictions when transferring the technology of others to apply to local conditions. Even a "made-in-Alberta" solution may require fine-tuning to meet performance expectations both in Lethbridge and Grande Prairie.

Conditions or factors that could be considered unique to Alberta urban municipalities, that either individually or combined with others could distinguish Alberta from other jurisdictions, are identified and discussed in the following sections.

2.1 Summer and Winter Temperatures

Table 2.1 presents two temperature statistics of interest to pavement technologists for several locations in Alberta and across Canada. The temperature statistics were developed as part of the U.S. and Canadian Strategic Highway Research Program (SHRP and C-SHRP). These temperatures are based on long-term historical air temperature data and represent the average seven-day maximum pavement temperature and minimum pavement temperature the pavement may be exposed to.
Table 2.1: Comparison of PG Binder Design Temperature and PG Binder Grades for Alberta Cities and Other Locations

<table>
<thead>
<tr>
<th>City</th>
<th>High Design Temperature ¹ (°C)</th>
<th>Low Design Temperature ² (°C)</th>
<th>Range (°C)</th>
<th>PG Binder Grade ³</th>
<th>Standard Traffic ⁴</th>
<th>Standing Traffic ⁵</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grand Prairie</td>
<td>46</td>
<td>-39</td>
<td>85</td>
<td></td>
<td>46-40</td>
<td>58-40</td>
</tr>
<tr>
<td>Edmonton</td>
<td>47</td>
<td>-35</td>
<td>82</td>
<td>52-34</td>
<td>52-34</td>
<td>64-34</td>
</tr>
<tr>
<td>Calgary</td>
<td>50</td>
<td>-34</td>
<td>84</td>
<td>52-34</td>
<td>64-34</td>
<td></td>
</tr>
<tr>
<td>Lethbridge</td>
<td>52</td>
<td>-34</td>
<td>86</td>
<td>52-34</td>
<td>64-34</td>
<td></td>
</tr>
<tr>
<td>Medicine Hat</td>
<td>54</td>
<td>-36</td>
<td>90</td>
<td>58-40</td>
<td>70-40</td>
<td></td>
</tr>
<tr>
<td>Vancouver</td>
<td>46</td>
<td>-13</td>
<td>59</td>
<td>46-16</td>
<td>58-16</td>
<td></td>
</tr>
<tr>
<td>Regina</td>
<td>53</td>
<td>-37</td>
<td>90</td>
<td>52-40</td>
<td>64-40</td>
<td></td>
</tr>
<tr>
<td>Winnipeg</td>
<td>52</td>
<td>-33</td>
<td>85</td>
<td>52-34</td>
<td>64-34</td>
<td></td>
</tr>
<tr>
<td>Toronto</td>
<td>54</td>
<td>-25</td>
<td>79</td>
<td>58-28</td>
<td>70-28</td>
<td></td>
</tr>
</tbody>
</table>

¹ SHRP High Design Temperature at 98% Reliability
² Revised TAC Low Design Temperature at 98% Reliability
³ PG Binder Grade at 98% Reliability
⁴ In accordance with AASHTO MP2-02 where the average traffic speed is greater than 70 km/h
⁵ In accordance with AASHTO MP2-02 where the average traffic speed is less than 20 km/h

These data indicate that the high design temperature across selected Alberta cities can range from 46°C in Grande Prairie (similar to Vancouver) to 54°C in Medicine Hat (similar to Toronto). Low design temperatures across selected Alberta cities can range from -39°C in Grande Prairie to -34°C in Lethbridge, significantly colder than -13°C for Vancouver and -25°C for Toronto.

2.2 Use of 150-200A Asphalt Cement

Asphalt cement grade 150-200A is the "work horse" grade used historically for urban paving in Alberta. In Canadian jurisdictions outside of the prairie region, 80-100A (or stiffer) asphalt cement grades are typically used. Relatively speaking, the asphalt cement grade used in Alberta is significantly softer at both high and low temperatures than used by other jurisdictions, primarily to address low temperature pavement performance issues.

Using this relatively soft asphalt cement grade increases the susceptibility of asphalt pavements at intersections to rutting.
2.3 Use of Performance Graded (PG) Asphalt Binders

Asphalt cements produced from heavy Alberta crude sources have long been recognized to provide superior temperature susceptibility properties than asphalt cements from almost anywhere else in the world. The availability of high quality, high viscosity, uniform consistency asphalt cements at relatively low and stable prices have resulted in a lesser impetus for western Canadian transportation agencies to adopt the SHRP PG specification system whereas agencies in other areas of Canada and the United States have fully implemented this system. Notwithstanding this, many Alberta agencies have more recently specified PG or modified asphalt binders on a project-by-project basis for specialty applications such as urban intersections.

Recommended PG binder grades for selected Alberta and Canadian cities based on AASHTO MP2-02 protocols for standard (average traffic speed greater than 70 km/h) and standing traffic (average traffic speed less than 20 km/h) are presented in Table 2.1. The PG binder grades for standing traffic for the selected Alberta cities suggest that modified asphalt binders would be necessary.

2.4 Aggregates

Virtually all paving aggregates processed in Alberta are fluvial or glacio-fluvial deposits – there are no quarries in Alberta that supply the paving industry. Compared to quarried materials, Alberta aggregates tend to be of lower quality in terms of a deficiency in fractured coarse aggregate and an abundance of medium and fine sand sizes. In general, aggregate quality generally improves from north to south.

In order to provide greater rutting resistance, increased processing, screening and crushing is required. In some areas this may require hauling higher quality aggregates from more distant sources.

2.5 Pavement Structure Types

Local experience and performance has resulted in flexible pavement structures with crushed granular base courses being the preferred pavement structure designed and constructed in Alberta. Although some jurisdictions may have designed concrete or soil cement base pavements in the past, they are generally not used anymore.
Except for portions of the Deerfoot Trail in Calgary and Anthony Henday Drive in Edmonton, Portland Cement Concrete Pavements are not used on roadway infrastructure in Alberta. Exceptions to this would be special applications of rigid concrete pavements, roller compacted concrete base and more recently, whitetopping, at urban intersections.

The City of Calgary has constructed fibre-reinforced concrete bus lanes and bus stop pads, e.g., along the Petro-Can block in downtown Calgary where numerous stops exist for a number of frequent bus routes. Calgary has also used similar concrete pavement at a common entrance to Esso/Shell Oil Terminals in southeast Calgary and other locations on a warrant basis. Currently, all bus lay-bys are specified and constructed with concrete pavement. Rutting triggered the need for concrete pavement at these locations.

2.6 Summary

In summary, there are conditions in Alberta that may have on an historical basis, exacerbated the rutting of asphalt concrete mixtures at urban intersections. High summer and low winter temperatures and the subsequent widespread use of relatively soft asphalt cement grade 150-200A, coupled with lower quality aggregates, and ever increasing truck haul of goods has resulted in increased susceptibility of asphalt concrete pavements at urban intersections to rutting.
3.0 LITERATURE REVIEW

One approach in evaluation of effectiveness of different materials in mitigation of rutting at intersections is to review the performance of past projects. Although findings or research by other jurisdictions may not be directly applied to Alberta conditions because of other traffic and environmental conditions, they can help to provide a better understanding of the effectiveness of different materials and procedures under specific conditions.

Published literatures and other information sources related to rutting at intersections were reviewed and summarized. Although the main focus of this literature review was on Canadian practices, findings from other agencies in the United States are presented. Application of different construction materials and design procedures such as whitetopping, ultra-thin whitetopping, roller compacted concrete, stone matrix asphalt, polymer modified asphalt, and Superpave hot mix asphalt were reviewed. Key sources for this literature review included Canadian Technical Asphalt Association (CTAA), Transportation Research Board (TRB), Transportation Research Information Service (TRIS), and National Center for Asphalt Technology (NCAT). Two guidelines, one from Canada which was prepared for the National Research Council, and one prepared for the Asphalt Institute, are summarized.

Title: Study of Bituminous Intersection Pavements in Texas
Authors: J.W. Button, D. Perdomo, M. Ameri-Ghaznon, and D.N. Little
Source: Transportation Research Record 1300, Year 1991

In this study, several intersections were selected from different districts in Texas to investigate the reasons for high rutting in their asphalt pavements. These intersections exhibited more than 0.25 in. of rutting and significant corrugations and flushing, or both, after four or more years of service. A cost comparison, without considering user's cost, between conventional asphalt mixtures, which normally last for two years, and a higher quality pavement mixture with an average service life of 10 years, showed a saving of $4,920 per intersection.

Researchers noticed that rut depths more than 250 ft from intersection were negligible and that ruts become progressively deeper nearer the intersection. The leading cause of intersection pavement failure was binder in excess of that required by the optimum mixture design. In some cases, asphalt content arbitrarily had been increased to...
facilitate compaction. Most of the mixtures studied contained relatively high percentages of natural sand (approximately 30 percent minus No. 40 sieve size material). State specifications for fine graded surface mix allow up to 40 percent passing the No. 40 sieve. Both VMA and air voids in wheelpaths were low which is an indication of very dense gradation or high compaction during construction. Low VMA and extra asphalt content can make the pavement unstable under the heavy traffic loads. Several recommendations were proposed based on findings from this study:

1. Reduce the allowable quantity of sand material and natural sand content (max. 15%) for intersection approach pavements.
2. Use larger maximum-size of aggregate or asphalt modifiers, or both, to increase stiffness at high pavement temperatures.
3. Employ a sequential construction technique in which all intersection approaches within the project are built or overlaid before the remainder of the job with a special tough mix to accommodate the special stresses.

Title: A National Study of Rutting in Hot Mix Asphalt (HMA) Pavements
Authors: E.R. Brown & S.A. Cross
Source: NCAT Report 92-5, Year 1992

The NCAT rutting study was initiated in 1987 to evaluate pavements from all areas of the United States encompassing various climatic regions, containing aggregates of differing origins and angularity, encompassing different specifying agencies and construction practices, and containing a large sample size to make the results national in scope.

Forty-two pavements were sampled from fourteen states across the United States. Rut depth measurements were made across each pavement. Detailed laboratory testing program and post and pre-construction information were analyzed to determine material and mixture properties and to identify procedures that are necessary for the design and construction of rut resistance HMA pavements. Based on data obtained in this study the following conclusions are warranted.

a) Most of the rutting observed from trench cuts of rutted pavements occurred in the top 3 to 4 inches of the HMA. Hence, high quality mixtures should be required in the top two layers.
b) In place air voids contents above approximately 3% are needed to decrease the probability of premature rutting throughout the life of the pavement. In place air void contents below approximately 3% greatly increase the probability of premature rutting.

c) The angularity of the aggregate (plus No. 4) with 2 or more crushed faces and uncompacted voids in the fine aggregates (passing No. 4) are highly correlated to rate of rutting.

d) The amount of asphalt cement is of the primary importance but the properties of the asphalt cement are of secondary importance.

e) A rate of rutting of $0.00023 \text{ inches per (ESALs)}^{0.5}$ delineated between good and rutted pavements for the pavement evaluated.

f) Pavements for heavy truck trafficked pavements should be designed utilizing a 75-blow Marshall mix design.

**Title:** Heavy Duty Asphalt Pavements in Pennsylvania: An Evaluation for Rutting  
**Authors:** P.S. Kandhal, S.A. Cross, and R. Brown  
**Source:** NCAT Report 93-2, Year 1993

Thirty-four heavy-duty asphalt pavements encompassing poor to excellent performance in terms of rutting were evaluated in this study. Based on statistical analysis, recommendations were made to Pennsylvania DOT. The main recommendations from this study were;

a) Coarse aggregate retained on 4.75 mm (No. 4) sieve should continue to have at least 85% of particles with 2 or more fractured faces for wearing and binder courses.
b) Use at least 75 percent crushed sand in the fine aggregate.  
c) Utilize 75 blows per side compactive effort using a rotating base/slanted foot Marshall compactor.  
d) Design mix with at least 4.0 percent air voids.
Title: Evaluation of Urban Asphalt Concrete Rutting  
Authors: Robert Burlie and John Emery  
Source: CTAA, pp. 256-283, Year 1997

This paper presents rutting inspection results of some 30 asphalt pavement sections and detailed field and laboratory evaluation of six severely rutted curb lane/bus bay locations from the Municipality of Metropolitan Toronto. Several interaction factors were identified as the main reasons for high rutting at curb lanes and bus bays such as:

- Hot-mix asphalt materials mix design and/or production not meeting specified requirements.
- Compaction of hot-mix asphalt not meeting specified requirements.
- Early heavy vehicle traffic on asphalt concrete mat before it has adequately cooled.
- Old asphalt concrete binder course(s) susceptible to rutting not removed (milled) to an adequate depth.
- Rutting resistance of the current high stability mixes is not adequate in some heavy traffic situation.

To specify which factors were involved in severe rutting of 30 pavement sections, six high rutted sections were selected for field and lab evaluation. Transverse profiles in rutted areas and in adjacent areas not exhibiting ruts were measured with a Dipstick. In addition, cores were taken from both of these locations; for rutted sections the zone of rutting and condition of other pavement layers were determined by cutting. Bulk and maximum density, air voids, stability, flow, asphalt cement content, aggregate gradation, and crushed content and viscosity and penetration of recovered asphalt cement were determined.

Starting from 1988, Toronto Metro Transportation has adopted several asphalt mixes to mitigate rutting in bus/curb lanes. Laboratory performance test, creep deformation with Nottingham Asphalt Tester were conducted to evaluate the rut resistance of these mixtures: Large Stone Binder Course (LSBC), Stone Matrix Asphalt (SMA), asphalt mixtures with PG binders (PG), and high stability binder course incorporating 10% RAP (HS, 10% RAP). It appears that SMA (0.3% cellulose fiber, 5.3% PMA) has exhibited the best overall potential performance. In addition, the LSBC and high stability mixes with and without RAP all meet the performance objectives.
Some other findings from this study area:

- Heavy commercial vehicle usage, particularly buses, is the main reason for rutting in curb/bus lanes of old pavements that have not been resurfaced with higher performance materials.
- The localized repair of bus bays has often not been successful due to not using high stability mixes, not milling out enough of the old asphalt concrete, and/or not achieving adequate compaction.
- There does appear to be a rutting problem with the resurfacing of some deep strength asphalt pavements, most probably related to not milling the old asphalt binder course out deep enough before resurfacing (minimum of 125 mm high stability mix recommended, preferably 150 mm).
- Some rutting has rapidly developed in isolated instance where the hot-mix asphalt has not met current specification requirements (low in-place air voids or high flat/elongated aggregate content).
- There does not appear to be a rutting problem for composite pavements surfaces after 1988 (only a few constructed or reconstructed) when high stability mixes were regularly adopted, particularly if the old binder course asphalt was removed completely down to the concrete base.
- The use of high stability, rut resistance asphalt mixes (HL 8 (HS), HL 3 (HS), HL 1 and DFC) has been largely successful in terms of overall pavement performance for new, resurfaced, and reconstructed composite and deep strength asphalt pavements.

Title: Hot Mix Asphalt for Intersections in Hot Climate
Authors: P.S. Kandhal, R.B. Mallick, and E.R. Brown
Source: NCAT Report 98-6, Year 1998

A field investigation of rutting near five signalized intersections in Pittsburgh, Pennsylvania indicated the following causes relate to in place HMA:

a) Low Voids in the Mineral Aggregate (VMA),
b) Low air voids, and
c) Use of sub rounded to sub angular sand.
Although the mixes were designed in the laboratory with high VMA and air void content, the asphalt pavements densified significantly in the field to yield very low VMA and air voids. It was felt that the HMA at the intersections should have the following attributes:

a) Should maintain adequate VMA to ensure durability.
b) Should not densify below 4 percent air voids under slow and standing traffic during hot summer days.
c) Should contain stiff asphalt binder to resist creep behaviour.

Based on the documented experiences in the United States with the performance of Stone Matrix Asphalt (SMA) and Superpave HMA mixes, the following recommendations have been made for asphalt pavements at intersections.

- For wearing course use 50 mm thick SMA wearing course with a maximum nominal aggregate size of 12.5 mm.
- For binder course use 50 mm thick SMA binder course with a maximum nominal aggregate size of 19.0 mm.
- For base course use 150 mm thick dense-graded large stone mix with a maximum nominal aggregate size of 25 mm. The mix should be designed either by Superpave mix design method or by Marshall method modified for large stone mixes.

Title: Ten year Performance Assessment of the Lethbridge Tests Pavements Designed to Mitigate Instability Rutting
Authors: C.B. Dawley, B.L. Hogeweide, and A.G. Johnston
Source: CTAA, pp. 273-288, Year 1998

This paper described the results of an assessment of the Lethbridge test pavements after 10 years in service. This initiative, commencing in 1987, had as its primary objective the mitigation of premature instability rutting on arterial roadways in the City of Lethbridge.

Six mixture types, including binder and aggregate composition, were used in this experiment. Table 3.1 provides information regarding asphalt cement types, different rut measurements indicators, and performance ranking of the sections.
Table 3.1: Asphalt Mix Information and Their Performance in Lethbridge

<table>
<thead>
<tr>
<th>Mix Code</th>
<th>Binder</th>
<th>Aggregate</th>
<th>Rut (mm) (Year 10)</th>
<th>Rut Rate (Veh. x10^3)/mm</th>
<th>Rut Rate (ESALx10^3)/mm</th>
<th>Composite Performance Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>150/200A</td>
<td>Control mix 12.5 mm</td>
<td>26.5</td>
<td>297</td>
<td>8.6</td>
<td>6</td>
</tr>
<tr>
<td>B</td>
<td>150/200A</td>
<td>Modified 16 mm</td>
<td>14.4</td>
<td>522</td>
<td>17.7</td>
<td>3-4</td>
</tr>
<tr>
<td>C</td>
<td>PMA II</td>
<td>Modified 16 mm</td>
<td>13.8</td>
<td>972</td>
<td>15.2</td>
<td>2</td>
</tr>
<tr>
<td>D</td>
<td>PMA IV</td>
<td>Modified 16 mm, 30% RAP</td>
<td>14.8</td>
<td>729</td>
<td>11.7</td>
<td>3-4</td>
</tr>
<tr>
<td>E</td>
<td>200/300A</td>
<td>Modified 16 mm, 30% RAP</td>
<td>20.9</td>
<td>608</td>
<td>10.2</td>
<td>5</td>
</tr>
<tr>
<td>F</td>
<td>150/200A</td>
<td>Modified 16 mm, 30% RAP</td>
<td>13.3*</td>
<td>750*</td>
<td>30.8*</td>
<td>1</td>
</tr>
</tbody>
</table>

*Year 9 performance data

The major conclusions of this study were:

1) Significant improvements in rutting performance over mixes used historically (i.e. in the order of 50%) have been achieved with enhancements to aggregate quality, including increased coarse aggregate fracture and utilization of manufactured fine aggregate.

2) Binder stiffness is a significant influencing factor with respect to instability rutting performance, particularly during the initial service period.

3) Mixes incorporating moderate portions of recycled asphalt pavement (RAP) have provided good performance using conventional 150/200A and PMA IV virgin binders. Selection of a softer grade of asphalt binder (i.e. 200/300A) for RAP mixes is not considered appropriate for the Lethbridge arterial roadway system.

4) Although these alternative mixtures typically had VMA values less than industry standards, the consideration of desirable design air voids and adequate film thickness, combined with excellent field compaction, has provided good durability performance.

5) Post-construction densification should not be a significant contributor to rut development provided adequate compaction is achieved in the field.

6) Moderate to severe rutting is typically confined to a relatively short distance at signalized intersections, which indicates that consideration of optimal construction techniques and materials selection are necessary to provide adequately performing pavements in these "critical" areas.
Title: Performance, Analysis and Repair of Ultra-Thin and Thin Whitetopping at Mn/Road
Authors: Julie M. Vandenbossche and Aaron J. Fagerness
Source: Minnesota DOT, Year 1999

In 1997 the Minnesota Department of Transportation constructed several thin and ultra-thin white topping test cells at the Minnesota Road Research (Mn/Road) facility. The test cells varied in overlay thickness from 76 mm to 152 mm. The joint spacing of these cells ranged from \(1.2 \times 1.2\) m to \(3.1 \times 3.7\) m. After 3.5 years of existence and 4.7 million ESALs, both temperature and load related distresses were observed on the 76 mm thick sections. There were no noticeable distresses in the 152 mm thick sections. Typical distresses included corner breaks, transverse cracks, and reflective cracks.

Different techniques for repairing ultra-thin whitetopping were investigated. It was determined that using a milling machine with tungsten carbide teeth to remove the concrete greatly reduced the time required per repair. Various techniques were also used to determine reflective cracking. This included the use of various bond-breaking materials and full-depth sawing at strategic locations along the longitudinal joint to prevent cracks from propagating into adjacent panels as misaligned transverse joints. Four of the six sections had Present Serviceability Index (PSI) values greater than 3.5 before the repairs, showing a good level of performance has been maintained after 4.7 million ESALs. The two sections that exhibited the largest drop in the PSI were the overlays with \(1.2 \times 1.2\) m panels. The importance of choosing an optimum panel size was exhibited. It has also been shown that, when necessary, it is easy to repair ultra-thin whitetopping sections.

Title: Life Cycle Cost Analysis for Ultra-Thin Whitetopping- Effectiveness in British Columbia's Lower Mainland
Source: St. Michel Consulting Inc., Year 1999

This report outlines the results of a Life Cycle Cost Analysis study of Ultra-Thin Whitetopping (UTW) for 150 intersections in the City of Surrey, BC. The study evaluates the cost effectiveness of competing rehabilitation strategies using five different life cycle costing philosophies:

- Maximizing the net road use cost saving (i.e. Road user cost saving minus direct agency costs),
• Comparing direct agency costs to road user cost savings,
• Minimizing an agency's direct agency costs,
• Maximizing the resulting pavement quality,
• Comparing direct agency costs to resulting pavement quality.

Of the 150 intersections studied, it was found that the UTW option was the most cost effective by all five life cycle costing philosophies for 36 intersections. UTW was not cost effective based on any of the five philosophies at 41 intersections. For the remaining 73 intersections, UTW was most effective by some but not all of the five different philosophies. Whether or not UTW will be effective, depends on several factors including existing asphalt thickness, amount of truck traffic, base thickness, subgrade strength, and pavement condition. However, the most important factors existed asphalt thickness and amount of truck traffic. The graph below was introduced as a rule of thumb for determining sites where an UTW option is most likely to be cost effective.

![Guidelines for UTW Effectiveness in the BC Lower Mainland](image)

**Title: Repair of Ultra-Thin Whitetopping Pavements**  
Authors: Chung- Lung Wu, Shiraz Tayabji, and James Sherwod  
Source: Transportation Research Record, No. 1778, pp. 164-173, Year 2001

The first Ultra-Thin Whitetopping (UTW) experimental project in the USA was constructed on the access road to a waste disposal landfill in Louisville, Kentucky, in September 1991. In this test section, two concrete slab thickness (51 mm and 89 mm) and two joint spacing (0.6 m and 1.8 m) were used. The Louisville UTW pavement has
performed well, carrying many more traffic loads than predicted by design procedures available at that time. After the success of the Louisville UTW project, many other states, including Tennessee, Georgia, North Carolina, Kansas, Iowa, Pennsylvania, New Jersey, Colorado, Missouri, Mississippi, Virginia, and Florida have constructed and are currently evaluating UTW projects. It has been estimated more than 150 UTW pavements have been constructed in the past decade.

**New Jersey DOT (NJDOT) Experiences**

This UTW test section consisted of three panel dimensions (0.9 m, 1.2 m, and 1.8 m), with a total project length of 275 m. Because of geometric limitations, the test pavements were constructed in two 3.7 m wide segments, with a construction joint between them. Data obtained from cores indicated an average UTW overlay thickness of 97 mm, ranging from 74 to 117 mm. Average existing asphalt thickness (after milling) was 168 mm, ranging from 132 to 188 mm.

NJDOT evaluated the UTW test section in 1997. It was reported that panels with 0.9 m dimensions performed the best and panels with 1.8 m dimensions had the most severe distresses. Most of the distresses occurred along the longitudinal constructing joints, which was subjected to frequent truck crossing. Load transfer across transverse joints was above 80 percent for most joints.

In September 1998, NJDOT identified areas with severe distresses that needed corrective work (about 466 m² total). In most cases, the center section of the pavement was identified as needing replacement. The original 1.8×1.8 m panels were reduced to 0.9×0.9 m and joints were sawed 25 mm deep by 3.2 mm wide.

**Iowa Experiences**

This project is located on Iowa Highway 21 in Iowa County and consisted of 41 UTW test sections. Major variables included in the construction of the test sections were slab thickness, panel dimension, asphalt pavement surface preparation and the use of fibers in the concrete. In 1998, a weigh in motion device recorded an average of 40 and 20 ESALs per day on the northbound and southbound lanes respectively.

All test sections have performed well to date with only minor surface distress being noted after 3 years of service (fewer than 2 percent of the slabs had visible distresses). Only a limited amount of repair work has been performed on the test sections, essentially involving panel removal and replacement.
Minnesota Experiences
Incorporated as part of the Minnesota Road Research test facility, a UTW project was constructed in the fall of 1997 on I-94. Experimental design variables for this test project included three levels of concrete slab thickness (76, 102, and 152 mm), three levels of panel dimensions (1.2x1.2, 1.5x1.8, and 3.1x3.7 m), and the use of different fibers in the concrete. I-94 is a heavy trafficked roadway with about 1 million ESALs per year. The purpose of this research was to evaluate the UTW as an overlay alternative for high-volume roads. Some cracking was observed in some of the test sections after 1 year of being opened to traffic but, in general, all sections had performed well up to that time.

Tennessee Experiences
The first UTW project in Tennessee was constructed in Nashville on May 1, 1992. The as-built panel thickness averaged 64 mm to 76 mm with joint spacing of 1.5 m. In Tennessee, the use of UTW has moved beyond its experimental status to become an accepted alternative to hot-mix asphalt in certain applications.

Florida Experiences
UTW pavements were chosen to rehabilitate the deteriorated asphalt pavement located at the Ellaville truck weight station. The truck weight station is located along I-10 in northern Florida, with more than 1,400 trucks passing each day. The existing asphalt pavement consisted of a 76 mm to 178 mm asphalt layer on a 279 mm stabilized limestone base. The heavy trucks had caused the asphalt pavement to rut severely, with rut depths ranging from 8.9 to 45.7 mm.

The UTW pavement consisted of six different sections. Design variables were two levels of slab thickness (76 mm and 102 mm), two levels of panel dimension (1.2 m and 1.6 m), and the use of fibers. The fiber concrete contained 1.8 kg of fibrillated polypropylene fibers per cubic meter of concrete. Corner breaks were observed on several panels after the pavements were opened to traffic. A likely cause of these cracks might be the late sawing of joints. Consequently, several panels with wide cracks were removed and replaced.
Title: Evaluation of Ultra-Thin Whitetopping
Source: Missouri Department of Transportation
Research, Development, and Technology Division, Year 2001

An asphalt intersection with a history of rutting and shoving problems was selected to
determine whether Ultra-Thin Whitetopping (UTW) would be a viable alternative to
placing a bituminous overlay.

The UTW project consisted of cold milling 3 inches of the old asphalt surface, placing a
3-inch concrete overlay, and sawing the concrete overlay into 3×3 ft squares using early
entry saws. The project was completed during a 60-hour period using a high-early
strength concrete mix, gradation "F" Bethany Falls limestone and fibrillated
polypropylene fibers. The design strength of 3500 psi was monitored using a maturity
curve and was achieved prior to 14 hours after placement.

Falling Weight Deflectometer (FWD) testing was performed prior to asphalt milling and
after UTW overlay placement. The FWD testing indicated a dramatic decrease in both
the radial strain and the vertical strain following the overlay. The freeze/thaw resistance
was lower than expected, with an average durability factor between 60-65 after 300
cycles. Chloride permeability tests placed the UTW in the moderate range. The air void
analysis demonstrated that the air void system contained proper sized and spaced air
voids that were evenly distributed through the concrete overlay. The concrete bond to
the milled asphalt surface was low, but all cores separated below the concrete and
asphalt interface. Visual surveys found no cracking in the concrete overlay until the
three month survey. Most of the cracking was found in an area where the concrete was
less than 3 inches thick. Based on 6 months of service, the UTW overlay seems to be a
viable alternative to an asphalt overlay on an intersection where rutting and shoving has
become a problem.

Title: Concrete Pavements in Canada, A Review of Their Usage and Performance
Authors: Tim Smith, Susan Tighe, and Rico Fung
Source: Annual Conference of the Transportation Association of Canada, Halifax, Nova
Scotia, Year: 2001
Intersection at Britannia and Dixie Roads in Mississauga, Ontario
The first controlled Canadian Ultra-Thin Whitetopping (UTW) project was constructed in August of 1995, in Mississauga at the intersection of Britannia and Dixie Roads. This intersection is located in an industrial area on the west side of the Pearson International Airport. One leg of this intersection had severely rutted after 8 years of heavy truck traffic. The rut depth was measured to a maximum depth of 175 mm from the top of the heaved asphalt to the bottom of the rut. Initially, approximately 100 mm of asphalt was to be removed and replaced with the same thickness of concrete. Due to the poor condition of the existing asphalt, the actual milling depths and resulting concrete thickness ranged between 118 to 166 mm based on the cores taken from the project. Two lanes were constructed with a polypropylene fibre reinforced concrete mix, saw cut at a 1.6 m square joint spacing. A third lane was constructed without fibres and a conventional Ontario Provincial Standard Specification (OPSS) 30 MPa mix. The intersection is in good condition today without any major distress and little or no maintenance. Since then, four more UTW projects have been constructed in the City of Brampton along a busy thoroughfare, Queen Street East, to address the rutting problem caused by both heavy commercial and transit traffic.

Intersections in Brampton, Ontario
The Brampton UTW projects consisted of 100 mm of high early strength concrete with a minimum 20 MPa compressive strength in 24 hours, joint spacing ranging from 0.5 m to 1.0 m and the use of a horizontal vibrating screed for consolidation and proper bonding. Early sawing of the joints was crucial to control the early cracking potential and the use of synthetic fibres provided some residual tensile strength and fatigue resistance to the pavement. To date, field performance of UTW has demonstrated that it is a good choice for fast track repairs and provides a durable surface in areas where rutting and shoving is a concern.

Campus Station Bus Stop in Ottawa, Ontario
Recently, UTW technology was applied to one of the transitway stations in the Capital City of Canada, Ottawa. This transitway is an exclusive bus corridor, with stations dotting the routes providing rapid transit service to the population across the Ottawa-Carleton Region. Initial construction on the transitway was completed using asphalt concrete as the paving material. Buses, including articulated models, travel in excess of 70 km/h and brake from this high speed when stopping at the stations. This tremendous speed and braking force have caused severe rutting of the asphalt pavement under the wheelpaths and in some cases have shoved the asphalt over the
curb creating an unsafe condition. The Campus Station had been recently rehabilitated, in 1997, with a mill and overlay using Stone Matrix Asphalt (SMA). Within two years of the SMA rehabilitation, the rutting in the wheelpaths was severe enough to require additional rehabilitation.

The bus volume in this station amounts to 200 buses/hour/direction and the scheduled daily trips are approximately 1200 per direction. UTW was chosen as a possible solution for rehabilitating the severely rutted and shoved asphalt at Campus Station, which would restore the safety and ride requirements. A layer of 75 mm and 100 mm of UTW was placed in the north and southbound bus/curb lanes respectively in early June 2000, with a saw cut joint spacing of 0.75 m in the northbound lane and 1.00 m in the southbound lane. A 24-hour compressive strength of 20 MPa was specified and the actual test strength was an average of 27 MPa.

Bus Stop in Vancouver, British Columbia
A demonstration UTW project with no contraction joints has also been constructed at a rutted and shoved asphalt bus stop on West 41st Avenue near West Boulevard in Vancouver, BC. The reconstructed area is 3.2 m wide and 21 m long. The existing asphalt pavement thickness ranged from 229 mm to 248 mm from the site investigation. The mill depth of rutted asphalt was 92 mm to 95 mm and was replaced with the same thickness of high volume synthetic fibre reinforced concrete. The remaining asphalt had a minimum thickness of 134 mm. The joints were eliminated to minimize the paths for potential water ingress into the pavement, in particular, due to Vancouver's frequent wet weather. Class C-1 exposure was specified for the UTW concrete with 7 kg/m^3 of Grace Structural Fibre. The minimum compression strength requirements were 20 MPa at 2 days and 35 MPa at 28 days. A cement/sand bonding slurry, with a 0.40 water/cement ratio was placed on the milled asphalt surface immediately prior to the placement of UTW concrete.

Title: Stone Matrix Asphalt (SMA), A Solution to Mitigate Rutting at Heavy Intersections and Bus Lanes
Authors: Paul Anderson, Keith MacInnis, and Gary Moore.
Source: CTAA, pp.199-218, Year: 2002

A site was selected by the city of Hamilton to evaluate the use of SMA to mitigate the rutting in high traffic areas, and to assess the potential of SMA for use on proposed multi-lane expressway.
In the fall of 1999, SMA was placed on Burlington Street between Victoria Avenue and Wellington Street. This section accommodates a high volume mix of multi axle tanker trucks, concrete trucks, and mixed tractor-trailer trucks. The traffic count for the Burlington Street section is approximately 13,000 AADT with 15% trucks. The conventional Hamilton surface course asphalt mix placed on Burlington Street had experienced severe rutting within a few years of paving. Subsequent to the successful completion of the Burlington Street project, in the fall of 2001, SMA was placed on James Street between King Street and Hunter Street in downtown Hamilton. The road section handles a high volume of mixed traffic which includes concentrated bus traffic in the west curb lane consisting of city buses and GO transit buses.

The Burlington Street section exhibited surface distress within a year of paving, especially at the Victoria Avenue-Burlington Street intersection where severe shoving and rutting were noted. An investigation of pavement conditions included visual assessment of the site as well as the procurement of asphalt slabs and asphalt cores. The findings of the pavement investigation indicated that pavement deformation was occurring primarily in the HM-3 HD wearing course.

The SMA test section included the three westbound lanes of Burlington Street from Victoria Avenue westerly to Wellington Street, as well as the intersection of Burlington Street and Victoria Avenue. The contractor on the project milled off the existing surface course the day before the SMA mix was placed. On May 2000, the rut data of SMA pavement at Burlington Street site, measured by ARAN, was to a maximum 11.2 mm.

The pavement section of James Street between King Street and Hunter Street was rehabilitated and paved in late June 2000. The pavement rehabilitation involved cold milling and removal of existing asphalt down to the underlying concrete base, concrete base repairs and paving with 60 mm of City of Hamilton HL-8 HS binder course and 50 mm of HM-3 HD surface course. Rutting of the asphalt in the west curb lane began shortly after HM-3 HD paving was completed. The requirements for City of Hamilton HL-8 HS are the same as for Ontario Provincial Standard Specifications (OPSS) HL-8 with additional requirement that aggregate be 100% crushed quarried bedrock (HL-8 HS and HM-3 HD requirements).

An investigation of the roadway was conducted in the fall of 2001. Visual inspection indicated that there was severe rutting and asphalt distortion in several areas of both wheelpaths of the west curb lane of James Street. Cores taken from the roadway
confirmed that pavement deformation was limited to the HM-3 HD surface course and that there was no deformation of HL-8 HS binder course. Based on the successful completion of the Burlington Street SMA test section, the City of Hamilton decided that rehabilitation of the curb lane on James Street from King Street to Hunter Street should be completed with SMA.

Title: MnROAD Mainline Rutting Forensic Investigation, Final Report
Authors: Ronald Mulvaney and Benjamine Worel
Source: Minnesota DOT, Year 2002

Findings from MnROAD regarding rutting of 14 hot-mix asphalt mainline test cells during the summer of 1998 and 2001 are summarized as follows:

- Majority of rutting occurred in the upper lifts of asphalt hot mixes and they have not extended down into the granular base or subgrade materials.
- The crown of the road also seems to play a role in the rutting experienced at MnROAD. Cells that were constructed with quarter-crowns have deeper ruts in the right wheelpath while cells constructed with a centreline crowns have deeper ruts in the left wheelpath.
- Cells constructed with the harder AC-20 (PG 64-22) asphalt binder rutted an average of 59% less in the driving lane and 24% in the passing lane than the cells constructed with the softer AC 120/150 (PG 58-28).
- A strong correlation has developed between the Marshall Mix Design methods and the amount of rutting. The 50 blow mixes are showing moderate rutting, and the leaner 75 blow and Gyratory mixes have developed the least amount of rutting.
- Pavement thickness does not seem to play a major function in the role of rutting. Both the thicker 10-year designs and thinner 5-year designs are experiencing nearly the same amount of rutting when similar asphalt PG grades are compared.
- On the mainline test cells where the asphalt thickness is sufficient to support the traffic loading, the base materials does not appear to have any effect on the amount of rutting.
- The rutting in the passing lane (left lane) has 51% less rutting than the driving lane (right lane) indicating that traffic has an impact on rutting, but it is not linear with the amount of traffic ESALs.
- Two cells (#20 and #23) were micro-surfaced because the rutting levels were nearing unsafe condition for interstate pavement. Initially the micro-surfacing
reduced the amount of rutting from 50% to 70%. Three years after initial application in 1991 the rutting in cells #20 is still down by over 40% and cell #23 by 50%.

- 50% of rutting has incurred in the first two years after construction, concluding the rutting is not linear with time or traffic level.

Title: Mechanics of Instability Rutting In Hot Mix Asphalt Pavements
Authors: Bjorn Birgisson, Reynaldo Roque, Christos Drakos, Marc E. Novak and Byron E. Ruth
Source: CTAA, pp. 136-152, Year 2002

Tire contact stresses are greatly influenced by the structural and design characteristics so it is necessary to understand the mechanism that induces rutting with in the surface layer. Several major near surface stress factors including truck tire, aggregate structure, and compaction characteristics were discussed in this study.

It has been shown that radial truck tires induce high transverse contact stresses on pavements, which may result in high surface shear stresses. A layered elastic analysis program BISAR and the finite element code ADINA were used in modeling the two and three dimensional effects of measured tire contact stresses in typical pavement configuration. Modern radial truck tires induced higher contact stresses as these tires have tendency to withstand higher loads and pressures. Higher shear stresses were calculated near and under the left most rib of both radial and bias-ply tires for one typical flexible pavement but the magnitude of shear stress near the surface developed under the bias-ply tire was lower than the radial tire because of the tire configuration. The measured tire-contact stresses showed that the stress distribution under truck tires is complex and non-uniform. Analysis performed with BISAR and ADINA provided that combination of high magnitude of shear stresses, low confinement at the edge of loaded area, and outward direction of the maximum shear stresses contribute to permanent deformation in the pavement. It was also concluded that factors influencing the amount of rutting or contributing to the pavement's resistance to failure have not been clearly identified.

In addition laboratory evaluations for coarse aggregate mixtures showed that adequate compaction is required to develop aggregate-to-aggregate interlocking which results in better rutting resistance whereas fine aggregate mixtures tend to be governed more by overall aggregate structure, composition of mastic, and the air voids level. In a typical field compacted mixture, there are significantly higher air voids in the near surface.
region of pavement and when combined with large predicted shear stresses from measured radial truck tire contact stresses, may lead to shear instability in the upper 50 mm of the pavement during hot summer conditions.

**Title: Stone Matrix Asphalt (SMA) – Hot Mix for High Stress Pavement Applications**  
Authors: Laverne J. Miller and Param Dhillon  
Source: CTAA, pp. 253-270, Year: 2003

This paper presents the practical experience in designing, production and layout of SMA on the southbound lanes of Huron Church Line (Highway 3) in Windsor Ontario and shows that SMA mix design exhibited excellent resistance to rutting. This section of road has six lanes; three in each direction connecting Hwy 401 to the United States. Since it is the main entry point, traffic is very heavy, slow moving with lots of stops and goes. Due to the heavy traffic of 30,000 vehicle per day per direction and 25% trucks, it was a big challenge to road builders for many years to overcome the distresses like rutting and cracking. Keeping in view the use of SMA and its benefits, it was decided to construct this section of pavement with SMA. The pavement structure of this site is a composite design and was constructed with 250 mm PCC rigid base and overlaid with two 45 mm lifts of HMA.

FWD testing confirmed adequate structural support of the existing pavement. The SMA mix design consisted of 5.7% design asphalt content (PG 70-28) with 12.5 mm trap rock coarse aggregate, trap rock fine aggregate, mineral dust, and cellulose–Class 70–Fibers. Mix requirements were achieved with 4% air voids and 17.4% VMA using the Superpave Gyratory Compactor (SGC). Two test procedures, Superpave Shear Tester (SST) and Asphalt Pavement Analyzer (APA), were employed to evaluate the rutting susceptibility of the mixture. Both test results indicated the SMA mix design has excellent resistance to rutting. The estimated rut depths from Repeated Shear at Constant Height (RSCH) and APA were found to be 0.84 mm and 1.52 mm respectively.

A trial section similar to Huron Church Line in terms of thicknesses and type of pavement structure was selected to establish protocols for mix and confirm the quality of SMA. This designated trial section, Dougall Avenue, was constructed with two lifts of SMA mix over a rigid base. Based on the laboratory test results, the mix design was slightly amended to use an asphalt content of 5.6%. It was also decided that for the
Huron Church Line, only static mode of compaction would be used, as the vibratory rollers did not improve the achieved compaction on the trial section.

For the construction of the Huron Church Line, it was decided to raise the crown by about 20 mm to accommodate 110 mm of SMA mix at centre and 90 mm at the edges. Prior to placing the SMA, the existing asphalt layer was removed completely by milling and the PCC base exposed; approximately 3,500 tonnes of SMA hot mix was placed in continuous 18 hour session to complete the job. A material transfer vehicle was used to avoid segregation and compaction was carried out with a 10 tonne dual steel drum roller operating in static mode. The quality assurance of mix was carried out using both Superpave and Marshall methodology and results indicated the SMA mix was consistent and met all the requirements of the project. The performance is being continuously monitored and to date Huron Church Line project performing very well. It seems that SMA mix can mitigate rutting under the most severe traffic applications through proper selection of materials, high quality of manufacturing process with detailed attention to each phase during mixing and construction.

Title: Whitetopping and Hot- Mix Asphalt Overlay Treatments for Flexible Pavement, Minnesota Case History
Authors: Tom Burnham and David Rettner
Source: Transportation Research Record 1823, Year 2003

The main objective of this study was to evaluate the performance and cost effectiveness for two hot mix asphalt and four whitetopping overlay test sections after nine years of service. These sections were constructed on low volume road TH 30 in southern Minnesota in 1993. In 1992 the AADT was 385 with 20 years projected value of 710 and the heavy commercial AADT in 1992 was 90, with a 20 years projected AADT of 110. The project consisted of two HMA and four Whitetopping test sections constructed over approximately 18-km.

The first two sections, TS-1 and TS-2, were designed to compare the performance of typical medium (76 mm) and thick (127 mm) HMA overlays. Sections constructed with whitetopping, TS-3 to TS-6, had thicknesses of 127 mm except TS-5, which had designed thickness of 152 mm. During the construction of the whitetopping overlay, variations in thicknesses from 133 mm to 248 mm were observed as the whitetopping was directly applied to the distressed surface of HMA. Since the construction of these sections, four field reviews have been completed in March 1994, September 1994, June
1999, and June 2002. Initial reports showed generally a good ride with small number of random transverse cracks in the whitetopping sections. The recent observations (2002) showed that all the sections are performing well.

An IRI value 1.52 m/km is quite satisfactory after 9-year of service for HMA and there is no sign of rutting, as traffic volume is very low on these sections of pavement.

Whitetopping sections also showing very good performance after this much service except some longitudinal cracks near the centre line of some panels of control section. This can be attributed to construction problems rather than design variables, as unfortunately, the as-built 28-day compressive strength of 20.5 MPa was lower than design value 26.9 MPa. IRI of the whitetopping sections is 0.94 m/km except TS-3, which had IRI value 1.01 m/km.

Another important aspect of this study was the cost differences between HMA and Whitetopping overlays; comparison of costs including the routine maintenance costs from 1993 to 2001 shows the most economical section on an annual basis is whitetopping TS-3 section while HMA TS-1 section would have the lower annual cost after discounting the routine preventive maintenance. Overall this study shows whitetopping is an economical and good rehabilitation method for low volume roads.

**Title: Performance Analysis of Ultra-Thin Whitetopping Intersections on US-169 Elk River Minnesota**

**Author:** Julie M. Vandenbossche,

**Source:** Transportation Research Record 1823, Year 2003

To gain experience with both design and performance of Ultra-Thin Whitetopping (UTW), Minnesota Department of Transportation (MnDOT) constructed three consecutive intersections on US-169 in 1997. Two types of panel sizes were used during the construction of these sections. The concrete used on Jackson Street and Main Street contained polypropylene fibres while for School Street the concrete contained polyofin fibers. The Jackson and Main Street intersections had 1.2×1.2 m panels and School Street had 1.8×1.8 m panels.

Before the construction of the overlay, a distress survey was performed on each of the 244 m sections. Severe rutting of 32 mm was observed as a result of stopping and starting of heavy trucks at each intersection. Traffic volume AADT was 16,000 in 1997
with 8% trucks and 49% of these trucks are categorized as five-axle semi trailers. The first 240 m of each intersection was overlaid with 75 mm thick concrete while the remaining 3.7 m on the north end of each section was milled and filled with a depth of 203 mm. It was observed that depth of 203 mm successfully prevented any distress due to the vehicles came off from HMA pavement onto the UTW.

The test sections on US-169 were in service since September 1997. Some cracks have been observed in the UTW test sections constructed with 1.2×1.2 m panels. The School Street test section that has 1.8×1.8 m panel size was also distressed with some corner breaks but very little cracks were observed in this section of pavement. The results from the strain measurements and cores indicates that the HMA is raveling at a faster rate along the joints. The lane to shoulder joints are most difficult to keep sealed, therefore HMA along these joints are more susceptible to raveling.

Title: Selection of Milling Depth for Asphalt Pavement Rehabilitation
Authors: Zhong Wu, Mustaque Hossain, and Andrew J. Gisi
Source: Mid-Continent Transportation Symposium Proceedings, Iowa State University, 2000

Kansas DOT's current practice of milling of asphalt pavement before inlaying was based on engineering judgment and was determined so that the ratio of mill and inlay depth to the remaining milled pavement thickness must be higher than 1.

Nine mill-and-inlaid pavement sections, selected on six difference routes in Kansas, were tested with an FWD after milling, and after inlaying. Laboratory fatigue tests were also done on AC beams sawn from four test sections. The results show that in order to achieve higher fatigue life, the mill and inlay thickness should be at least 1.25 times the thickness of the remaining AC pavement layer.

Title: Trends in the Use of Roller Compacted Concrete Pavements in Canada
Author: Robert A. Serne
Source: Canadian Portland Cement Association

This paper covers the development and use of Roller Compacted Concrete (RCC) pavements in Canada since its inception in 1976. Along with specialty applications such as RCC inlays for intersections, and innovative construction technique for
subdivision residential and arterial roadways, examples exist where RCC has been used exclusively for reconstruction of truck lanes.

In 1993, the first section of RCC for "Fast-Track" was constructed in Edmonton Alberta on Yellowhead Trail. This six-lane freeway carries 65,000 ADT; all the major intersections exhibited severe rutting. Westbound approaches to 122 Street and the Yellowhead Trail was milled out to a depth of 250 mm and overlaid with 200 mm of RCC and an immediate bituminous 50 mm cap over a 48-hour period.

In 1995, Fort McMurray was concerned about the rutted truck/bus lane climbing the 8% grade southbound from the city centre on Hwy 63. The 1.6 km, 200 mm RCC inlay of the lane was constructed in one day. This roadway serves the multi-billion dollar oil sands operations 35 km from the city.

In 1996, the B.C. Ministry of Transportation and Highways selected RCC as a 200 mm inlay for reconstruction treatment for five major intersections serving Terrace. Four of these rutted intersections were "mainstreet" locations (two abutting the downtown bridge over multi-lane railroad tracks), and the remaining location was at a "T" highway intersection. Traffic control was maintained during the construction period.

In 1996, the City of Fort St. John, in northeast British Columbia, chose to build an exposed 125 mm RCC pavement to rejuvenate the parking lot for their recreation centre. This project became the largest RCC overlay in Canada.

**Title: Rut Mitigation Techniques at Intersections, Best Practices**
National Guide to Sustainable Municipal Infrastructure
Source: National Research Council (NRC), Year: 2003

This guide provides an outline for the cost effective, technically sound mitigation of asphalt pavement rutting at intersections. The main focus of this guide is mitigation of asphalt concrete instability rutting. Alternative pavement types such as Portland cement concrete (PCC), Roller compacted concrete (RCC) and interlocking concrete pavers were also considered. It was emphasized that pavement intersections may need to be specified, designed, and constructed differently than regular asphalt pavements to achieve the desired performance of asphalt intersections. Some important recommendations from this report are presented here:
Important considerations for good rut resistance are to design the mix so the load is carried primarily by the stone skeleton, the selection of coarse and fine aggregates with characteristics that develop good inter-particle interlock and shear strength, and incorporate the proper asphalt binder grade and optimum content for durability and adequate air voids. Superpave mix design procedure and material requirements were also recommended as this method recognizes the impacts of higher stress and heavy vehicle speed through the gyratory mix design method.

An alternative pavement type such as Ultra-Thin whitetopping is recommended for parking areas, bus bays, and intersections and flexible pavements are recommended lower volumes of heavy traffic. Short slab panels, typically square, are recommended to reduce bending and thermal stresses, also it is very important to saw the joints in a timely manner a minimum of 25 mm deep cuts. Early-entry saws are required to prevent cracking.

Municipal agencies support the need for a best practice to mitigate rutting techniques at intersections. All agencies reported they have severe problems with rutting and their arterials and collectors roadways. Small municipalities indicated rutting occurs between 3 m and 30 m before intersection stop bars; medium size municipalities observed rutting is present 10 m to 30 m before stop bars and finally large municipalities indicated 20 m to 60 m before stop bars.

Traffic composition and volume are also key factors as the majority of responses reported rutting is occurring where AADT is between 15,000 to 45,000 with trucks and buses involvement. It is very clear municipalities and agencies need a standard approach for the identification, evaluation, and rehabilitation of high stress rutted intersections. Implementation of this best practice as recommended will result in longer life with significant construction and maintenance cost savings to municipalities.

**Title: Intersection Strategy**
Authors: Dwight Walker and Mark Buncher
Source: Asphalt Institute, http://www.asphaltinstitute.org/hot/interstrat.htm

This guideline, provided by the Asphalt Institute, presents three steps including structural evaluation, material selection, and construction as strategies for intersection pavements. Some highlighted topics from this report are summarized here:
• Intersection pavements need to be treated differently than regular road pavements.

• Trenching, coring, and rut measurements could be used to assess possible structural or surface layer problem.

• As a safety factor, some states routinely increase the design thickness at intersections by as much as 25%, which pays big dividends in term of reducing future user delay costs.

• For slow moving design loads, the binder should be selected one high temperature grade to the right (one grade "warmer"), such as PG 64 instead of PG 58. For standing design loads, the binder should be selected two high temperature grades to the right or two grades "warmer", such as a PG 70 instead of a PG 58.

• Performance testing is strongly recommended. Several devices are available to perform this evaluation. One of the best, and the least common, is the Superpave Shear Tester (SST). Other equipment that can be used includes the Asphalt Pavement Analyzer, the Hamburg Wheel Tracking device, and other loaded wheel testers. Whether or not strength testing equipment is available, the designer should give careful thought to the candidate mixture.

• Mixes with marginally low VMA can be sensitive to relatively small changes in the total fluids content (asphalt binder, moisture, and fine filler). Small increases in fluids can then cause these mixes to be subject to rutting or shoving. On the other hand, mixes with too high VMA will produce thick asphalt coatings on the aggregate particles, which can act as a lubricant, allowing the particles to reorient themselves under traffic, which leads to rutting, shoving or bleeding.

• Selection of the appropriate aggregate blend is even more critical than binder selection. The aggregate must have high internal friction to develop the degree of interlock to resist shearing or rutting. Tough, durable aggregate is necessary.

• For mix design, Superpave Gyratory Compactor (SGC) is well suited for laboratory mix design compaction since it produces a reasonably comparable aggregate particle orientation to that observed in roadway cores. One of the higher gyratory compactive levels ($N_{design} = 100-125$) should be used. If a SGC is not available, a
Marshall compactor may be used. Seventy-five or more blows of compactive effort should be applied.

- One solution to the low-volume project barrier is combining many inter-sections into one project. This may require several districts or jurisdictions getting together and combining inter-sections that need rehabilitation into one project. For many roads with a series of closely spaced intersections, it would be logical to use the improved mix for the full length rather than alternate with a series of intersection strips and regular strips.

- Many agencies are reluctant to write a special specification for their intersection, and many contractors do not want to do a small volume project that requires special attention and possibly different materials.
4.0 CURRENT PRACTICES OF ALBERTA AGENCIES

4.1 Overview

The following Alberta agencies were contacted and interviewed to capture and document recent and current practices with respect to mitigating rutting at urban intersections:

- City of Edmonton
- City of Calgary
- City of Lethbridge
- Strathcona County
- Alberta Transportation

In terms of planning intersection rehabilitations, funding is a primary consideration for Alberta agencies. Balancing the need to maintain an adequate level of service and safety, and providing legitimate enhanced solutions to intersection rutting is a challenge with available funds. The cost of paving intersections is as much as 50% higher than typical mainline paving. The issues associated with traffic accommodation are significant with respect to intersection rehabilitation. In some cases this type of construction is scheduled for fall to avoid the problems associated with allowing traffic on newly paved surfaces.

The situation for most agencies is that the pavements are generally found to be structurally adequate, and instability rutting is the primary cause for intersection rutting. Most agencies concur that although general “rules of thumb” have been used in the past (e.g. 50 mm replacement, replace two times the rut depth), there is significant value to conducting a proper evaluation and design. For example, the fact that no accepted guidelines exist for the identification of the zone of disturbance, has led in many cases to a more experienced based, or “band-aid”, approach.

Typically no change to structural design is made for the new construction of intersections. Agencies have, and continue to, adopt HMA enhancements (e.g. larger top-size, coarse and fine angularity, cleaner mixes), which they hope will reduce the need to change binders for intersection areas. Superpave mixes, SMA mixes and/or modified binders have shown promise but, in most cases, come with a significant cost premium.
Although it is generally accepted that good construction practices are even more important for intersection treatments, accommodation of traffic in some cases compromises the construction quality. Workability (or constructability) is often an issue with high stability, enhanced HMA mixes.

Agencies agree that there is significant value to the monitoring of new or innovative intersection treatments. A more “scientific” approach to the monitoring of these installations, and a means for sharing this information, would be beneficial.

A Summary Project Template was developed and completed for recent projects. These are presented in Appendix A. This template provides summary project and agency contact information that provides an overview of each project.

Detailed pre- and post-construction data for selected projects constructed by the Cities of Edmonton and Calgary was collected and summarized and are presented in Appendix B. This detailed information will be of interest to agencies as it includes project traffic, materials properties and rutting performance information.

### 4.2 City of Edmonton

In the late eighties and nineties, the City of Edmonton constructed Portland cement structural concrete inlays at two intersections: Yellowhead Trail and 127 Street, and 170 Street and 100 Avenue (eastbound). Both installations are reported to be performing very well in terms of rutting at these very high traffic locations. However, capital costs were very high.

Over the last few years, the City of Edmonton has evaluated almost all rut resistance materials and practices at its intersections. Most of these installations were constructed after the year 2000.

Table 4.1 summarizes locations and materials which have been evaluated by the City of Edmonton to mitigate rutting at intersections. In Appendix B, detailed construction and performance data for some of the projects has been assembled. Some intersections have been built recently and performance data was not available. Table 4.2 provides a summary of available traffic and short-term performance data for these projects.
### Table 4.1: Intersections in Edmonton Using Different Materials to Mitigate Rutting

<table>
<thead>
<tr>
<th>Type of Mix</th>
<th>Location of Intersections in Edmonton (Year of Rehabilitation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stone Matrix Asphalt (SMA)</td>
<td>Section 1 St. Albert Trail and 137 Avenue (2000)</td>
</tr>
<tr>
<td></td>
<td>Section 2 23 Avenue and Calgary Trail (2000)</td>
</tr>
<tr>
<td>Superpave Mix</td>
<td>Calgary Trail and South Side Whitemud CD Road Southbound Gateway Boulevard and 34 Southbound Calgary Trail and 34 Avenue (2001)</td>
</tr>
<tr>
<td>Ultra-Thin white topping (UWT)</td>
<td>Eastbound and Westbound Approach to 170 Street on 118 Avenue (2002)</td>
</tr>
<tr>
<td>Roller Compacted Concrete (RCC)</td>
<td>170 Street and 87 Avenue (Southeast of West Edmonton Mall) (2002)</td>
</tr>
</tbody>
</table>

1 CD - Distributor Road
Table 4.2: Summary of Selected Intersections Paved with Different Materials in Edmonton

<table>
<thead>
<tr>
<th>Type of Treatment</th>
<th>Location of Treatment</th>
<th>Traffic</th>
<th>Year of Treatment</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VPD</td>
<td>% Truck</td>
<td>ESALs per year</td>
<td>Years after Construction</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stone Matrix Asphalt (SMA)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. Albert Trail and 137 Avenue</td>
<td>23,000</td>
<td>10</td>
<td>470,000</td>
<td>2000</td>
</tr>
<tr>
<td>23 Avenue and Calgary Trail (Northbound)</td>
<td>33,700</td>
<td>15</td>
<td>1,040,000</td>
<td>2000</td>
</tr>
<tr>
<td>23 Avenue and Calgary Trail (Southbound)</td>
<td>34,300</td>
<td>15</td>
<td>1,060,000</td>
<td>2000</td>
</tr>
<tr>
<td>97- Street Southbound and 127-135 Avenue</td>
<td>49,200</td>
<td>4</td>
<td>400,000</td>
<td>2002</td>
</tr>
<tr>
<td>Superpave</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calgary Trail Southbound and 34 Avenue</td>
<td>34,300</td>
<td>15</td>
<td>1,060,000</td>
<td>2001</td>
</tr>
<tr>
<td>Gateway Boulevard Northbound and 34 Avenue</td>
<td>33,700</td>
<td>15</td>
<td>1,040,000</td>
<td>2001</td>
</tr>
<tr>
<td>Ultra-Thin Whitetopping (UTW)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>118 Avenue and 170 Street (Eastbound)</td>
<td>21,700</td>
<td>15</td>
<td>670,000</td>
<td>2002</td>
</tr>
<tr>
<td>118 Avenue and 170 Street (Westbound)</td>
<td>17,505</td>
<td>3</td>
<td>110,000</td>
<td>2002</td>
</tr>
<tr>
<td>Roller Compacted Concrete (RCC) with Asphalt Concrete Overlay (ACO)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>170 Street and 87 Avenue (Northbound)</td>
<td>60,600</td>
<td>15</td>
<td>1,870,000</td>
<td>2002</td>
</tr>
<tr>
<td>170 Street and 87 Avenue (Southbound)</td>
<td>54,500</td>
<td>15</td>
<td>1,680,000</td>
<td>2002</td>
</tr>
</tbody>
</table>

1  ESALs/year = VPD * f_t * f_d * 365 * % Truck, where:
   f_t = truck factor = 1.25 (assumed for all trucks)
   f_d = design lane factor = 0.45 (average for 2 to 4 lanes)
2  This section exhibited poor performance because of material design deficiencies

The two intersections, 23 Avenue and Calgary Trail and St. Albert Trail and 137 Avenue, paved in 2000 were the City of Edmonton's first trial SMA projects. The SMA's placed did not meet mix design requirements and initial rutting performance was poor. The SMA originally placed at 23 Avenue and Calgary Trail was replaced later in 2000 with a modified SMA with PG76-28 binder. The original SMA placed at the St. Albert...
Trail and 137 Avenue intersection is still in place. The City of Edmonton has recently reported their experiences with SMA\(^1\).

\[\text{Photo 4.1: 2003 SMA Installation at Yellowhead Trail and 124 Street, City of Edmonton (photo take August 2004)}\]

\(^1\) "The City of Edmonton's SMA Odyssey" - CTAA Proceedings, 2004, Montreal, Quebec
4.3 City of Calgary

The City of Calgary has identified that rutting performance at intersections has improved significantly over the last 20 years. This is a result of extensive research done in the 1970's which produced a pavement structure design consisting of a base layer of coarse aggregate City of Calgary Mix A to provide strength; and overlaying with a thin layer of oil rich fine aggregate City of Calgary Mix B for smoothness and protection against UV degradation. Further enhancement was achieved by an increased use of PMA's at problematic locations, changes to specifications calling for manufactured versus natural aggregates, reduced filler content, and greater attention to air void and VMA properties. In spite of the above, rut performance at intersections is still an issue. The City of Calgary is continuing its effort in pursuing an improved design for a rutting resistance pavement.

Their first SMA project was constructed in 1992 on the two westbound lanes on Glenmore Trail from 5 Street SW to Elbow Drive SW. The City reported average 23 mm ruts after 5 years and 28 mm ruts after 10 years performance. They will be re-evaluating SMA. The eastbound lanes were paved with City Mix B with PMA. Rut depth performance at 10 years was comparable to the westbound carriageway.
They feel that they have excellent aggregates compared to other jurisdictions and recognize that an effective aggregate structure can provide more cost-effective rutting resistance than premium, high cost, asphalt binders. Superpave coarse graded mixes, in some cases with PMAs, have been used in some instances to mitigate rutting potential.

The City of Calgary has completed two rut resistant pavement projects in September 2004:

1) SMA and Superpave

- Eastbound Anderson Road - 2 lanes: SMA-V
- Westbound Anderson Road - 3 lanes: SMA-MSM (Manufactured Shingle Modifier)
- Left Turn Bays and Median Fill on Anderson Road - Superpave-Fine (SP-Fine)

Anderson Road is an Expressway carrying 45,000 vpd with 8% trucks. Thickness of SMA mixes was increased from 40 mm to 80 mm at intersections.
• Bonaventure Drive and Acadia Drive - 2 through lanes and 1 left turn lane in the northbound and southbound directions: SP-fine.

Bonaventure Drive and Acadia Drive are Primary Collector Roadways carrying between 18,000 to 27,000 vpd and are not truck routes. Thickness of SP-fine asphalt was increased from 40 mm to 60 mm at intersections.

2) Sulphur Extended Asphalt Modifier (SEAM)/Superpave

Table 4.3 summarizes locations and materials which have been evaluated by the City of Calgary prior to 2004 to mitigate rutting at intersections.

Elbow Drive is a Divided Major Roadway carrying 11,000 vpd with 5% trucks. Canyon Meadows Drive is a Divided Major Roadway carrying 17,000 vpd with 2% trucks. Thickness of SP-fine asphalt was increased from 40 mm to 60 mm at intersections.
Table 4.3: Intersections in Calgary
Using Different Materials to Mitigate Rutting

<table>
<thead>
<tr>
<th>Type of Mix</th>
<th>Location of Intersections in Calgary (Year of Rehabilitation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stone Matrix Asphalt</td>
<td>Glenmore Trail from 5th Street to Elbow Drive, westbound carriageway (1992)</td>
</tr>
<tr>
<td></td>
<td>16 Avenue and 19 Street Northeast (NE) (1988)</td>
</tr>
<tr>
<td></td>
<td>Glenmore Trail from 5th Street to Elbow Drive, eastbound carriageway (1992)</td>
</tr>
<tr>
<td></td>
<td>McKnight Boulevard and Barlow Trail Intersection (1998)</td>
</tr>
<tr>
<td></td>
<td>Glenmore Trail and Barlow Trail Intersection (1999)</td>
</tr>
<tr>
<td></td>
<td>16 Avenue and Bowfort Road Intersection (2003)</td>
</tr>
</tbody>
</table>

In Appendix B, detailed construction and performance data for some of these projects has been assembled. Table 4.4 provides a summary of available traffic and short-term performance data for the PMA projects.
Table 4.4: Summary of Selected Intersections Paved with PMA in Calgary

1 Rut depth observed at stop line
2 PMA mix may have been over-asphalted

<table>
<thead>
<tr>
<th>Type of Treatment</th>
<th>Location of Treatment</th>
<th>Traffic (24 hrs Count)</th>
<th>Year of Treatment</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MacLeod Trail SE from 5 to 7 Avenues.</td>
<td>7,610</td>
<td>1986</td>
<td>Years after Construction</td>
</tr>
<tr>
<td></td>
<td>16 Avenue and 19 Street NE</td>
<td>24,151 (EB)</td>
<td>1988</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>27,439 (WB)</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td><strong>Polymer Modified Asphalt (PMA)</strong></td>
<td>McKnight Boulevard and Barlow Trail Intersection</td>
<td>10,230 (NB)</td>
<td>1998</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25,353 (WB)</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Glenmore Trail and Barlow Trail Intersection</td>
<td>15,615 (NB)</td>
<td>1999</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9,475 (EB)</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>16 Avenue and Bowfort Road Intersection</td>
<td>4,896 (NB)</td>
<td>2003(^2)</td>
<td>1/12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6,510 (SB)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>23,449 (EB)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>24,217 (WB)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Photo 4.5: 1986 PMA Installation on MacLeod Trail South of 5 Avenue
(photo taken in 2003 - courtesy of Husky)

Photo 4.6: 1992 SMA Installation on Westbound Lanes on Glenmore Trail
from 5th Street SW to Elbow Drive SW
(photo courtesy of City of Calgary)
4.4 City of Lethbridge

The City of Lethbridge began efforts to mitigate rutting in the mid 1980s with the Lethbridge Rutting Study and Test Section Installation. These research initiatives resulted in development of material specifications, which required aggregate enhancements (e.g. coarse aggregate fracture, use of manufactured fine, sand equivalent criteria etc.). As the research had indicated, significant overall improvements in rutting performance where attained, but localized rutting at high volume intersections continued to be an issue.

Beginning in 1995 the City began utilizing HMA designed with the Superpave system. In some cases the mixes were designed with PMA, but in most cases these mixes used conventional 150/200A binder, which had been used historically. In the late 1990's PMA binder was becoming the preference for high traffic installations, and its use continues today.

With respect to new construction, the use of more competent pavement structures at intersection locations has not been the practice. In one case a PCC pavement was placed in an intersection as part of the new construction of 43 Street (Hwy 3 and 4 connector). In 1997, the upgrading of Hwy 4 project incorporated a high temperature grade bumping of the binder in slow and standing traffic areas consistent with Superpave recommendations.

The most prevalent strategy for mitigating rutting at intersections has been milling and inlaying with HMA. Over the past ten years the materials used for these rehabilitations has evolved from conventional dense graded mixtures, to Superpave coarse graded mixtures (later with PMA binder), to Superpave fine graded mixtures with PMA binder. The area of rehabilitation has typically been selected based on a pre-rehabilitation rut survey. The depth of replacement has ranged from 50 mm to 100 mm in the close proximity to signalized intersections. Although trenching or coring investigations have been used in some instances, engineering judgment (largely based on the severity of rutting which exists and the traffic loading) has been used to select the replacement depth.

In 2003, a Value Engineering (VE) exercise was undertaken to aid in the selection of the most appropriate surfacing material for a 2 km section of Mayor Magrath Drive, which had been reconstructed to a six-lane configuration. The VE team comprised consultant
specialists, agency representatives from the Cities of Lethbridge, Calgary and Edmonton, contractor representatives and binder suppliers. The team went through a LCCA exercise and examined and weighted numerous other criteria during the two-day session. The surfacing strategy selected included the use of SMA for the six through lanes and Superpave fine graded mix for the turn lanes and intersection areas. Both mixes incorporated PG 70-31 PMA binder. The construction took place later that year and the early performance has been favorable (Photo 4.7).

Due largely to the 2003 experience, a similar strategy utilized SMA and Superpave fine graded mixes is being used on an adjacent section of Mayor Magrath Drive being constructed in 2004. In addition, Superpave fine graded mixes using PG 70-31, and in one case terminal blend asphalt rubber, are being used for intersection related pavement rehabilitations at various locations in the City.

Photo 4.7: Mayor Magrath Drive, Lethbridge, 2003 SMA and Superpave Fine Mixtures (photo taken in June 2004)
4.5 Strathcona County

Strathcona County has experienced major rutting problems along 17 Street, concentrated at the CP Rail Spur Line Crossing and at the intersection at Baseline Road. There can be 20 trains per day crossing 17 Street and there are large volumes of heavy trucks, estimated at 30%, which service the major refineries in the area. Aggregates and asphalt mixes typically used within the County are the same as those used in the City of Edmonton.

The most significant rutting problems historically have occurred at the 17 Street - Baseline Road intersection. The rutting problems are exacerbated by the three phase signal, heavy and slow moving truck traffic, long cycle times and high levels of commuter traffic.

This intersection was repaved in 1996. An investigation of rutting performance at that time indicated ruts up to 50 mm in the northbound lane of 17 Street south of Baseline Road. Based on a coring and survey program, it was established that the "zone of disturbance" extended in excess of 120 mm of total 450 mm thick full depth pavement structure. The recommended rehabilitation treatment of 17 Street was to cold mill to a 100 mm depth and inlay followed by a 50 mm overlay. Alberta Transportation Type 1 asphalt concrete mix was specified for the inlay and overlay. This section, along with other portions of 17 Street northbound and at the CP Rail Spur Crossing were rehabilitated in 2000; the treatment was to cold mill to a 100 mm depth and inlay with City of Edmonton ACO asphalt concrete mix with a polymer modified PG72-28.

The southbound lanes of 17 Street at Baseline Road were rehabilitated in 2002; the treatment was to cold mill to a 100 mm depth and inlay with 40 mm of City of Edmonton ACS with a PG64-34 specified followed by 60 mm asphalt rubber mix. Shortly after rehabilitation, the pavement started to rut. A limited investigation indicated the rutting resulted in part from deficiencies in the ACS (PG64-34) mix; a slab removed from the roadway also indicated that the underlying asphalt concrete showed signs of deformation.

The County is considering using a Roller Compacted Concrete inlay with a 50 mm high stability asphalt mix in future treatments.
4.6 Alberta Transportation

There are not many high traffic signalized intersections on the rural highway network although more recently AT has assumed jurisdiction for primary highways through most urban municipalities. Typical past rehabilitation treatments have been to cold mill and inlay intersections exhibiting unacceptable levels of rutting using the appropriate mix type for the climate zone and 20 year Design ESALs following selection protocols developed by AT for high speed rural highways. An RCC inlay with an asphalt concrete wearing surface was constructed on Hwy 63 at the Beacon Hill intersection in the mid nineties. Structural concrete inlays and a PG70-28 modified binder have been recently installed at the approach lanes to weigh scales where slow moving truck traffic has resulted in severe rutting performance.

In 2003, Hwy 3/36 Street intersection in Lethbridge was rehabilitated by cold milling to a 60 mm depth and inlaying with 60 mm of SMA. In 2004, portions of Hwy 3/43 Street (Hwy 4) intersection in Lethbridge was rehabilitated by cold milling to a 100 mm depth in the inner turning lane and 125 mm depth in the outer turning lane and inlaying with Portland Cement Concrete (ultra-thin whitetopping).\(^2\) AT sees the requirements for small quantities of specialty mixes for intersections as an issue in terms of consistency and quality. They would consider Portland Cement Concrete pavements at intersections based on a Life Cycle Cost Analysis (LCCA). AT expects to expend more effort on the design of intersections and other rut-prone areas in the future.

4.7 Some General Observations from Rut Mitigation Project Methods

The following are some general observations from the data documented from City of Edmonton and Calgary rut mitigation projects.

1) Based on latest rehabilitations at several intersections, conventional asphalt mixtures at different intersections have lasted between 2 to 7 years.

2) Some materials such as SMA have shown a good performance to specific level of traffic volume but they did not show good rutting performance in the other direction of the same intersection with higher traffic volumes.

3) Since many of the rutting mitigation projects constructed in Edmonton have only been in service for a few years, additional time is required to have a complete performance evaluation. By reviewing the short-term performance data from various rutting mitigation projects, it can be concluded that traffic, and more specific truck traffic volumes, are the main factors which control rutting performance at intersections. The City of Edmonton should continue to monitor these sections in the future. By collecting more performance data at intersections in Edmonton, it will be possible to identify appropriate design solutions for different levels of traffic in the future.

4) Comparing one-year performance of one Superpave and two SMA pavements at intersections in Edmonton with similar AADT (34,000) and truck traffic volumes (15%) concluded that Superpave pavement showed higher average rutting (19 mm) than the SMA average rutting (12.5 mm) after one year in service. The same trend was observed for maximum rut at these intersections.

5) For two directions of one intersection paved with PMA in Calgary (McKnight and Barlow), increasing 2.5 times daily traffic (10,000 and 25,000) resulted in approximately a two fold increase in average and maximum rut, 15.5 mm compared to 8 mm and 19 mm compared to 9 mm respectively, after 5 years in service. This suggests an average of 0.39 mm rutting per one million vehicles for this intersection.

6) For two directions of another intersection (Glenmore Trail and Barlow Trail) paved with PMA in Calgary, increasing the daily traffic by 1.6 times (9,475 to 15,615) has resulted in approximately a 1.5 fold increase in average and maximum rut, 34 mm compared to 25 mm and 46 mm compared to 30 mm respectively after four years in service. This suggests an average of 1.65 mm rutting per one million vehicles at this intersection.

7) From observations explained in 5 and 6, it can be concluded that the same rutting mitigation practice (PMA) was more effective at one intersection (McKnight and Barlow Trail) than the other intersection (Glenmore and Barlow Trail). One possible reason could be difference truck traffic volumes at these intersections. As truck volume data for these intersections was not available, it was not possible to investigate this.
5.0 EVALUATING RUTTING AT URBAN INTERSECTIONS

5.1 Introduction

The design of a pavement system at urban intersections, whether for new construction or for rehabilitation, simply has to address two issues:

- What is the extent of the roadway, both in area and in depth, that requires special consideration?
- What type of materials/mixes and properties should be selected for that area and depth?

The answer to the first question could be based on local experience, ad hoc observations, or detailed field survey and investigation of existing intersections. As part of the literature search and detailed interviews with the Cities of Edmonton, Calgary and Lethbridge, and Strathcona County, very little if any detailed comprehensive rut survey information from urban intersections was available. Although these jurisdictions and others have carried out significant efforts, documented rut measurement data was limited to adhoc or spot measurements.

Consequently, in conjunction with the City of Edmonton, a section of 170 Street in west Edmonton was selected for a comprehensive rut survey with the following objectives:

- Measure and document the extent and severity of rutting across three or four lanes leading into and away from a major signalized intersection
- Assess how rutting severity is affected by vehicle speed, braking and acceleration/deceleration effects
- Evaluate the SurPRO surface profiler and Dipstick for measuring transverse profiles of rutted intersections
- Develop a protocol for measuring and reporting rut depths.

5.2 170 Street Case Study

5.2.1 170 Street Project Description

170 Street is located in west Edmonton and is a major north-south arterial and 24 hour truck route. The section selected was the northbound lanes north of 99 Avenue,
extending through and north of the signalized intersection with 100 Avenue eastbound. Except for a short portion near 99 Avenue, this roadway was five lanes. The AADT is about 60,600 with 15% trucks. Photo 5.1 was taken looking north from about 40 m south of 100 Avenue eastbound. Photo 5.2 was taken looking east at the stop bar on the south side of 100 Avenue eastbound. This roadway was last paved about 10 years ago.

Photo 5.1: 170 Street, Edmonton - Looking North at 100 Avenue Eastbound Intersection

Photo 5.2: 170 Street, Edmonton - Looking East at 100 Avenue Eastbound Intersection
5.2.2 Survey Methodology

Based on a field reconnaissance and traffic accommodation requirements, transverse profiles of the inner four lanes were surveyed; the outer (No. 1) lane was left open for through traffic. All surveying was carried out on a Sunday morning in August 2003 when traffic volumes were light. Station 0 m was located at the painted line corresponding to the curb line along the south edge of 100 Avenue eastbound. Transverse profiles were surveyed at the following stations:

<table>
<thead>
<tr>
<th>Station</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>- 230 m</td>
<td>North of 99 Avenue; 4 lanes wide, 3 inner lanes surveyed</td>
</tr>
<tr>
<td>- 160 m</td>
<td>5 lanes wide; 4 inner lanes surveyed</td>
</tr>
<tr>
<td>- 120 m</td>
<td>5 lanes wide; 4 inner lanes surveyed</td>
</tr>
<tr>
<td>- 80 m</td>
<td>5 lanes wide; 4 inner lanes surveyed</td>
</tr>
<tr>
<td>- 40 m</td>
<td>5 lanes wide; 4 inner lanes surveyed</td>
</tr>
<tr>
<td>- 20 m</td>
<td>5 lanes wide; 4 inner lanes surveyed</td>
</tr>
<tr>
<td>- 10 m</td>
<td>5 lanes wide; 4 inner lanes surveyed</td>
</tr>
<tr>
<td>-5.1 m</td>
<td>Corresponds to stop bar south of 100 Avenue eastbound</td>
</tr>
<tr>
<td>0 m</td>
<td>5 lanes wide; 4 inner lanes surveyed</td>
</tr>
<tr>
<td>+ 40 m</td>
<td>5 lanes wide; 4 inner lanes surveyed</td>
</tr>
<tr>
<td>+ 80 m</td>
<td>5 lanes wide; 4 inner lanes surveyed</td>
</tr>
<tr>
<td>+ 120 m</td>
<td>5 lanes wide; 4 inner lanes surveyed</td>
</tr>
</tbody>
</table>

The SurPRO 2000 multi-purpose Class 1 surface profiler manufactured by International Cybernetics Corporation was used for surveying all profiles (Photo 5.3). This instrument is pushed by the operator at about walking speed (depending on how rough or distorted the road profile is). The wheel spacing was set at 250 mm. The SurPRO establishes a pavement elevation on a 250 mm interval. Therefore, the transverse profile of each lane is represented by about 14 discreet elevation data points.

A profile survey was also carried out along the stop bar at Station –5.1 m using the Dipstick, also a Class 1 profiler, manufactured by FACE (Photo 5.4). The foot spacing was set at 50 mm which provided about 70 discreet elevation data points for each lane. This survey is time consuming and requires a very dedicated and attentive operator. It took about the same time to carry out all the SurPRO profile surveys as one Dipstick profile.
Photo 5.3: 170 Street, Edmonton - SurPRO Survey at Station 0 m

Photo 5.4: 170 Street, Edmonton - Dipstick Survey at Station - 5.1 m
5.2.3 Analysis of Results

Figure 5.1 presents 12 profiles as surveyed by the SurPRO for all lanes tested. The transverse profiles have been offset vertically to allow for visual comparison and evaluation. A visual examination allows for the two wheelpath ruts in lanes 2, 3 and 4 to be distinguished with very little rutting noted in Lane 5 which was a left turn bay added on sometime after original construction.

![Graph showing transverse profiles from SurPRO survey](image)

Figure 5.1: 170 Street, Edmonton - Transverse Profiles from SurPRO Survey
(Note that the profiles have been offset vertically)

The transverse rutting profile of the outer wheelpath of Lane 2, which corresponds to the most heavily loaded lane surveyed, was examined in detail. At each station, the rut depth was scaled from the transverse profile using three virtual straight edges: 1.2 m, 1.8 m and 3.7 m. This is presented in Figure 5.2.
Figure 5.2 provides the following observations regarding measuring and reporting rut depths:

1. Rut depths based on a 1.2 m straight edge length were always lower than those based on a 1.8 m or 3.7 m straight edge length.
2. The difference in rut depth based on a 1.2 m straight edge compared to a 1.8 m straight edge was less than 3 mm for ruts less than about 20 mm.
3. The difference in rut depth based on a 1.2 m straight edge compared to a 1.8 m straight edge was about 15 mm for ruts greater than about 30 mm.

This data indicates that a straight edge of 1.8 m should be used to measure and report rut depths at urban intersections. The use of a shorter straight edge can significantly under-estimate rut depths when rut depths are greater than about 35 mm. This is due to the shorter straight edge sitting within the rut depression rather than spanning it.
Figure 5.2 provides the following observations regarding the longitudinal variation in rut depth along 170 Street and are based on rut depths determined using a 1.8 m straight edge:

1. Rut depths are about 15 mm up to about 175 m from the intersection. This area could correspond to regular speed to slow speed truck traffic.
2. Rut depths increase from about 15 mm to about 25 mm up to about 100 m from the intersection. This area could correspond to slow speed truck traffic as well as deceleration or acceleration forces.
3. Rut depths increase from about 25 mm to about 40 mm peaking about 15 m short of the stop bar. This area could correspond to slow speed or standing truck traffic as well as deceleration and acceleration forces.
4. Rut depths north of 100 Avenue east bound are in the 15 mm range over about a 100 m length. This area could correspond to slow speed truck traffic as well as acceleration forces. Traffic light synchronization with Stony Plain Road westbound would result in few trucks decelerating and braking in this area. North of this area the rut depths are less than 15 mm.
5. This data indicates significant differences in the severity of rutting distresses along the length of 170 Street associated with the intersection. These differences would be important design input parameters and could influence the rehabilitation treatments considered.

5.3 Defining Traffic Condition Zones

The term "Traffic Condition" in this report is used to describe the combined effects and interaction of traffic speed, and braking/acceleration/deceleration effects at urban intersections. Traffic condition, at least in flexible and composite pavement systems, will directly affect the "zone of disturbance" or the depth where high shear stresses may exceed the shear resistance of the asphalt pavement.

The Traffic Load Rates as defined in AASHTO MP2-02, Standard Specification for Superpave Volumetric Mix Design\(^3\), forms the basis of the Traffic Condition Zones for Urban Intersections presented in Table 5.1.

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Table 5.1: Traffic Condition Zones for Urban Intersections

<table>
<thead>
<tr>
<th>Traffic Condition Zone</th>
<th>Description</th>
<th>AASHTO Terminology and Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Standing Traffic – area of combined acceleration, deceleration and standing</td>
<td>Standing Traffic – where the average traffic speed is less than 20 km/h</td>
</tr>
<tr>
<td></td>
<td>traffic; average traffic speed is less than 20 km/h</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Slow Traffic – area of acceleration or deceleration; average traffic speed</td>
<td>Slow Traffic – where the average traffic speed ranges from 20 to 70 km/h</td>
</tr>
<tr>
<td></td>
<td>ranges from 20 to 50 km/h</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Standard Traffic – average traffic speed is greater than 50 km/hr</td>
<td>Standard Traffic – where the average traffic speed is greater than 70 km/h</td>
</tr>
</tbody>
</table>

The existence or extent of the three zones will vary from intersection to intersection. All three zones can theoretically be present in any lane at any urban intersection depending on a number of factors:

- amount of truck traffic
- lane distribution of truck traffic
- posted speed limit
- distance or separation between intersections
- longitudinal grade

Normally Zone 1 and Zone 2 conditions would exist at an intersection. Zone 3 would correspond to the 'normal' traffic conditions associated with an urban roadway. On some roadways with closely spaced intersections and high truck traffic, Zone 3 may not exist. In any case, each zone should be identified and evaluated separately as a different design solution may be required for each zone.

Based on limited observations of traffic operations and the longitudinal variation in Rut Depth, Traffic Condition Zones for 170 Street Lane 2 is presented in Figure 5.3.
Figure 5.3: 170 Street, Edmonton - Lane 2 Outer Wheelpath, Traffic Condition Zones
6.0 PROPOSED DESIGN METHODOLOGY FOR MITIGATING RUTTING AT URBAN INTERSECTIONS

6.1 Objectives and Scope of Design Guidelines

Based upon information obtained through the literature survey, the experiences and practices of Alberta agencies, and discussions and outcomes of the Expert Group Workshop, a proposed generic design methodology for mitigating rutting at urban intersections has been developed.

These guidelines reflect the best practices currently being followed in Alberta and include other findings resulting from the literature search and discussions with individual agencies. These guidelines provide a rational approach to a design methodology but leave detailed design issues to the agencies to incorporate local experience, materials, and practice and as such specific detailed design criteria have not been established. It is envisioned that over the next several years, as performance data is gathered on the new treatments installed over the last few years, that more detailed guidelines and design criteria can be developed to reflect made-in Alberta state-of-the-art design practices applicable to all jurisdictions across Alberta.

Separate guidelines have been developed for both the construction of new intersections and the rehabilitation of existing intersections. The differences between the two guidelines are primarily related to the different potential treatments that are feasible for either new construction or rehabilitation and to issues related to traffic accommodation and costs which are significantly greater when rehabilitating an existing intersection. The guidelines are generic and would apply to the design of flexible, rigid and composite pavement systems.

As a result of this presentation format, there is considerable repetition in the discussions relating to both new construction and rehabilitation – this has been done with purpose to allow each section to stand alone and aid the reader.

6.2 New Construction of Intersections

A design methodology flow chart for new construction of intersections is presented in Figure 6.1. Although the number of new signalized intersections being constructed in Alberta municipalities is very low, there are significant performance benefits that can be achieved through technology transfer and lessons learned from the performance of
intersections that have been rehabilitated. A more detailed elaboration of the guidelines for mitigating rutting for the new construction of intersections follows.

Figure 6.1: Design Methodology for Mitigating Rutting for New Construction of Intersections
Step 1 – Develop Performance Criteria

It is fundamental to establish performance criteria that will drive the design process, evaluation of alternatives, innovation and life cycle cost analysis.

Performance criteria should primarily relate to permanent deformation or rutting of the pavement surface as this is considered to be the primary trigger for future rehabilitation. Other performance attributes include ride quality (as influenced by low temperature transverse cracking and jointing), skid resistance and durability. Different criteria can be considered for different traffic condition zones to reflect driver/vehicle performance requirements.

An example of target performance criteria developed by the City of Kelowna and B.C. Ministry of Highways in February 2004 for the rehabilitation of the Harvey Avenue Intersection was "to limit pavement rutting to a maximum of 12.5 mm within a 20 m zone leading into the intersection stop bar and less than 10 mm in other areas, while maintaining acceptable durability, skid resistance and low temperature cracking performance"\(^4\).

Step 2 – Analyze Traffic

The following traffic-related information should be assembled:

- estimated initial AADT
- estimated initial % trucks and truck factors (ESALs/truck type), or daily ESALs
- growth rate
- estimated initial truck traffic distribution by lane

These data would be used as direct input to the pavement structural design (Step 4), and as indirect considerations in determining the depth and area of treatments (Step 3), and selection of materials properties (e.g. asphalt binder grades, mix and aggregate requirements) (Step 5).

\(^4\) EBA Engineering Consultants Ltd., Correspondence to City of Kelowna dated January 26, 2004.
Step 3 – Determine the Length and Depth of the Intersection Pavement Requiring Special Treatment

As defined in Section 5.3, the Traffic Condition Zones for each lane leading into and away from the intersection should be established. This would typically be based on the observed traffic and performance at other similar existing intersections and agency experience. Also the geometric design and traffic signalization (which can differ significantly from intersection to intersection and from jurisdiction to jurisdiction) should be reviewed to assess traffic movements, turn bays, anticipated queue lengths, etc.

The Traffic Condition Zones along with agency experience can form the basis for the area and depth of the intersection pavement that will require special treatment.

Step 4 – Carry Out Pavement Structural Design

It is recognized that most roadway pavement structural design methods in use today have been developed for high speed urban or rural applications.

For rigid Portland Cement Concrete pavements, design procedures developed by the Cement Association (formerly the Portland Cement Association) or AASHTO can be used based on individual agency preference and experience.

For flexible pavement systems, design procedures developed by the AASHTO or Asphalt Institute can be used. It should be noted that these procedures do not consider time of loading as an input design parameter. The stiffness of an asphalt mix is a function of the time of loading. Short loading times (for example high speed traffic) results in higher stiffnesses, all other factors being equal. Long loading times (for example standing traffic) results in lower stiffnesses, and consequently, reduced load distribution properties and higher stresses on the subgrade. For the relatively "soft" asphalt cement grades (e.g. 150-200A) historically used by Alberta cities, the development of a mechanistic-based design procedure could result in increased thickness of pavement structures at intersections. In the absence of a mechanistic-based design procedure, the thickness of the pavement structure in Zone 1 and Zone 2 (as defined in Step 5), may need to be increased to account for slow or standing traffic conditions. The amount of increase should be based on engineering judgement and local experience.
A design period of 30 years or more should be considered recognizing that it can be impractical to increase the structural strength of an intersection pavement as surface elevations are constrained by curb and gutter, tie-ins to other roadways, approaches, etc.

Step 5 – Design and Select Materials Alternates

The outputs of Step 3 may result in the identification of three traffic condition zones:

Zone 1
• Standing Traffic – area of combined acceleration, deceleration and standing traffic; average traffic speed is less than 20 km/h.

Zone 2
• Slow Traffic – area of acceleration or deceleration; average traffic speed ranges from 20 to 50 km/h.

Zone 3
• Standard Traffic – average traffic speed is greater than 50 km/h.

Each zone would most likely have a similar structural pavement design although for flexible pavement systems, the pavement layer thicknesses within Zone 1 may be increased to account for very long loading time conditions.

Generally for rigid pavements systems, which would provide excellent rutting performance, the structural thickness is governed by the heaviest vehicle and therefore one design and set of materials properties (e.g. flexural strength) would apply to all three traffic condition zones.

For flexible pavement systems, there is greater flexibility to identify alternate treatment depths and alternate materials to address the difference in loading conditions in the three traffic condition zones. This is illustrated as follows:

Zone 3 – Standard Traffic:
• "normal" structural design
• "normal" asphalt concrete mixtures
Zone 2 – Slow Traffic:
- "normal" structural design or increased pavement structure thickness over "normal" design to account for increased time of loading
- use stiffer binders in surface lifts
- use aggregates with higher coarse and fine aggregate angularity in surface lifts
- specify different mix design systems, e.g. Superpave, SMA

Zone 1 – Standing Traffic:
- increased pavement structure thickness over "normal" design to account for time of loading
- use stiffer binders in the upper 100 mm or more
- use aggregates with higher coarse and fine aggregate angularity in all lifts
- specify different mix design systems; e.g. Superpave, SMA

Step 6 – Carry Out Life Cycle Cost Analyses of Alternates

A simplified life cycle cost analysis should be undertaken. The Life Cycle Costs of a pavement alternate are defined as the total costs over the analysis period expressed in today's cost; i.e. Present Value.

The following inputs and values are recommended:

Initial Capital Costs – These would only include the costs that are unique to each alternate, i.e. costs of subgrade, curb and gutter which would be common to all alternatives, would not be included.

Rehabilitation Costs – Costs associated with restoring the serviceability of the pavement surface over the analysis period would be included. These could include cost of diamond grinding of Portland Cement Concrete to restore ride quality or skid resistance, or could include mill and inlay of Asphalt Concrete Pavement to mitigate a rutting condition.

Maintenance Costs – These costs, which include crack or joint sealing, should be included if they differ significantly between alternates.

Residual Value – The residual or salvage value of the pavement structure at the end of the analysis period can be ignored as it will likely be very similar for all alternates.
However, the residual value of the last major rehabilitation treatment should be included.

Analysis Period – The analysis period is the time period over which the economic analysis is conducted. An analysis period of at least 40 years is recommended.

Design Period – The design period is the time period for which the pavement structure is designed to carry the anticipated truck loadings. For intersections, a design period of at least 30 years is recommended.

Service Life – The service life is the time period for which the pavement treatment will provide adequate rut, ride quality or structural performance before a major rehabilitation treatment is required. For major intersections, it is assumed that unacceptable rutting would trigger a rehabilitation treatment.

The following service lives for new construction designs are suggested based on the outcomes of the Expert Workshop:

- Portland Cement Concrete Pavement (Structural pavement) 30 years
- Ultra-Thin Whitetopping/Whitetopping (over a new flexible pavement system) 15 to 20 years
- Roller Compacted Concrete with Thin Asphalt Pavement 20 years
- Flexible Pavement System with:
  - SMA 15 years
  - Superpave Mix 7 to 12 years
  - PMA Binder 7 to 12 years
  - Conventional Asphalt Pavement 4 to 7 years

Discount Rate – The discount rate is the rate of interest used to adjust future dollars to present values, normally taken as the difference between the prime interest rate and the rate of inflation. A value of 4% is recommended. Higher values of discount rate result in alternates with higher initial capital costs to be less economically attractive.

User Costs – These costs can include the operating costs to the user using the facility (such as vehicle operating costs) or the costs to the user during construction or future rehabilitation activities (such as delay costs or costs of detouring). Little consensus amongst agencies across North America exists regarding the values for user costs.
User costs associated with the new construction of an intersection may be very low and therefore can be ignored in the Life Cycle Cost Analysis.

**Step 7 – Assess Evaluation Criteria, Rank Alternates and Select Optimal Design**

In Step 1, project specific performance criteria were developed. The design alternates identified in Step 5 should be reviewed against these criteria in order to eliminate those that don’t meet minimum criteria.

The ranking of alternates can consider a number of criteria including:

- Present worth established from the LCCA
- Initial Capital Cost
- Contractor Capability
- Constructability
- Risk (Owner, Contractor, Consultant)
- Skid Resistance
- Pavement Marking Effectiveness and Retention
- Engineering Effort (prior to and during construction)
- Applicability of New Technologies for Future Applications
- Scheduling
- Traffic Disruption/Accommodation
- Relative Noise Level

There are tools available to aid in weighting criteria and then scoring each alternate (e.g. Pair-comparison process, value engineering). The final analysis can result in a weighted ranking of all viable alternates that considers economic, traffic, technical and risk factors. The final design solution would consider these factors.

**6.3 Rehabilitation of Existing Intersections**

A design methodology flow chart for the rehabilitation of existing intersections is presented in Figure 6.2.

Although there are many commonalities, the mitigation of rutting at existing intersections differs from new construction in several significant areas:
• Existing rutting performance and traffic patterns can aid in identifying Traffic Condition Zones.
• Traffic disruption/accommodation during rehabilitation can be significant to the selection process in some cases.
• Existing curb and gutter, medians and auxiliary lanes can complicate the structural design of rigid pavement systems and construction of coarse asphalt mixtures.
• Costs are increased due to the necessity to remove material prior to replacement.
• Structural evaluation (and other data collection) is typically required.
• Investigation of zone of disturbance, pavement thickness and composition may be required.
Figure 6.2: Design Methodology for Mitigating Rutting for Rehabilitation of Existing Intersections
A more detailed elaboration of the guidelines for mitigating rutting for the rehabilitation of existing intersections follows.

**Step 1 – Develop Performance Criteria**

It is fundamental to establish performance criteria that will drive the design process, evaluation of alternatives, innovation and life cycle cost analysis.

Performance criteria should primarily relate to permanent deformation or rutting of the pavement surface as this is considered to be the primary trigger for future rehabilitation. Other performance attributes include ride quality (as influenced by low temperature transverse cracking and jointing or the reflection of existing cracking patterns), skid resistance and durability. Different criteria can be considered for different traffic condition zones to reflect driver/vehicle performance requirements.

An example of target performance criteria developed by the City of Kelowna and B.C. Ministry of Highways in February 2004 for the rehabilitation of the Harvey Avenue Intersection was "to limit pavement rutting to a maximum of 12.5 mm within a 20 m zone leading into the intersection stop bar and less than 10 mm in other areas, while maintaining acceptable durability, skid resistance and low temperature cracking performance".

**Step 2 – Analyze Traffic**

The following traffic-related information should be assembled:

- present AADT
- present % trucks and truck factors (ESALs/truck type), or daily ESALs
- growth rate
- present truck traffic distribution by lane

These data will be used as direct input to the pavement structural design (Step 4), and as indirect considerations in determining the depth and area of treatments (Step 3), and selection of materials properties (e.g. asphalt binder grades, mix and aggregate requirements) (Step 5).
**Step 3 – Determine the Lengths and Depth of the Intersection Pavement Requiring Special Treatment**

Information regarding the original pavement design and subsequent rehabilitation treatments, as-built layer thickness and materials quality should be reviewed to provide insights into past and present performance.

As defined in Section 5.3, the Traffic Condition Zones for each lane leading into and away from the intersection should be established.

A field evaluation of rutting performance should be carried out to determine traffic condition zones, the "zone of disturbance" and subsequent depths of treatments, and the area of treatment. (The "zone of disturbance" is defined as the depth within the pavement structure that has failed in shear or has exhibited plastic permanent deformation. In some cases this zone may be within the top 75 mm to 150 mm of the asphalt pavement layer. In other cases, the rutting may extend into the base or subgrade.) The level of effort and detail of this investigation will be based on:

- availability of accurate historical construction history and performance
- past experience with intersections of similar construction, materials and traffic
- risk, in terms of future traffic.

A recommended evaluation methodology follows:

i) Detailed field inspection to assess materials and structural-related distresses and conditions.

ii) Field observations to assess existing traffic patterns and movements.

iii) Survey the severity and extent area of rutting. The survey should extend into the Zone 3 (Standard Traffic - average traffic speed is greater than 50 km/h) even if this area extends beyond the limits of the intersection to be rehabilitated. Rut surveys should be carried out every 30 to 50 m with a closer spacing approaching the intersection. The survey should include the measurement of rut depths in both wheelpaths of all lanes. The surveys can be carried out by:

- 1.8 m straight edge - this will provide a depression depth for each wheelpath
• SurPRO or Dipstick - this will provide a depression depth for each wheelpath, a true cross-section which will identify the degree of shoving and lateral movement and cross-slope information for each lane. Although the Dipstick with a 50 mm foot spacing will provide the most complete and precise profile survey, the testing is cumbersome and slow resulting in high traffic control disruption and costs. The SurPRO with a 250 mm recording interval can provide similar profile data. Testing can be carried out at night or on weekends to reduce traffic disruption and control costs.

This profile survey data and traffic condition observations can be analyzed to identify Traffic Condition Zones. These Traffic Condition Zones along with agency experience can form the basis for the area of the intersection that will require special treatment. These areas may differ by lane.

iv) The existing "zone of disturbance" should be established to determine the depth of treatment for each Traffic Condition Zone. Although the zone of disturbance can be inferred from the rut profile survey, it can be confirmed by field sampling either by:
• Coring - the zone of disturbance can be established in some cases by coring the pavement structure (150 mm diameter cores from at least 5 locations across the lane: both edges, both wheelpaths and between the wheelpaths), and retrieving full depth cores for detailed visual examination. In addition, the top of pavement elevation of each core location needs to be established from a rod and level survey or from a Dipstick or SurPRO survey. From the visual examination and elevation information, the rutting of the various layers may be able to be identified, the amount (if any) of structural rutting identified and the "zone of disturbance" inferred.
• Trenching - the zone of disturbance and the structural rutting can most accurately be determined by sawing a trench across the entire lane and retrieving slab samples for detailed examination (and additional laboratory testing if required). Sampling and testing of intermediate pavement layers to determine voids, aggregate and asphalt binder properties can aid in determining the zone of disturbance and the depth of treatment.
Step 4 – Carry Out Pavement Structural Evaluation

The structural adequacy of the existing pavement structure for the projected Design Traffic needs to be evaluated. This evaluation will assist in determining whether observed rutting is related to instability of the asphalt pavement layers or structural deficiencies. This evaluation will identify any structural strengthening requirements that have to be included as part of the rehabilitation design. The structural adequacy can be evaluated following agency practice and experience.

Step 5 - Design and Select Materials Alternates

The outputs of Step 3 may result in the identification of three traffic condition zones:

Zone 1  •  Standing Traffic - area of combined acceleration, deceleration and standing traffic; average traffic speed is less than 20 km/h
Zone 2  •  Slow Traffic - area of acceleration or deceleration; average traffic speed ranges from 20 km/h to 50 km/h
Zone 3  •  Standard Traffic - average traffic speed is greater than 50 km/h

Step 3 may also identify the zone of influence and the required depth of treatment. The required depth of treatment may be different for each traffic condition zone.

Within the Alberta agencies included in this project, all existing intersections exhibiting unacceptable rutting performance are asphalt concrete pavements over granular base or cement treated base.

For flexible pavement systems, there is greater flexibility to identify alternate treatment depths and alternate materials to address the difference in loading conditions and required depth of treatment in the three traffic condition zones.

This is illustrated in Table 6.1.
Table 6.1: Potential Treatments for Rehabilitation of Existing Intersections

<table>
<thead>
<tr>
<th></th>
<th>Zone 3</th>
<th>Zone 2</th>
<th>Zone 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Standard Traffic</td>
<td>Slow Traffic</td>
<td>Standing Traffic</td>
</tr>
<tr>
<td>Normal Asphalt Concrete Mixtures</td>
<td>In all lifts</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>State-of-the-Practice Rut Resistant Asphalt Mixtures:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• SMA</td>
<td>In surface lifts</td>
<td>In surface lifts</td>
<td>In all lifts</td>
</tr>
<tr>
<td>• PMA Binder</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Modified Binders (SEAM)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Higher coarse &amp; fine aggregate angularity requirements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultra-Thin Whitetopping Inlay</td>
<td>X</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Roller Compacted Concrete Inlay and Rut Resistant Asphalt Mixtures</td>
<td>X</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Concrete Inlays (Structural Pavement)</td>
<td>X</td>
<td>X</td>
<td>√</td>
</tr>
</tbody>
</table>

Note: X may not be suitable based on cost or performance considerations. √ should be considered.

Step 6 – Carry Out Life Cycle Cost Analyses of Alternates

A simplified life cycle cost analysis should be undertaken. Alternates are defined as the total costs over the analysis period expressed in today’s cost; i.e. Present Value.

The following inputs and values are recommended:

Initial Rehabilitation Costs – These would only include the costs that are unique to each alternate.

Future Rehabilitation Costs – Costs associated with restoring the serviceability of the pavement surface would be included. These could include cost of diamond grinding of Portland Cement Concrete to restore ride quality or skid resistance, or could mill and inlay of Asphalt Concrete Pavement to mitigate a rutting condition.

Maintenance Costs – These costs, which include crack or joint sealing, should be included if they differ significantly between alternates.
Residual Value – The residual or salvage value of the pavement structure at the end of the analysis period can be ignored as it will be very similar for all alternates. However, the residual value of the last major rehabilitation treatment should be included.

Analysis Period – The analysis period is the time period over which the economic analysis is conducted. An analysis period of at least 40 years is recommended.

Design Period – The design period is the time period for which the pavement structure is designed to carry the anticipated truck loadings. For intersections, a design period of at least 30 years is recommended.

Service Life – The service life is the time period for which the pavement treatment will provide adequate rut, ride quality or structural performance before a major rehabilitation treatment is required. For major intersections, it is assumed that unacceptable rutting would trigger a rehabilitation treatment. The following service lives are suggested based on the outcomes of the Expert Workshop:

- Portland Cement Concrete (Structural Pavement) 30 years
- Ultra-Thin Whitetopping/Whitetopping 15 to 20 years
- Roller Compacted Concrete with Thin Asphalt Pavement 20 years
- Cold Mill and Inlay with:
  - SMA 15 years
  - Superpave Mix 7 to 12 years
  - PMA Binder 7 to 12 years
  - Conventional Asphalt Pavement 4 to 7 years
- Rut Fill 2 to 3 years
- Reprofiling of Asphalt Pavement <1 year

Discount Rate – The discount rate is the rate of interest used to adjust future dollars to present values, normally taken as the difference between the prime interest rate and the rate of inflation. A value of 4% is recommended. Higher values of discount rate result in alternates with higher initial capital costs to be less economically attractive.

User Costs – User costs can include the costs to the user using the facility (such as vehicle operating costs) or the costs to the user during maintenance and rehabilitation (such as delay costs or costs of detouring). Little consensus amongst agencies across North America exists regarding the values for user costs. It is difficult to consider all
aspects of user costs directly in a life cycle costs analysis. However user costs associated with delay costs could be addressed in the final selection of the optimal design. These can be addressed, for example, through road rental charges that vary throughout the day based on traffic volumes, or requiring rehabilitation be carried out at night or on weekends. Higher cost associated with off-peak hour construction or rehabilitation should be reflected in the rehabilitation costs.

**Step 7 – Assess Evaluation Criteria, Rank Alternates and Select Optimal Design**

In Step 1, project specific performance criteria were developed. The design alternates identified in Step 5 should be reviewed against these criteria in order to eliminate those that don't meet minimum criteria.

The ranking of alternates can consider a number of criteria including:

- Present worth established from the LCCA
- Initial Capital Cost
- Contractor Capability
- Constructability
- Risk (Owner, Contractor, Consultant)
- Skid Resistance
- Pavement Marking Effectiveness and Retention
- Engineering Effort (prior to and during construction)
- Applicability of New Technologies for Future Applications
- Scheduling
- Traffic Disruption/Accommodation
- Relative Noise Level

Typically, the number of criteria considered for intersection rehabilitation would be limited to present worth, and several other priority criteria.

There are tools available to aid in weighing criteria and then scoring each alternate (e.g. Pair-comparison process, value engineering). The final analysis can result in a weighted ranking of all viable alternates that considers economic, traffic, technical and risk factors. The final design solution would consider these factors.
7.0 RECOMMENDATIONS

This research study on the mitigation of instability rutting at intersections in the Alberta context should be viewed as work-in-progress. Recently, much progress has been made by agencies to evaluate new technologies, materials and treatments and in many cases the results have been promising. However, it will require several more years of monitoring to determine long-term performance.

In the interim, the following recommendations are offered:

1. The generic design guidelines should be adopted by individual agencies and fine-tuned to incorporate local practice and experience.

2. Agencies should develop performance criteria for rutting at urban intersections which will drive the design process, evaluation of alternatives, innovation and life cycle cost analysis.

3. Agencies should continue to research innovative materials and methods, and to improve on existing technologies, e.g. SMA, Ultra-Thin Whitetopping, to enhance performance of pavements at intersections in Alberta.

4. All agencies should continue long-term performance monitoring of rutting mitigation projects.

5. All practitioners in the pavements field should adopt a common standard for measuring and reporting rut depths. A 1.8 m straight edge (measured manually or electronically from a surveyed transverse profile) is recommended.

6. The Summary Project Template should be used as a tool to document intersection treatments and be maintained with ongoing performance information. This Template can be used to facilitate the transfer of technology amongst C-TEP members.
8.0 CLOSURE

Respectfully submitted,

Principal Engineer, Materials and Pavements
EBA Engineering Consultants Ltd.

Hamid R. Soleymani, Ph.D., P.Eng.
Assistant Professor
Department of Civil and Environmental Engineering
University of Alberta

Art Johnston, C.E.T.
Principal Consultant
EBA Engineering Consultants Ltd.
APPENDIX A

MITIGATING PAVEMENT RUTTING AT INTERSECTIONS:
SUMMARY PROJECT TEMPLATES
MITIGATING PAVEMENT RUTTING AT INTERSECTIONS:
SUMMARY PROJECT TEMPLATE

AGENCY: City of Edmonton

CONTACT INFORMATION:
Name/Title: Hugh Donovan
Phone: 780-944-5666 Fax: 780-944-7707
Email: Hugh.Donovan@gov.edmonton.ab.ca
Other Information: N/A

PART I: PROJECT DESCRIPTION
Treatment/Strategy/Repair: Stone Matrix Asphalt
Location: 107 Avenue and 170 Street
Date of Treatment (mm/yy): 2003
Original Construction History: N/A

Pre-Treatment Condition: N/A

<table>
<thead>
<tr>
<th>Pre-Treatment Rut Depths:</th>
<th>&lt;12.5 mm</th>
<th>12.5-25 mm</th>
<th>&gt; 25 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Treatment Structural Evaluation:</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Pre-Treatment Test Pits, Coring, Trenches Carried Out</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Existing Traffic Volume:</td>
<td>AADT 19400</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Trucks</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daily ESALs</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

PART II – PERFORMANCE EVALUATION
Date Evaluated: N/A

Rut Depths: Location Description: N/A

<table>
<thead>
<tr>
<th></th>
<th>≤ 12.5 mm</th>
<th>12.5-25 mm</th>
<th>&gt; 25 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Observations:</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Date Evaluated: 

Rut Depths: Location Description: 

<table>
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MITIGATING PAVEMENT RUTTING AT INTERSECTIONS:
SUMMARY PROJECT TEMPLATE

**AGENCY:** City of Edmonton

**CONTACT INFORMATION:**
Name/Title: Hugh Donovan
Phone: 780-944-5666 Fax: 780-944-7707
Email: Hugh.Donovan@gov.edmonton.ab.ca
Other Information: N/A

**PART I: PROJECT DESCRIPTION**
Treatment/Strategy/Repair: Superpave Mix (PG64-34)
Location: Calgary Trail and South Side Whitemud CD Road Southbound and Intersection
Date of Treatment (mm/yy): 2001
Original Construction History: N/A
Pre-Treatment Condition: N/A

<table>
<thead>
<tr>
<th>Pre-Treatment Rut Depths:</th>
<th>&lt;12.5 mm</th>
<th>12.5-25 mm</th>
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<tbody>
<tr>
<td>Pre-Treatment Structural Evaluation:</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Pre-Treatment Test Pits, Coring, Trenches Carried Out</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

Existing Traffic Volume:
- AADT: N/A
- % Trucks: N/A
- Daily ESALs: N/A

**PART II – PERFORMANCE EVALUATION**
Date Evaluated: N/A
Rut Depths: Location Description: N/A

<table>
<thead>
<tr>
<th>Rut Depths: Location Description:</th>
<th>≤ 12.5 mm</th>
<th>12.5-25 mm</th>
<th>&gt; 25 mm</th>
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Date Evaluated:
Rut Depths: Location Description:

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Date Evaluated:
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**SUMMARY PROJECT TEMPLATE**

**AGENCY:** City of Edmonton  
**CONTACT INFORMATION:**  
Name/Title: Hugh Donovan  
Phone: 780-944-5666  
Fax: 780-944-7707  
Email: Hugh.Donovan@gov.edmonton.ab.ca  
Other Information: N/A

**PART I: PROJECT DESCRIPTION**
- **Treatment/Strategy/Repair:** Superpave Mix (PG64-34)  
- **Location:** Gateway Boulevard and South Side Whitemud CD Road Northbound and Intersection  
- **Date of Treatment (mm/yy):** 2001  
- **Original Construction History:** N/A  
- **Pre-Treatment Condition:** N/A  
- **Pre-Treatment Rut Depths:**  
  - [ ] ≤ 12.5 mm  
  - [ ] 12.5-25 mm  
  - [ ] > 25 mm  
- **Pre-Treatment Structural Evaluation:**  
  - [ ] Yes  
  - [ ] No  
- **Pre-Treatment Test Pits, Coring, Trenches Carried Out:**  
  - [ ] Yes  
  - [ ] No  
- **Existing Traffic Volume:**  
  - AADT: N/A  
  - % Trucks: N/A  
  - Daily ESALs: N/A

**PART II – PERFORMANCE EVALUATION**
- **Date Evaluated:** N/A  
- **Rut Depths: Location Description:** N/A  
  - [ ] ≤ 12.5 mm  
  - [ ] 12.5-25 mm  
  - [ ] > 25 mm  
- **General Observations:** N/A

Date Evaluated:  
**Rut Depths: Location Description:**  
- [ ] ≤ 12.5 mm  
- [ ] 12.5-25 mm  
- [ ] > 25 mm  
**General Observations:**

Date Evaluated:  
**Rut Depths: Location Description:**  
- [ ] ≤ 12.5 mm  
- [ ] 12.5-25 mm  
- [ ] > 25 mm  
**General Observations:**

Date Evaluated:  
**Rut Depths: Location Description:**  
- [ ] ≤ 12.5 mm  
- [ ] 12.5-25 mm  
- [ ] > 25 mm  
**General Observations:**
MITIGATING PAVEMENT RUTTING AT INTERSECTIONS:
SUMMARY PROJECT TEMPLATE

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Email: Hugh.Donovan@gov.edmonton.ab.ca
Other Information: N/A

PART I: PROJECT DESCRIPTION
Treatment/Strategy/Repair: Stone Matrix Asphalt (PG78-28) / 100 mm milling of existing HMA and 100 mm overlay with SMA.
Location: 23 Avenue & Calgary Trail
Date of Treatment (mm/yy): October 7/8, 2000
Original Construction History: Constructed in 1966, 410 mm HMA, 150 mm GB
Pre-Treatment Condition: Longitudinal cracking, rutting and raveling also some alligator cracking was observed before treatment.

Pre-Treatment Rut Depths:

| <12.5 mm | 12.5-25 mm | > 25 mm |

Pre-Treatment Structural Evaluation: Yes
Pre-Treatment Test Pits, Coring, Trenches Carried Out: Yes
Existing Traffic Volume: AADT 33700(NB) and 34300(SB)
% Trucks: 15% (NB) and 15% (SB)
Daily ESALs: 1213(NB) and 1235(SB)

PART II – PERFORMANCE EVALUATION
Date Evaluated: October 10, 2001
Rut Depths: Location Description: Southbound Direction

| ≤ 12.5 mm | 12.5-25 mm | > 25 mm |

General Observations: Generally this SMA section is working well. An average of 10 mm rut was measured.

Date Evaluated: September 19, 2002
Rut Depths: Location Description: Southbound Direction

| ≤ 12.5 mm | 12.5-25 mm | > 25 mm |

General Observations: An average of 15 mm rut was measured and section is performing well.

Date Evaluated:
Rut Depths: Location Description:

| ≤ 12.5 mm | 12.5-25 mm | > 25 mm |

General Observations:
MITIGATING PAVEMENT RUTTING AT INTERSECTIONS: SUMMARY PROJECT TEMPLATE

AGENCY: City of Edmonton

CONTACT INFORMATION:
Name/Title: Hugh Donovan
Phone: 780-944-5666 Fax: 780-944-7707
Email: Hugh.Donovan@gov.edmonton.ab.ca
Other Information: N/A

PART I: PROJECT DESCRIPTION
Treatment/Strategy/Repair: Superpave Mix (PG64-34) Milling 100 mm of existing asphalt concrete and placement of 100 mm of Superpave Mix.
Location: Gateway Boulevard Northbound & 34 Ave
Date of Treatment (mm/yy): July 04 & 05, 2001
Original Construction History: N/A (but this section was last rehabilitated in 1997) 100 mm milled and 100 mm filled by ACO

Pre-Treatment Condition: N/A

Pre-Treatment Rut Depths:  
- 0-mm
- ≤ 12.5 mm
- 12.5-25 mm
- > 25 mm

Pre-Treatment Structural Evaluation:  
- Yes
- No

Pre-Treatment Test Pits, Coring, Trenches Carried Out:  
- Yes
- No

Existing Traffic Volume:  
- AADT: 33,700
- % Trucks: 15%
- Daily ESALs: 1213

PART II – PERFORMANCE EVALUATION
Date Evaluated: July 15, 2001
Rut Depths: Location Description: Gateway Boulevard Northbound & 34 Ave
- 0-mm
- ≤ 12.5 mm
- 12.5-25 mm
- > 25 mm

General Observations: Measure rutting just after 10 days and it was zero

Date Evaluated: August 17, 2001
Rut Depths: Location Description:
- 0-mm
- ≤ 12.5 mm
- 12.5-25 mm
- > 25 mm

General Observations: Average 5 mm rut was measured on lane 3, 4(turn) and 5(turn) while 16 mm rut was measured on lane 1 and lane 2.

Date Evaluated: Sept 19, 2002
Rut Depths: Location Description:
- 0-mm
- ≤ 12.5 mm
- 12.5-25 mm
- > 25 mm

General Observations: Average of 17 mm rut was measured after one year two months.
MITIGATING PAVEMENT RUTTING AT INTERSECTIONS:
SUMMARY PROJECT TEMPLATE

AGENCY: City of Edmonton

CONTACT INFORMATION:
Name/Title: Hugh Donovan
Phone: 780-944-5666 Fax: 780-944-7707
Email: Hugh.Donovan@gov.edmonton.ab.ca
Other Information: N/A

PART I: PROJECT DESCRIPTION
Treatment/Strategy/Repair: Superpave Mix (PG64-34) Milling 100 mm of existing asphalt concrete and placement of 100 mm of Superpave Mix.
Location: Calgary Trail Southbound & 34 Avenue
Date of Treatment (mm/yy): July 04 & 05, 2001
Original Construction History: N/A (but this section was last rehabilitated in 1997) 100 mm milled and 100 mm filled by ACO

Pre-Treatment Condition: N/A
Pre-Treatment Rut Depths: □ <12.5 mm □ 12.5-25 mm √ □ > 25 mm
Pre-Treatment Structural Evaluation: √ Yes □ No
Pre-Treatment Test Pits, Coring, Trenches Carried Out: □ Yes □ No
Existing Traffic Volume: AADT 34,300
% Trucks 15%
Daily ESALs 1235

PART II – PERFORMANCE EVALUATION
Date Evaluated: July 15, 2001
Rut Depths: Location Description: Calgary trail and 34 Ave SB
□ 0-mm □ ≤ 12.5 mm □ 12.5-25 mm □ > 25 mm
General Observations: Measure rutting just after 10 days and it was zero

Date Evaluated: August 17, 2001
Rut Depths: Location Description: Average 7 mm rut was measured on lane 3,4(turn) and 5(turn) while 16 mm rut was measured on lane 1 and lane 2.
□ 0-mm √ □ ≤ 12.5 mm □ 12.5-25 mm □ > 25 mm
General Observations: 

Date Evaluated: Sept 19, 2002
Rut Depths: Location Description: Average of 21 mm rut was measured after one year two months.
□ 0-mm □ ≤ 12.5 mm √ □ 12.5-25 mm □ > 25 mm
General Observations:
MITIGATING PAVEMENT RUTTING AT INTERSECTIONS:
SUMMARY PROJECT TEMPLATE

AGENCY: City of Edmonton

CONTACT INFORMATION:
Name/Title: Hugh Donovan
Phone: 780-944-5666 Fax: 780-944-7707
Email: Hugh.Donovan@gov.edmonton.ab.ca
Other Information: N/A

PART I: PROJECT DESCRIPTION
Treatment/Strategy/Repair: 200 mm of RCC with 50 mm of ACO (milling and filling)
Location: 170 Street and 87th Avenue
Date of Treatment (mm/yy): May 24 to 26, 2002
Original Construction History:
Originally constructed in 1953 original pavement thicknesses were
200 HMA, 150 mm of cement base and 150 mm of soil cement.

Pre-Treatment Condition: N/A
Pre-Treatment Rut Depths: N/A
Pre-Treatment Structural Evaluated: Yes
Pre-Treatment Test Pits, Coring, Trenches Carried Out: Yes
Existing Traffic Volume: AADT 60,600 (Northbound), 54,500 (Southbound)
% Trucks: 15% (Northbound), 15% (Southbound)
Daily ESALs: 2182 (Northbound), 1962 (Southbound)

PART II – PERFORMANCE EVALUATION
Date Evaluated: October, 2002
Rut Depths: Location Description: North and southbound direction of 170 street-87th avenue

<table>
<thead>
<tr>
<th>Rut Depths</th>
<th>Location Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-mm</td>
<td>0-mm</td>
</tr>
<tr>
<td>≤ 12.5 mm</td>
<td>≤ 12.5 mm</td>
</tr>
<tr>
<td>12.5-25 mm</td>
<td>12.5-25 mm</td>
</tr>
<tr>
<td>&gt; 25 mm</td>
<td>&gt; 25 mm</td>
</tr>
</tbody>
</table>

General Observations:
There was 6-7 mm rut measured after 5 months of RCC treatment. It is difficult to judge the performance in very short span of time.

Date Evaluated: N/A
Rut Depths: Location Description:

<table>
<thead>
<tr>
<th>Rut Depths</th>
<th>Location Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 12.5 mm</td>
<td>≤ 12.5 mm</td>
</tr>
<tr>
<td>12.5-25 mm</td>
<td>12.5-25 mm</td>
</tr>
<tr>
<td>&gt; 25 mm</td>
<td>&gt; 25 mm</td>
</tr>
</tbody>
</table>

General Observations:

Date Evaluated: N/A
Rut Depths: Location Description:

<table>
<thead>
<tr>
<th>Rut Depths</th>
<th>Location Description</th>
</tr>
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<tbody>
<tr>
<td>≤ 12.5 mm</td>
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</tr>
<tr>
<td>12.5-25 mm</td>
<td>12.5-25 mm</td>
</tr>
<tr>
<td>&gt; 25 mm</td>
<td>&gt; 25 mm</td>
</tr>
</tbody>
</table>

General Observations:
# Mitigating Pavement Rutting at Intersections

## Summary Project Template

**Agency:** City of Edmonton

**Contact Information:**
- **Name/Title:** Hugh Donovan
- **Phone:** 780-944-5666
- **Fax:** 780-944-7707
- **Email:** Hugh.Donovan@gov.edmonton.ab.ca

### Part I: Project Description

**Treatment/Strategy/Repair:** Stone Matrix Asphalt (PG78-28) Milling 100 mm of existing HMA and overlay with 100 mm SMA

**Location:** St. Albert Trail and 137 Avenue

**Date of Treatment (mm/yy):** July 8/9, 2000

**Original Construction History:** This pavement was originally constructed in 1966, and the thicknesses were 410 mm (HMA) & 150 mm (GB)

**Pre-Treatment Condition:** N/A

<table>
<thead>
<tr>
<th>Pre-Treatment Rut Depths</th>
<th>&lt;12.5 mm</th>
<th>12.5-25 mm</th>
<th>&gt; 25 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Treatment Structural Evaluation</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Pre-Treatment Test Pits, Coring, Trenches Carried Out</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

**Existing Traffic Volume:**
- **AADT:** 45400
- **% Trucks:** 10%
- **Daily ESALs:** 1090

### Part II – Performance Evaluation

**Date Evaluated:** August 17, 2001

**Rut Depths:** Location Description: North, South, Westbound and East Directions

<table>
<thead>
<tr>
<th>≤ 12.5 mm</th>
<th>12.5-25 mm</th>
<th>&gt; 25 mm</th>
</tr>
</thead>
</table>

**General Observations:** After one year of performance this section demonstrating an average rut depth of more than 25 mm in all the directions.

**Date Evaluated:** September 19, 2002

**Rut Depths:** Location Description: North, South, Westbound and East Directions

<table>
<thead>
<tr>
<th>≤ 12.5 mm</th>
<th>12.5-25 mm</th>
<th>&gt; 25 mm</th>
</tr>
</thead>
</table>

**General Observations:** It was evaluated the average rut depth after two year was more than 25 mm so this section is showing poor performance of SMA.

**Date Evaluated:**

**Rut Depths:** Location Description:

<table>
<thead>
<tr>
<th>≤ 12.5 mm</th>
<th>12.5-25 mm</th>
<th>&gt; 25 mm</th>
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**General Observations:**
MITIGATING PAVEMENT RUTTING AT INTERSECTIONS:
SUMMARY PROJECT TEMPLATE

AGENCY: City of Edmonton

CONTACT INFORMATION:
Name/Title: Hugh Donovan
Phone: 780-944-5666 Fax: 780-944-7707
Email: Hugh.Donovan@gov.edmonton.ab.ca
Other Information: N/A

PART I: PROJECT DESCRIPTION
Treatment/Strategy/Repair: Stone Matrix Asphalt (PG78-28) / 100 mm milling of existing HMA and
100 mm overlay with SMA.
Location: 97- Street Southbound curb lane b/w 127 Avenue and 135-Avenue
Date of Treatment (mm/yy): October 26/27, 2002
Original Construction History: Originally constructed in 1953 the original pavement thicknesses were
200 mm HMA, 150 mm Concrete base and 150 mm of Soil cement.

Pre-Treatment Condition: Raveling, Transverse cracking, Longitudinal cracking and Rutting were observed
during the condition survey the VCI of this section was 6.1 before treatment.

Pre-Treatment Rut Depths: □ <12.5 mm □ 12.5-25 mm □ > 25 mm
Pre-Treatment Structural Evaluation: □ Yes □ No
Pre-Treatment Test Pits, Coring, Trenches Carried Out □ Yes □ No
Existing Traffic Volume: AADT 49203
% Trucks 4%
Daily ESALs 472

PART II – PERFORMANCE EVALUATION
Date Evaluated: November 2002
Rut Depths: Location Description:
□ □ ≤ 12.5 mm □ 12.5-25 mm □ > 25 mm
General Observations: The average rut of this 1210-m section was 7 mm after one month of
treatment.

Date Evaluated: N/A
Rut Depths: Location Description:
□ □ ≤ 12.5 mm □ 12.5-25 mm □ > 25 mm
General Observations:

Date Evaluated:
Rut Depths: Location Description:
□ □ ≤ 12.5 mm □ 12.5-25 mm □ > 25 mm
General Observations:
MITIGATING PAVEMENT RUTTING AT INTERSECTIONS:
SUMMARY PROJECT TEMPLATE

AGENCY: City of Edmonton

CONTACT INFORMATION:
Name/Title: Hugh Donovan
Phone: 780-944-5666 Fax: 780-944-7707
Email: Hugh.Donovan@gov.edmonton.ab.ca
Other Information: N/A

PART I: PROJECT DESCRIPTION

Treatment/Strategy/Repair: Ultra-Thin White Topping (UTW)/ 100 mm milled the section of existing HMA and replaced it by 100 mm fibre reinforced Ultra-Thin Whitetopping.
Location: 118 Avenue-170 Street
Date of Treatment (mm/yy): June 8th, 2002 for (Eastbound) and June 15th, 2002 for (Westbound).

Original Construction History: Originally constructed in 1978 the original pavement thicknesses were 280 mm HMA, 150 mm of Soil cement and 150 mm Cement stabilized sub-grade.

Pre-Treatment Condition: Poor VCI (2.1) @ Eastbound and (4.5) @ Westbound directions distresses like raveling, rutting, transverse cracks, longitudinal cracks and alligator cracks were observed before treatment.

Pre-Treatment Rut Depths:
- □ <12.5 mm
- □ 12.5-25 mm
- □ > 25 mm

Pre-Treatment Structural Evaluated:
- □ Yes
- □ No

Pre-Treatment Test Pits, Coring, Trenches Carried Out:
- □ Yes
- □ No

Existing Traffic Volume:
- AADT: 21,700 (Eastbound), 17,505 (Westbound)
- % Trucks: 15% (Eastbound), 3% (Westbound)
- Daily ESALs: 781 (Eastbound), 126 (Westbound)

PART II – PERFORMANCE EVALUATION

Date Evaluated: Date N/A (but there is no rutting since treatment with UTW)
Rut Depths: Location Description:
- □ 0-mm
- □ ≤ 12.5 mm
- □ 12.5-25 mm
- □ > 25 mm

General Observations: The Ultra-Thin whitetopping seems to be a good treatment method for rutted intersections.

Date Evaluated: N/A
Rut Depths: Location Description:
- □ ≤ 12.5 mm
- □ 12.5-25 mm
- □ > 25 mm

General Observations:

Date Evaluated: N/A
Rut Depths: Location Description:
- □ ≤ 12.5 mm
- □ 12.5-25 mm
- □ > 25 mm

General Observations:
# Mitigating Pavement Rutting at Intersections

## Summary Project Template

**Agency:** City of Edmonton

**Contact Information:**
- **Name/Title:** Hugh Donovan
- **Phone:** 780-944-5666
- **Fax:** 780-944-7707
- **Email:** Hugh.Donovan@gov.edmonton.ab.ca
- **Other Information:** N/A

## Part I: Project Description

- **Treatment/Strategy/Repair:** Stone Matrix Asphalt
- **Location:** Wayne Gretzky Drive and 118 Av.
- **Date of Treatment (mm/yy):** 2003
- **Original Construction History:** N/A
- **Pre-Treatment Condition:** N/A
- **Pre-Treatment Rut Depths:**
  - $< 12.5$ mm
  - $12.5 - 25$ mm
  - $> 25$ mm
- **Pre-Treatment Structural Evaluation:** Yes
- **Pre-Treatment Test Pits, Coring, Trenches Carried Out:** Yes
- **Existing Traffic Volume:**
  - AADT: 18900
  - % Trucks: N/A
  - Daily ESALs: N/A

## Part II – Performance Evaluation

- **Date Evaluated:** N/A
- **Rut Depths:** Location Description: N/A
  - $\leq 12.5$ mm
  - $12.5 - 25$ mm
  - $> 25$ mm
- **General Observations:** N/A

- **Date Evaluated:**
- **Rut Depths:** Location Description:
  - $\leq 12.5$ mm
  - $12.5 - 25$ mm
  - $> 25$ mm
- **General Observations:**

- **Date Evaluated:**
- **Rut Depths:** Location Description:
  - $\leq 12.5$ mm
  - $12.5 - 25$ mm
  - $> 25$ mm
- **General Observations:**
MITIGATING PAVEMENT RUTTING AT INTERSECTIONS:
SUMMARY PROJECT TEMPLATE

AGENCY: City of Edmonton

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Name/Title: Hugh Donovan
Phone: 780-944-5666 Fax: 780-944-7707
Email: Hugh.Donovan@gov.edmonton.ab.ca
Other Information: N/A

PART I: PROJECT DESCRIPTION
Treatment/Strategy/Repair: Stone Matrix Asphalt
Location: Yellowhead Trail b/w 124 and 121 Street. East and Westbound
Date of Treatment (mm/yy): 2003
Original Construction History: N/A

Pre-Treatment Condition: N/A

Pre-Treatment Rut Depths: 
- < 12.5 mm
- 12.5-25 mm
- > 25 mm

Pre-Treatment Structural Evaluation: Yes No

Pre-Treatment Test Pits, Coring, Trenches Carried Out Yes No

Existing Traffic Volume:
- AADT: 76500
- % Trucks: 10
- Daily ESALs: 1836

PART II – PERFORMANCE EVALUATION
Date Evaluated: N/A

Rut Depths: Location Description: N/A
- ≤ 12.5 mm
- 12.5-25 mm
- > 25 mm

General Observations: N/A

Date Evaluated: ________________________________

Rut Depths: Location Description: ________________________________
- ≤ 12.5 mm
- 12.5-25 mm
- > 25 mm

General Observations: ________________________________

Date Evaluated: ________________________________

Rut Depths: Location Description: ________________________________
- ≤ 12.5 mm
- 12.5-25 mm
- > 25 mm

General Observations: ________________________________
MITIGATING PAVEMENT RUTTING AT INTERSECTIONS:
SUMMARY PROJECT TEMPLATE

AGENCY: City of Calgary

CONTACT INFORMATION:
Name/Title: Ken Yeung
Phone: 403-268-5016 Fax: 403-268-1861
Email: ken.yeung@calgary.ca
Other Information: N/A

PART I: PROJECT DESCRIPTION
Treatment/Strategy/Repair: Polymer Modified Asphalt (Black Max), Overlaid
Location: 16th Avenue and Bowfort Road
Date of Treatment (mm/yy): June 10th 2003
Original Construction History:
Pre-Treatment Condition: Severely rutted before construction
Pre-Treatment Rut Depths: <12.5 mm 12.5-25 mm > 25 mm
Pre-Treatment Structural Evaluation: Yes No
Pre-Treatment Test Pits, Coring, Trenches Carried Out: Yes No
Existing Traffic Volume: AADT One-day traffic counts 4896 NB (08/03/2000), 6510 SB (08/03/2000), 23449 EB (07/28/2000) and 24217 WB (07/28/2000).

PART II – PERFORMANCE EVALUATION
Date Evaluated: July 30th 2003
Rut Depths: Location Description:
≤ 12.5 mm 12.5-25 mm > 25 mm
General Observations: This section of pavement exhibiting not very good performance and showing the rut depth from 2 mm to 15 mm at various points although the surface texture is still in excellent condition, but in some area asphalt binder has bled to the surface.

Date Evaluated:
Rut Depths: Location Description:
≤ 12.5 mm 12.5-25 mm > 25 mm
General Observations:

Date Evaluated:
Rut Depths: Location Description:
≤ 12.5 mm 12.5-25 mm > 25 mm
General Observations:
MITIGATING PAVEMENT RUTTING AT INTERSECTIONS:
SUMMARY PROJECT TEMPLATE

AGENCY: City of Calgary

CONTACT INFORMATION:
Name/Title: Ken Yeung
Phone: 403-268-5016 Fax: 403-268-1861
Email: ken.yeung@calgary.ca
Other Information: N/A

PART I: PROJECT DESCRIPTION
Treatment/Strategy/Repair: Polymer Modified Asphalt (Black Max), Overlaid
Location: Glenmore Trail and Barlow Trail
Date of Treatment (mm/yy): June 6th 1999

Original Construction History:

<table>
<thead>
<tr>
<th>Pre-Treatment Condition</th>
<th>Severeley rutted before construction</th>
</tr>
</thead>
</table>

Pre-Treatment Rut Depths:

<table>
<thead>
<tr>
<th>Depth Range</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;12.5 mm</td>
<td></td>
</tr>
<tr>
<td>12.5-25 mm</td>
<td></td>
</tr>
<tr>
<td>&gt;25 mm</td>
<td></td>
</tr>
</tbody>
</table>

Pre-Treatment Structural Evaluation:

<table>
<thead>
<tr>
<th>Structural Evaluation</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

Pre-Treatment Test Pits, Coring, Trenches Carried Out:

<table>
<thead>
<tr>
<th>Carried Out</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

Existing Traffic Volume:

<table>
<thead>
<tr>
<th>Traffic Volume</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>AADT</td>
<td></td>
</tr>
</tbody>
</table>

One-day traffic count 15615 NB Barlow Trail (07/15/2002) and 9475 EB Glenmore Trail (08/26/2002).

<table>
<thead>
<tr>
<th>Traffic Volume</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Trucks</td>
<td>26% NB and 20% EB (based on 6 hrs intersection count) July 30, 2001</td>
</tr>
</tbody>
</table>

Daily ESALs:

<table>
<thead>
<tr>
<th>ESALs</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

PART II – PERFORMANCE EVALUATION
Date Evaluated: July 30th 2003

Rut Depths: Location Description:

<table>
<thead>
<tr>
<th>Depth Range</th>
<th>Location Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤12.5 mm</td>
<td></td>
</tr>
<tr>
<td>12.5-25 mm</td>
<td></td>
</tr>
<tr>
<td>&gt;25 mm</td>
<td></td>
</tr>
</tbody>
</table>

General Observations:

After 4-years of service this section of pavement was not performed very well, but fair amount of rutting is present with a depth varying from 21 mm to 30 mm on Glenmore trail eastbound and 22 mm to 46 mm on Barlow trail northbound.

Date Evaluated:

Rut Depths: Location Description:

<table>
<thead>
<tr>
<th>Depth Range</th>
<th>Location Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤12.5 mm</td>
<td></td>
</tr>
<tr>
<td>12.5-25 mm</td>
<td></td>
</tr>
<tr>
<td>&gt;25 mm</td>
<td></td>
</tr>
</tbody>
</table>

General Observations:

Date Evaluated:

Rut Depths: Location Description:

<table>
<thead>
<tr>
<th>Depth Range</th>
<th>Location Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤12.5 mm</td>
<td></td>
</tr>
<tr>
<td>12.5-25 mm</td>
<td></td>
</tr>
<tr>
<td>&gt;25 mm</td>
<td></td>
</tr>
</tbody>
</table>

General Observations:
MITIGATING PAVEMENT Rutting at Intersections: Summary Project Template

AGENCY: City of Calgary

CONTACT INFORMATION:
Name/Title: Ken Yeung
Phone: 403-268-5016 Fax: 403-268-1861
Email: ken.yeung@calgary.ca
Other Information: N/A

PART I: PROJECT DESCRIPTION
Treatment/Strategy/Repair: Polymer Modified Asphalt (Black Max), Overlay (milled 150 mm and replaced with 115 mm of PMA base course and 35 mm of PMA overlay)
Location: 16 Avenue 19th Street NE
Date of Treatment (mm/yy): September 9th 1988
Original Construction History: Not available

Pre-Treatment Condition: Raveling, Transverse cracking, Longitudinal cracking and Rutting were observed before construction.

Pre-Treatment Rut Depths: ❑ <12.5 mm ❑ 12.5-25 mm √ > 25 mm
Pre-Treatment Structural Evaluation: ❑ Yes √ No
Pre-Treatment Test Pits, Coring, Trenches Carried Out: ❑ Yes √ No
Existing Traffic Volume: AADT
One-day traffic counts 24,151 EB (08/10/1989) and 27,439 WB (08/10/1989).
% Trucks
5% EB and 5% WB (based on 6-hrs intersection count)
May 9, 2003.

PART II – PERFORMANCE EVALUATION
Date Evaluated: July 30th 1990
Rut Depths: Location Description:
❑ ❑ < 12.5 mm ❑ 12.5-25 mm √ > 25 mm
General Observations: Rut depth was 5 mm on westbound lanes and on east bound lanes it was occurred significant.

Date Evaluated: July 30th 1992
Rut Depths: Location Description:
❑ ❑ < 12.5 mm ❑ 12.5-25 mm √ > 25 mm
General Observations: On westbound lanes rut depth was 5 mm while on eastbound lanes it was 25-30-mm.

Date Evaluated: July 30th 2003
Rut Depths: Location Description:
❑ ❑ < 12.5 mm ❑ 12.5-25 mm √ > 25 mm
General Observations: On westbound lanes rut depth was 15-20 mm while on eastbound lanes it was 26-31-mm.
MITIGATING PAVEMENT RUTTING AT INTERSECTIONS:
SUMMARY PROJECT TEMPLATE

AGENCY: City of Calgary

CONTACT INFORMATION:
Name/Title: Ken Yeung
Phone: 403-268-5016 Fax: 403-268-1861
Email: ken.yeung@calgary.ca
Other Information: N/A

PART I: PROJECT DESCRIPTION
Treatment/Strategy/Repair: Polymer Modified Asphalt (Black Max), 50 mm milled and 50 mm PMA thin overlay.
Location: Macleod Trail SE and 5th Avenue
Date of Treatment (mm/yy): August 10th 1986
Original Construction History: Last overlaid in 1984
Pre-Treatment Condition: Raveling, Transverse cracking, Longitudinal cracking and Rutting were observed before construction.
Pre-Treatment Rut Depths: □ <12.5 mm □ 12.5-25 mm □ > 25 mm
Pre-Treatment Structural Evaluation: □ Yes □ No
Pre-Treatment Test Pits, Coring, Trenches Carried Out: □ Yes □ No
Existing Traffic Volume: AADT One-day traffic counts 7610 north of intersection 5th Ave SE and Macleod Trail SE (08/01/2002)
% Trucks 3% SB (based on 6-hrs intersection count) July 26,2000.
Daily ESALs -

PART II – PERFORMANCE EVALUATION
Date Evaluated: June 1st 1991
Rut Depths: Location Description:
□ □ □ □ 
General Observations: Moderate rutting was observed b/w 10-12-mm

Date Evaluated: July 1st 1993
Rut Depths: Location Description:
□ □ □ □ 
General Observations: No sign of raveling and cracking, surface texture was good

Date Evaluated: July 30th 2003
Rut Depths: Location Description:
□ □ □ □ 
General Observations: The 2003, data shows significant amount of rutting present in the centre lanes of this section of pavement, while the outside lanes are performing very well.
MITIGATING PAVEMENT RUTTING AT INTERSECTIONS:
SUMMARY PROJECT TEMPLATE

AGENCY: City of Calgary

CONTACT INFORMATION:
Name/Title: Ken Yeung
Phone: 403-268-5016 Fax: 403-268-1861
Email: ken.yeung@calgary.ca
Other Information: N/A

PART I: PROJECT DESCRIPTION
Treatment/Strategy/Repair: Polymer Modified Asphalt (Black Max), (Rehabilitated)
Location: McKnight Boulevard and Barlow Trail
Date of Treatment (mm/yy): July 25th 1998
Original Construction History: Pre-Treatment Condition: Severely rutted before construction

Pre-Treatment Rut Depths:
- Yes <12.5 mm
- Yes 12.5-25 mm
- Yes > 25 mm
Pre-Treatment Structural Evaluated: Yes
Pre-Treatment Test Pits, Coring, Trenches Carried Out: Yes

Existing Traffic Volume: AADT
One-day traffic counts 10230 NB (09/18/2002) and 25353 WB (07/30/2003).

PART II – PERFORMANCE EVALUATION
Date Evaluated: July 30th 2003

Rut Depths: Location Description:
- ≤ 12.5 mm
- 12.5-25 mm
- > 25 mm

General Observations: This section of pavement was showing the excellent performance after 5-years of service. The surface texture of westbound of McKnight Boulevard and northbound of Barlow Trail was very good. There was no raveling and cracking observed after five years.

Date Evaluated:
Rut Depths: Location Description:
- ≤ 12.5 mm
- 12.5-25 mm
- > 25 mm

General Observations:

Date Evaluated:
Rut Depths: Location Description:
- ≤ 12.5 mm
- 12.5-25 mm
- > 25 mm

General Observations:
MITIGATING PAVEMENT RUTTING AT INTERSECTIONS:
SUMMARY PROJECT TEMPLATE

AGENCY: Strathcona County

CONTACT INFORMATION:
Name/Title: Bob Horton
Phone: 780-464-8175 Fax: N/A
Email: Hortonr@Strathcona.ab.ca
Other Information: N/A

PART I: PROJECT DESCRIPTION
Treatment/Strategy/Repair:
Polymer Modified Asphalt (PMA)+Asphalt Rubber Concrete (AR), milling 100 mm and overlay 40 mm (PMA) and on top of that 60 mm (AR). 17th Street Southbound Lanes (210-m) and Baseline Road left Turn Lane (130-m) only.

Location: 17th Street and Baseline Road
Date of Treatment (mm/yy): June 29th, 2002
Original Construction History:
Average 372 mm ACP (17th Street Southbound Lanes) and Average 515 mm ACP (Baseline Road left Turn Lane).

Pre-Treatment Condition:
Longitudinal cracking, rutting, raveling also some alligator cracking and patches were observed before treatment. (Survey carried out on June 10th, 2002)

Pre-Treatment Rut Depths:

<table>
<thead>
<tr>
<th>Depth</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;12.5 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.5-25 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 25 mm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Pre-Treatment Structural Evaluation:

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Pre-Treatment Test Pits, Coring, Trenches Carried Out:

<table>
<thead>
<tr>
<th>Carried Out</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Existing Traffic Volume:
AADT 4745 (17th Street southbound south of Baseline road).

<table>
<thead>
<tr>
<th>% Trucks</th>
<th>Daily ESALs</th>
</tr>
</thead>
<tbody>
<tr>
<td>12%</td>
<td>1180</td>
</tr>
</tbody>
</table>

PART II – PERFORMANCE EVALUATION
Date Evaluated: August 26, 2002
Rut Depths: Location Description: (17th Street southbound south of Baseline road).

<table>
<thead>
<tr>
<th>Depth</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 12.5 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.5-25 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 25 mm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

General Observations: Average 4 mm rut was observed during performance evaluation.

Date Evaluated: N/A
Rut Depths: Location Description:

<table>
<thead>
<tr>
<th>Depth</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 12.5 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.5-25 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 25 mm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

General Observations:

Date Evaluated:
Rut Depths: Location Description:

<table>
<thead>
<tr>
<th>Depth</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 12.5 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.5-25 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 25 mm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

General Observations:
APPENDIX B

RUT MITIGATION PROJECTS
BY EDMONTON AND CALGARY
APPENDIX B: RUT MITIGATION PROJECTS BY EDMONTON AND CALGARY

B.1 Introduction

This Appendix provides detailed pre- and post-construction data for pavement rutting mitigation at intersection projects constructed by the Cities of Edmonton and Calgary.

Different materials and practices that have been used in Edmonton and Calgary to mitigate rutting at intersections are:

- Stone Matrix Asphalt (SMA),
- Ultra-Thin white topping (UTW),
- Roller Compacted Concrete (RCC),
- Superpave Asphalt Mix,
- Polymer Modified Asphalt (PMA).

This data could be used to evaluate effectiveness of different methods and practices for mitigation of rutting at intersections by collecting more performance data in the future.

B.2 City of Edmonton SMA Projects

The latest traffic data including Annual Average Daily Traffic (AADT) and truck percentage for all SMA intersections in Edmonton are reported in Table B.1. All of these intersections have a high traffic volume. Truck percentage reaches a maximum of 15% in some of these intersections.

Table B.1: Traffic Data for SMA Intersections in Edmonton
(Source: City of Edmonton)

<table>
<thead>
<tr>
<th>Location</th>
<th>Trucks %</th>
<th>AADT</th>
</tr>
</thead>
<tbody>
<tr>
<td>St. Albert Trail and 137 Avenue</td>
<td>10</td>
<td>45,400</td>
</tr>
<tr>
<td>23 Avenue and Calgary Trail (Northbound)</td>
<td>15</td>
<td>33,700</td>
</tr>
<tr>
<td>23 Avenue and Calgary Trail (Southbound)</td>
<td>15</td>
<td>34,300</td>
</tr>
<tr>
<td>97 Street Southbound and 127 Avenue</td>
<td>4</td>
<td>49,203</td>
</tr>
<tr>
<td>Yellowhead Trail and 124 Street</td>
<td>N/A</td>
<td>76,500</td>
</tr>
<tr>
<td>Wayne Gretzky Drive Northbound and 118 Avenue</td>
<td>N/A</td>
<td>18,900</td>
</tr>
<tr>
<td>107 Avenue and 170 Street</td>
<td>N/A</td>
<td>19,400</td>
</tr>
</tbody>
</table>
Several road sections and intersections were paved with SMA during 2000-2003 in Edmonton. These intersections are located at:

- St. Albert Trail and 137 Avenue (2000),
- 23 Avenue and Calgary Trail (2000),
- 97 Street Southbound bus lane between 127 and 135 Avenue (2002),
- Yellowhead Trail Eastbound from approximately 100 m West of 124 Street to approximately 150 m West of 121 Street (2003),
- Wayne Gretzky Drive Northbound and 118 Avenue (2003),
- 107 Avenue and 170 Street (2003).

Traffic, materials, mix design, and performance data, for sections paved with SMA in 2000 and 2002 are reported here.

**B.2.1 2000 SMA Projects**

Two intersections, 23 Avenue and Calgary Trail and St. Albert Trail and 137 Avenue intersections, were paved with SMA in year 2000. Based on City of Edmonton reports, the mix placed was deficient and did not meet the mix design in material passing 0.080 mm sieve. This mix was over-asphalted with a gap-graded gradation. Both of these pavement sections showed high rutting in a short time after rehabilitation. The pavement intersection in the northbound lanes at 23 Avenue and Calgary Trail was removed 45 days after paving and all directions of this intersection were replaced by a modified SMA with PG 76-28 binder. Pavement placed at the St. Albert and 137 Avenue Intersection, in spite of the early high deformation, is still in place. The City of Edmonton has monitored the rut progression of these two intersections after rehabilitation. For all 2000 SMA intersections in Edmonton, the rut depths were measured using a 1.2 m straight edge and a calibrated wedge. The rut depths are maximum values measured behind the stop line. The location of the maximum rut depth varies from intersection to intersection.

**B.2.1.1 St. Albert Trail and 137 Avenue**

This section of pavement was originally constructed in 1966 with conventional Hot Mix Asphalt (HMA). The original pavement thickness consisted of 410 mm conventional asphalt and 150 mm of granular base. This section of road was milled and overlaid with 50 mm conventional HMA in 1995. Considering that conventional asphalt pavement was rehabilitated in July 2000, it can be concluded that conventional asphalt pavement
lasted only five years at this intersection. Figure B.1 shows the layout of SMA rehabilitation at this intersection.

![Diagram of SMA Treatment of 137 Avenue and St. Albert Trail Intersection]

**Figure B.1: SMA Treatment of 137 Avenue and St. Albert Trail Intersection**

Figures B.2 to B.5 show rutting progress at all directions of St. Albert Trail and 137 intersection after rehabilitation. As it can be seen, there was rapid pavement rutting during the first weeks after rehabilitation. This early pavement plastic deformation reached 15 to 25 mm. After that early rapid rutting, rutting rate became lower however; it reached up to 54 mm for some directions after 2 years. The higher rutting progress during specific time periods could be due to higher traffic volumes and higher pavement temperatures during summer times. It is interesting that rutting progression was of a lower rate during the colder periods of the year. Both east-west and north-south directions show up to 55 mm rutting which could be an indication of similar traffic volume in both directions.

In general, this section of pavement exhibited a poor performance, in terms of rutting resistance, because of deficiencies in mix design and high traffic. An early opening of the road to traffic could be another possible reason for early failure of this pavement.
Figure B.2: Inner Wheelpath (IWP) and Outer Wheelpath (OWP) Rutting in Southbound (SB) Lanes of St. Albert Trail and 137 Avenue

Figure B.3: IWP and OWP Rutting in NB Lanes of St. Albert Trail and 137 Avenue
Figure B.4: IWP and OWP Rutting in WB Lanes of St. Albert Trail and 137 Avenue

Figure B.5: IWP and OWP Rutting in EB Lanes of St. Albert Trail and 137 Avenue
B.2.1.2 23 Avenue and Gateway Blvd.

This pavement section was originally constructed in 1966. The original pavement thickness was 410 mm conventional HMA and 150 mm of granular base. This section was milled and filled with 50 mm of conventional HMA in 1995. Similar to the St. Albert Trail and 137 Avenue intersection, the conventional HMA was left in service only five years. On August 2000, the City of Edmonton milled the rutted conventional pavement and paved the northbound portion of the intersection with the SMA. Figure B.6 shows the layout of the SMA rehabilitation at this intersection. SMA mix used at this intersection was deficient and failed in a short time after paving. After 45 days the rutted area was milled and replaced with a modified SMA incorporating PG binder.

![Layout of Treatment for 23 Avenue and Gateway Blvd Intersection](image)

Figure B.6: SMA Treatment of 23 Avenue and Gateway Blvd. Intersection

Figure B.7 shows rutting performance of the first SMA placed on the NB lanes of this intersection. As it can be seen, the pavement rutting reached to 22 mm in less than 35 days after paving. This pavement was removed and all directions of this intersection paved with a new modified SMA with a revised aggregate gradation and PG76-28. Figures B.8 to B.11 show pavement rutting progress for modified SMA for different lanes of this intersection until the year 2003. This modified SMA pavement material showed a better rutting performance compared to first SMA during its first year of service. Measured rutting on different directions of this intersection show cycles of high
and slow progress of rutting during specific times of its service life. This behaviour could be attributed to a combination of higher traffic and/or higher pavement temperature during summer times. The highest rutting was at NB lane 1, which has reached to 45 mm. The maximum measured rutting in the north-south direction is approximately twice the measured rutting at the east-west direction. This could be due to difference in traffic volume in these directions.

![Figure B.7: IWP and OWP Rutting of First SMA in NB Lanes of 23 Ave. and Gateway Blvd. Intersection](image-url)
Figure B.8: IWP and OWP Rutting of Modified SMA in NB Lanes of 23 Ave. and Gateway Blvd. Intersection

Figure B.9: IWP and OWP Rutting of Modified SMA in SB Lanes of 23 Ave. and Gateway Blvd. Intersection
Figure B.10: IWP and OWP Rutting of Modified SMA in EB Lanes of 23 Ave. and Gateway Blvd. Intersection

Figure B.11: IWP and OWP Rutting of Modified SMA in WB Lanes of 23 Ave. and Gateway Blvd. Intersection
B.2.2 2002 SMA Project

B.2.2.1 97 Street Southbound Bus Lane

This road was originally constructed in 1953. The original pavement thickness was 200 mm HMA, 150 mm concrete base, and 150 mm of soil cement sub-base. This intersection was rehabilitated with 100 mm milling and filling with conventional HMA in 1997. In 2002, The City of Edmonton proposed to replace the rutted bus lane in the southbound direction of 97 Street from 135 Avenue to 127 Avenue by 100 mm milling and overlay with SMA. The length of pavement that was paved with SMA was 1305 m. The latest SMA rehabilitations in the year 2002 showed that conventional HMA had a service life of five years at this intersection.

Pre-Rehabilitation Pavement Condition

A condition survey was performed from 128 to 137 Avenue prior to rehabilitation by the City of Edmonton. The Visual Condition Index (VCI) was 6.1 (out of 10) for all lanes in southbound direction. Distresses survey prior to rehabilitation is illustrated in Table 6.2. Based on this survey, the major distresses at this intersection were rutting, raveling, and cracks. Figure B.12 shows the measured rut depths before rehabilitation. As it can be seen, the maximum measured rut reached 22 mm.
Table B.2: Pre-rehabilitation Distresses Survey for 97 Street Southbound Lane SMA 2002

<table>
<thead>
<tr>
<th>Distress Type</th>
<th>Level of Severity</th>
<th>Project Location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>97 Street 127-132 Avenue</td>
</tr>
<tr>
<td>Ravelling (m²)</td>
<td>Low</td>
<td>720</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>0.0</td>
</tr>
<tr>
<td>Transverse Cracks (m)</td>
<td>Low</td>
<td>707</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>0.0</td>
</tr>
<tr>
<td>Longitudinal Cracks (m)</td>
<td>Low</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>0.0</td>
</tr>
<tr>
<td>Alligator Crack (m²)</td>
<td>Low</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>0.0</td>
</tr>
<tr>
<td>Edge Cracks (m)</td>
<td>Low</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>0.0</td>
</tr>
<tr>
<td>Rutting Area (m²)</td>
<td>Low</td>
<td>784</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Figure B.12: Pre-rehabilitation Rut Measurement for 97 Street Southbound Bus Lane
Materials and Mix Design for SMA 2002

Mix design for SMA, paved in the year 2002, was completed with Superpave and Marshall mix design methods according to the City of Edmonton SMA Specification. The binder used was the PG 76-28 supplied by Husky. Tables B.3 to B.5 present material testing and mix design results. The recommended design asphalt content was 5.7% (by mass of dry aggregate) based on the Superpave mix design and 6.1% (by mass of dry aggregate) based on the Marshall mix design. The City of Edmonton decided to follow the Superpave mix design.

Table B.3: SMA 2002 Aggregate Properties

<table>
<thead>
<tr>
<th>Aggregate Property</th>
<th>Coarse Aggregate</th>
<th>Fine Aggregate</th>
<th>City of Edmonton Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA Abrasion test (AASHTO-T96) %</td>
<td>26.1</td>
<td>-</td>
<td>30 max.</td>
</tr>
<tr>
<td>Flat and Elongated (ASTM D-4791) %</td>
<td>2.0 (3:1)</td>
<td>-</td>
<td>20 max.</td>
</tr>
<tr>
<td>Crush counted (AASHTO-T85)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One face%</td>
<td>100</td>
<td>-</td>
<td>100</td>
</tr>
<tr>
<td>Two faces%</td>
<td>99.8</td>
<td></td>
<td>95 min.</td>
</tr>
<tr>
<td>Absorption (AASHTO-T85) %</td>
<td>0.85</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Angularity (AASHTO-TP33) %</td>
<td>-</td>
<td>47.8</td>
<td>45 min.</td>
</tr>
<tr>
<td>Liquid limit (AASHTO-T89) %</td>
<td>-</td>
<td>0</td>
<td>25 max.</td>
</tr>
<tr>
<td>Plasticity Index (AASHTO-T90) %</td>
<td>-</td>
<td>Non plastic</td>
<td>Non plastic</td>
</tr>
</tbody>
</table>

Table B.4: Aggregate Sources for SMA 2002

<table>
<thead>
<tr>
<th>Material Description</th>
<th>Blend %</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 mm Crushed Stone</td>
<td>40</td>
<td>Blueridge</td>
</tr>
<tr>
<td>Stollery SMA Chips</td>
<td>40</td>
<td>Stollery</td>
</tr>
<tr>
<td>Manufactured Fines</td>
<td>6</td>
<td>Blueridge</td>
</tr>
<tr>
<td>Mineral Filler</td>
<td>14</td>
<td>Graymont</td>
</tr>
</tbody>
</table>
Table B.5: Superpave and Marshall Mix Design for SMA 2002

<table>
<thead>
<tr>
<th>SMA Mix Properties</th>
<th>Test Results (Superpave Mix Design)</th>
<th>Test Results (Marshall Mix Design)</th>
<th>City of Edmonton Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix Type</td>
<td>SMA 12.5 NMA</td>
<td>SMA 12.5 NMA</td>
<td>-</td>
</tr>
<tr>
<td>Compaction Method</td>
<td>SGC 100 Gyration</td>
<td>50 Blows each side</td>
<td>-</td>
</tr>
<tr>
<td>Asphalt Cement Type</td>
<td>Husky PG 76-28</td>
<td>Husky PG 76-28</td>
<td>-</td>
</tr>
<tr>
<td>Asphalt Binder content</td>
<td>5.7</td>
<td>6.1</td>
<td>-</td>
</tr>
<tr>
<td>Density (kg/m³)</td>
<td>2337</td>
<td>2318</td>
<td>-</td>
</tr>
<tr>
<td>VMA %</td>
<td>15.2</td>
<td>16.2</td>
<td>17 min.</td>
</tr>
<tr>
<td>Air voids %</td>
<td>3.8</td>
<td>4</td>
<td>3-4</td>
</tr>
<tr>
<td>Asphalt Absorption %</td>
<td>0.4</td>
<td>0.4</td>
<td>-</td>
</tr>
<tr>
<td>Stability (N)</td>
<td>-</td>
<td>10,600</td>
<td>6,200 min.</td>
</tr>
<tr>
<td>Flow, 0.25 mm units</td>
<td>14.2</td>
<td>17.5</td>
<td>8-18</td>
</tr>
</tbody>
</table>

Quality Control/Assurance for SMA 2002

During construction of this intersection, the City of Edmonton took three samples from the plant and five core samples from different locations of the pavement for quality assurance testing. J.R. Paine and Associates took additional samples for quality control. Results from plant and cores are presented in Tables B.6 and B.7.

Table B.6: Aggregate Gradation from SMA Plant and Core Samples

<table>
<thead>
<tr>
<th>Sieve Size (mm)</th>
<th>% Passing (Samples) From Plant</th>
<th>% Passing (Core Samples) From City of Edmonton</th>
<th>% Passing (Core Samples) From J.R.P.</th>
<th>% Passing (Design Blend)</th>
<th>% Passing (City of Edmonton SMA Specifications)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>16</td>
<td>99.3</td>
<td>-</td>
<td>-</td>
<td>99.6</td>
<td>95-100</td>
</tr>
<tr>
<td>12.5</td>
<td>86.1</td>
<td>89.1</td>
<td>89.6</td>
<td>87.8</td>
<td>90-100</td>
</tr>
<tr>
<td>10</td>
<td>64.0</td>
<td>66.1</td>
<td>64.8</td>
<td>63.7</td>
<td>26-78</td>
</tr>
<tr>
<td>5</td>
<td>27.6</td>
<td>28.8</td>
<td>28.2</td>
<td>25.8</td>
<td>20-28</td>
</tr>
<tr>
<td>2.5</td>
<td>21.1</td>
<td>22.6</td>
<td>21.9</td>
<td>19.7</td>
<td>16-24</td>
</tr>
<tr>
<td>1.25</td>
<td>19.7</td>
<td>21.1</td>
<td>20.5</td>
<td>18.4</td>
<td>14-21</td>
</tr>
<tr>
<td>0.630</td>
<td>19.0</td>
<td>20.4</td>
<td>19.8</td>
<td>17.8</td>
<td>13-18</td>
</tr>
<tr>
<td>0.315</td>
<td>18</td>
<td>19.1</td>
<td>18.4</td>
<td>16.8</td>
<td>12-15</td>
</tr>
<tr>
<td>0.160</td>
<td>16.4</td>
<td>16.3</td>
<td>15.8</td>
<td>14.5</td>
<td>11-13</td>
</tr>
<tr>
<td>0.080</td>
<td>13.5</td>
<td>11.4</td>
<td>11.6</td>
<td>10.3</td>
<td>9-11</td>
</tr>
</tbody>
</table>
Table B.7: QC/QA Results for SMA 2002

<table>
<thead>
<tr>
<th>SMA Mix Property</th>
<th>Average (Samples) From Plant</th>
<th>Average from City of Edmonton (Core Samples)</th>
<th>Average from J.R.P. (Core Samples)</th>
<th>Design Mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt Binder content (% by mass of dry aggregate)</td>
<td>5.7</td>
<td>5.4</td>
<td>5.6</td>
<td>5.7</td>
</tr>
<tr>
<td>Density (kg/m³)</td>
<td>2334</td>
<td>-</td>
<td>2266</td>
<td>2337</td>
</tr>
<tr>
<td>VMA (%)</td>
<td>15.2</td>
<td>-</td>
<td>-</td>
<td>15.2</td>
</tr>
<tr>
<td>Air voids (%)</td>
<td>3.9</td>
<td>3.6</td>
<td>6.5</td>
<td>3.8</td>
</tr>
<tr>
<td>Stability (N)</td>
<td>8968</td>
<td>9784</td>
<td>-</td>
<td>10,600</td>
</tr>
<tr>
<td>Film Thickness (µm)</td>
<td>5.96</td>
<td>6.34</td>
<td>-</td>
<td>7.1</td>
</tr>
<tr>
<td>Voids Filled (%)</td>
<td>74.3</td>
<td>75.8</td>
<td>-</td>
<td>75.2</td>
</tr>
</tbody>
</table>

Field Performance for SMA 2002

The City of Edmonton measured the rutting of the bus lane at this intersection. Figure B.13 depicts the rutting progress for SMA material paved at this intersection. The maximum rutting measurement was to 7 mm at this intersection one year after placing, which indicates a good rutting performance.

![Figure B.13: Rut Measurement of SMA for 97 Street Southbound Bus Lane](image-url)
B.2.3 2002 and 2003 SMA Asphalt Pavement Analyzer (APA) Testing Program

Asphalt Pavement Analyzer (APA), an accelerated laboratory test for evaluation of rutting resistance of asphalt mixture, was conducted on laboratory and core samples of SMA paved in 2002 and 2003. Testing results are reported in Table B.8. All rutting measurements were after 5000 cycles of loading at 52°C. Laboratory and core samples of SMA 2003 show a slight increase in APA testing results comparing to SMA 2002. For SMA 2002 and 2003 mixtures, laboratory samples compacted with the Superpave Gyratory Compaction (SGC) show higher air voids than the air voids of core samples. However, there is not a significant difference between their ARA testing results.

<table>
<thead>
<tr>
<th>SMA Project Location- Rehabilitation year</th>
<th>APA (SGC) (mm)</th>
<th>Air Voids (%)</th>
<th>APA (Cores) (mm)</th>
<th>Air Voids (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>97 Street -2002</td>
<td>3.2</td>
<td>6.4</td>
<td>2.8</td>
<td>3.7</td>
</tr>
<tr>
<td>Yellowhead Trail and 124-2003</td>
<td>4.1</td>
<td>6.8</td>
<td>3.9</td>
<td>2.5</td>
</tr>
<tr>
<td>107 Avenue and 170 Street-2003</td>
<td>4.3</td>
<td>7.5</td>
<td>3.5</td>
<td>6.8</td>
</tr>
<tr>
<td>Wayne Gretzky Drive and 118 Avenue-2003</td>
<td>3.0</td>
<td>7.1</td>
<td>3.3</td>
<td>3.6</td>
</tr>
<tr>
<td>Average</td>
<td>3.7</td>
<td>7.0</td>
<td>3.4</td>
<td>4.2</td>
</tr>
</tbody>
</table>

B.3 City of Edmonton UTW Project

B.3.1 118 Avenue and 170 Street

One intersection was paved with Ultra-Thin whitetopping (UTW) in the year 2002 in Edmonton. This intersection is located at 118 Avenue and 170 Street. The original pavement was constructed in 1978 on a cement-stabilized subgrade with 150 mm of soil cement base and 280 mm HMA. This section of pavement was rehabilitated with 100 mm mill and overlay with conventional asphalt mixture in 1995. To address the rut problem at a high traffic intersection and to evaluate the application of Portland cement concrete at this intersection, the City of Edmonton decided to pave this intersection with thin Portland cement concrete, Ultra-Thin Whitetopping (UTW), in year 2002. The proposed design for this intersection was 100 mm mill of existing rutted asphalt pavement and replacing it with 100 mm fibre reinforced UTW. This UTW concrete section stretches 229 m on eastbound and 126 m on westbound directions at this intersection as it is shown in Figure B.14. Similar to previous sections, the service life of conventional asphalt mix could be estimated to be 7 years for this intersection.
Traffic data including Annual Average Daily Traffic (AADT) and percentage of trucks for this intersection is presented in Table B.9. Traffic loading is higher on eastbound compared to westbound at this intersection.

**Table B.9: Traffic Data for UTW Intersections (Source: City of Edmonton)**

<table>
<thead>
<tr>
<th>Location</th>
<th>% Trucks</th>
<th>AADT</th>
</tr>
</thead>
<tbody>
<tr>
<td>118 Avenue and 170 Street (Eastbound)</td>
<td>15</td>
<td>21,700</td>
</tr>
<tr>
<td>118 Avenue and 170 Street (Westbound)</td>
<td>3</td>
<td>17,505</td>
</tr>
</tbody>
</table>
Pre-rehabilitation Pavement Condition

The City of Edmonton measured rutting at this intersection, with ARAN, prior to UWT rehabilitation on September 2001. Figure B.15 shows the rut depth measured in the eastbound and westbound direction, and depicts a significant difference in measured rut between westbound and eastbound at this intersection before rehabilitation. The average rut measurements in the eastbound direction for lane 1 and lane 2 were 16.6 and 19.7 mm. The average rutting measurements in the westbound direction for lane 1 and lane 2 were 6.6 and 4.5 mm respectively.

The significant difference in rutting before rehabilitation in two directions at this intersection could be due to considerable difference in truck percentage in these directions. A difference of 10% in volume of heavy vehicles had caused 3 to 4 times more rut eastbound of this intersection compared to the westbound direction for conventional asphalt pavement before rehabilitation.

Prior to construction of UTW, on June 2002, a pavement condition survey was conducted by the City of Edmonton at this intersection. The Visual Condition Index (VCI) of the eastbound and westbound was evaluated as 2.1 and 4.5 (out of 10) respectively. Table B.10 illustrates pavement distresses at this intersection prior to
rehabilitation. As it can be seen, rutting and ravelling were the main distresses at this intersection before rehabilitation.

**Table B.10: Pre-rehabilitation Distress Survey**

<table>
<thead>
<tr>
<th>Distress (%)</th>
<th>Level of Severity</th>
<th>118 Avenue 163-170 Street (WB)</th>
<th>118 Avenue 170-163 Street (EB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ravelling</td>
<td>Low</td>
<td>8.53</td>
<td>8.96</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>0.94</td>
<td>0.61</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>0.04</td>
<td>0.09</td>
</tr>
<tr>
<td>Transverse and Longitudinal Cracks</td>
<td>Low</td>
<td>4.13</td>
<td>4.96</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>1.04</td>
<td>2.37</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>0.0</td>
<td>0.59</td>
</tr>
<tr>
<td>Alligator Crack</td>
<td>Low</td>
<td>0.07</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>0.01</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Edge Cracks</td>
<td>Low</td>
<td>0.16</td>
<td>1.02</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>0.03</td>
<td>0.064</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>0.01</td>
<td>0.06</td>
</tr>
<tr>
<td>Rutting Area</td>
<td>Low</td>
<td>14.31</td>
<td>39.51</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>5.63</td>
<td>8.65</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**Materials and Construction of UTW**

Concrete mix design was based on the American Concrete Pavement Association procedure. Cement type 10, maximum size of aggregate of 20 mm, and 4.55 kg/m³ polypropylene synthetic fibre were used for this concrete. To check the quality of concrete mix, eleven samples were taken before and during construction. Results of slump and compressive tests at 7 and 28 days are shown in Table B.11. The compressive strength of concrete was 20.5 MPa after 48 hours.

**Table B.11: QC Testing Results for UTW at 118 Ave. and 170 St. Intersection**

<table>
<thead>
<tr>
<th>Test</th>
<th>Average</th>
<th>Standard Deviation</th>
<th>Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slump (mm)</td>
<td>87</td>
<td>16.4</td>
<td>90</td>
</tr>
<tr>
<td>7-days Compressive Strength (MPa)</td>
<td>33</td>
<td>2.69</td>
<td>-</td>
</tr>
<tr>
<td>28-days Compressive Strength (MPa)</td>
<td>43.5</td>
<td>1.95</td>
<td>35</td>
</tr>
</tbody>
</table>
Performance of UTW

UTW pavement at this intersection has been under service for only 2 years. This short life does give a full picture of performance of this material. Visual inspection of this pavement has not shown any rutting.

B.4 City of Edmonton RCC Project

B.4.1 170 Street and 87 Avenue

Roller Compacted Concrete (RCC) was used at the intersection located at 87 Avenue and 170 Street in May 2002. This section of pavement was originally constructed in 1953, which consisted of 200 mm HMA, 150 mm of concrete base and 150 mm of soil cement. In 1997 rutted pavement was milled and overlaid with 100 mm conventional asphalt concrete overlay. To evaluate the performance of RCC for intersection pavement applications, it was decided to mill out the existing asphalt pavement and replace it with 200 mm of RCC with 50 mm conventional asphalt concrete overlay (ACO). Figure B.16 shows the layout of RCC rehabilitation at this intersection. It could be concluded that the last conventional asphalt pavement lasted only 5 years at this intersection.

![Layout of Treatment for 87-Avenue and 170 Street Intersection](image-url)

Figure B.16: RCC Treatment for 170 Street and 87 Avenue Intersection
Traffic Data

The Traffic data including Average Annual Daily Traffic (AADT) and truck percentage for this intersection is reported in Table B.12.

Table B.12: Traffic Data for 87 Avenue And 170 Street Intersection  
(Source: City of Edmonton)

<table>
<thead>
<tr>
<th>Location</th>
<th>Trucks</th>
<th>AADT</th>
</tr>
</thead>
<tbody>
<tr>
<td>170 Street and 87 Avenue (Northbound)</td>
<td>15</td>
<td>60,600</td>
</tr>
<tr>
<td>170 Street and 87 Avenue (Southbound)</td>
<td>15</td>
<td>54,500</td>
</tr>
</tbody>
</table>

Pre-rehabilitation Rut Measurement

Rut measurement data before rehabilitation with RCC was not available for this section.

RCC Materials

To evaluate the quality of RCC, nine cores were taken from different locations of this intersection after rehabilitation. Core testing results are presented in Table B.13.

Table B.13: Core Sample Testing Results from RCC

<table>
<thead>
<tr>
<th>Properties</th>
<th>Average</th>
<th>Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt Thickness (mm)</td>
<td>54</td>
<td>50</td>
</tr>
<tr>
<td>RCC Thickness (mm)</td>
<td>205</td>
<td>200</td>
</tr>
<tr>
<td>Compressive Strength of Concrete (MPa)</td>
<td>30.3</td>
<td>30</td>
</tr>
<tr>
<td>RCC Density (kg/m³)</td>
<td>2415</td>
<td>-</td>
</tr>
</tbody>
</table>
Rut Measurements After RCC Rehabilitation

In September 2002, five months after RCC rehabilitation, the City of Edmonton measured the rut at this intersection. Figure B.17 presents the rut measurements at this intersection. The maximum rutting measurement reached to 10 mm after 5 months at this intersection. Several transverse cracks existed on the asphalt overlay. It is necessary to monitor this intersection in the future to evaluate performance of RCC for intersection application.

![Rut Measurements five months after Rehabilitation with RCC](image)

B.5 City of Edmonton Superpave Projects

B.5.1 Calgary Trail/Gateway Blvd. and 34 Avenue

Two intersections were paved with Superpave mix in 2001 in Edmonton. These intersections are located at:

- Calgary Trail Southbound and Gateway Boulevard Northbound approaching to 34 Avenue,
- Calgary Trail Southbound and Gateway Boulevard Northbound approaching to Whitemud Drive South Road.
This intersection was rehabilitated with 100 mm milling of rutted pavement and overlaying with conventional asphalt concrete in 1997. As this section was rehabilitated again in July 2001, the service life of conventional asphalt pavement could be estimated 4 years at this intersection. The length of section was 111 m north and 94 m south of 34 Avenue in the south direction as it is shown in Figure B.18. The proposed overlay design was 100 mm in two 50 mm lifts of Superpave mix after removal of the existing pavement.

Traffic Data

The Traffic data including Average Annual Daily Traffic (AADT) and truck percentage for this intersection is reported in Table B.14.
Table B.14: Traffic Data for Calgary Trail and 34 Avenue  
(Source: City of Edmonton-2002)

<table>
<thead>
<tr>
<th>Location</th>
<th>Trucks %</th>
<th>AADT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calgary Trail Southbound and 34 Ave</td>
<td>15</td>
<td>34,300</td>
</tr>
<tr>
<td>Gateway Boulevard Northbound and 34 Ave</td>
<td>15</td>
<td>33,700</td>
</tr>
</tbody>
</table>

Pre-Construction Rut Measurement

Pre-construction rut data was not available for the Calgary trail southbound and 34-Avenue.

Material Characterization

Superpave mix that was utilized at this intersection consisted of PG 64-34 asphalt binder from Husky and coarse and manufactured fine aggregates from Lafarge Blueridge pit. Aggregate gradation for this Superpave mix is reported in Table 6.15. The mix design was completed in accordance with Superpave mix design method. The recommended design asphalt content was 5.2% (by mass of dry aggregate) for this mix design. The properties of mix are shown in Table B.16. To confirm the quality of the designed mix, the City of Edmonton took several core samples from this section of pavement during the construction. Test results are reported in Tables B.17 and B.18.

Table B.15: Aggregate Gradation of Superpave Mix

<table>
<thead>
<tr>
<th>Sieve Size (mm)</th>
<th>% Passing</th>
<th>Min-Max Limits</th>
<th>Restricted Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.5</td>
<td>99.7</td>
<td>90-100</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td>88.6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>54.8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2.5</td>
<td>31.1</td>
<td>28-58</td>
<td>39</td>
</tr>
<tr>
<td>1.25</td>
<td>23.1</td>
<td>-</td>
<td>26-32</td>
</tr>
<tr>
<td>0.630</td>
<td>19.3</td>
<td>-</td>
<td>19-23</td>
</tr>
<tr>
<td>0.315</td>
<td>14.5</td>
<td>-</td>
<td>16</td>
</tr>
<tr>
<td>0.160</td>
<td>8.5</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>0.080</td>
<td>4.4</td>
<td>2-10</td>
<td></td>
</tr>
</tbody>
</table>
Table B.16: Mix Design Properties of Superpave Mix

<table>
<thead>
<tr>
<th>Superpave Mix Property</th>
<th>Test Results for Superpave Mix Design</th>
<th>City of Edmonton Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimum Asphalt Binder content (% Dry Aggregate)</td>
<td>5.2</td>
<td>-</td>
</tr>
<tr>
<td>Density (kg/m³)</td>
<td>2328</td>
<td>-</td>
</tr>
<tr>
<td>VMA (%)</td>
<td>14.7</td>
<td>14 min.</td>
</tr>
<tr>
<td>Air voids (%)</td>
<td>3.8</td>
<td>4 %</td>
</tr>
<tr>
<td>Max. specific gravity (Gmm)</td>
<td>2.419</td>
<td>-</td>
</tr>
<tr>
<td>Bulk. Specific gravity (Gmb)</td>
<td>2.360</td>
<td>-</td>
</tr>
<tr>
<td>Asphalt Binder Sp/gravity</td>
<td>1.01</td>
<td>-</td>
</tr>
<tr>
<td>Bulk Sp/gravity(C/Agg)</td>
<td>2.583</td>
<td>-</td>
</tr>
<tr>
<td>Mixing Temp. (°C)</td>
<td>168</td>
<td>-</td>
</tr>
<tr>
<td>Compaction Temp (°C)</td>
<td>155</td>
<td>-</td>
</tr>
<tr>
<td>%Gmm @ N_initial</td>
<td>87.6</td>
<td>89 max.</td>
</tr>
<tr>
<td>%Gmm @ N_des</td>
<td>96.2</td>
<td>96 max.</td>
</tr>
<tr>
<td>%Gmm @ N_max</td>
<td>97.6</td>
<td>98 max.</td>
</tr>
</tbody>
</table>

Table B.17: Aggregate Gradation

<table>
<thead>
<tr>
<th>Sieve Size (mm)</th>
<th>% Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.5</td>
<td>98.5</td>
</tr>
<tr>
<td>5</td>
<td>50.8</td>
</tr>
<tr>
<td>2.5</td>
<td>29.1</td>
</tr>
<tr>
<td>1.25</td>
<td>21.7</td>
</tr>
<tr>
<td>0.630</td>
<td>18.4</td>
</tr>
<tr>
<td>0.315</td>
<td>13.9</td>
</tr>
<tr>
<td>0.160</td>
<td>8.1</td>
</tr>
<tr>
<td>0.080</td>
<td>4.1</td>
</tr>
</tbody>
</table>
Table B.18: QC Results of Superpave Mixture for Calgary Trail Southbound and 34 Avenue

<table>
<thead>
<tr>
<th>Superpave Mix Property</th>
<th>Average from Core (Samples)</th>
<th>Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt Binder content (% by mass of dry aggregate)</td>
<td>4.9</td>
<td>5.2</td>
</tr>
<tr>
<td>Mixture Specific Gravity</td>
<td>2.260</td>
<td>2.328</td>
</tr>
<tr>
<td>VMA (%)</td>
<td>-</td>
<td>14 min.</td>
</tr>
<tr>
<td>Voids (%)</td>
<td>7.4</td>
<td>3.8</td>
</tr>
<tr>
<td>Stability (N)</td>
<td>14,912</td>
<td>-</td>
</tr>
<tr>
<td>Flow (0.25 mm)</td>
<td>10.3</td>
<td>-</td>
</tr>
<tr>
<td>VFA (%)</td>
<td>56</td>
<td>-</td>
</tr>
</tbody>
</table>

Field Rut Measurements

The City of Edmonton has measured the rut depth of different lanes of this intersection several times after Superpave rehabilitation. The average rut depths of different lanes at this intersection are reported in Figure B.19. The rut progress has been higher for lanes 1, 2, and 4 compared to the rut depths for lanes 3 and 5.

Figure B.19: Rut Measurements for Calgary Trail and 34 Avenue
B.6 City of Calgary PMA Projects

The City of Calgary has used Polymer Modified Asphalt (PMA) for intersections since 1986. Some of these intersections and their rehabilitation year are:
- 16 Avenue and 19 Street North East (1986),
- MacLeod Trail South East (SE) from 5 to 7 Avenue (1986),
- McKnight Boulevard and Barlow Trail intersection (1998),
- Glenmore Trail and Barlow Trail Intersection (1999),
- 16 Avenue and Bowfort road Intersection (2003).

The main sources of information presented in this section of report are from three reports prepared for the Husky Oil Ltd. in 1991\(^5\), 1993\(^6\), and 2003\(^7\).

The City of Calgary provided traffic data for the above sections. Table B.19 shows the latest 24 hour traffic count at these intersections.

### Table B.19: Traffic Data for PMA Intersections in Calgary
(Source: City of Calgary)

<table>
<thead>
<tr>
<th>Location</th>
<th>Traffic (24 hrs count)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16(^{th}) Ave and 19(^{th}) Street NE</td>
<td>24151 (EB), and 27439 (WB).</td>
</tr>
<tr>
<td>Macleod Trail South East (SE) from 5(^{th}) to 7(^{th}) Avenue</td>
<td>76100</td>
</tr>
<tr>
<td>McKnight Boulevard and Barlow Trail intersection</td>
<td>10230 (NB) and 25353 (WB).</td>
</tr>
<tr>
<td>Glenmore Trail and Barlow Trail Intersection</td>
<td>15615 (NB) Barlow Trail and 9475 (EB) Glenmore Trail.</td>
</tr>
<tr>
<td>16(^{th}) Ave and Bowfort Road</td>
<td>4896 (NB), 6510 (SB), 23449 (EB), and 24217 (WB).</td>
</tr>
</tbody>
</table>

---

B.6.1 16 Avenue and 19 Street NE (1986)

This intersection is located on the Trans Canada Highway on 16 Avenue and 19 Street and is known for having a serious rutting problem. Prior to PMA trial, several attempts to repair the rutted pavement have failed. Due to the history of pavement failure at this site, a study was carried out by the City of Calgary to determine the depth of rut damage. The results of this study revealed that at least 150 mm of asphalt pavement should be milled out. In September of 1988, approximately 200 m back from the intersection stop line was milled to a depth of 150 mm and was replaced with two lifts of a total of 115 mm of Mix "A" and 35 mm of Mix "D" PMA mix.

Pre-rehabilitation Rut Measurements

This section of pavement was severely rutted prior of rehabilitation. The measured rut at the wheelpaths of westbound on 16 Avenue was 180 mm and slightly less in the eastbound lanes.

PMA Material and Mix Design

PMA binder grade I was used for the modified asphalt mixture at this intersection. Properties of original and extracted binder from core samples are presented in Table 6.20. Separate mix designs were developed for a coarse graded 32 mm and 19 mm PMA mixture. Table B.21 presents City of Calgary aggregate gradation specification with testing results for these two modified asphalt mixtures. Compared to conventional asphalt mixture, this modified mixture contained more coarse aggregate and more manufactured sand instead of natural sand, which increases stiffness and strength of mixture and consequently is expected to reduce rutting. Table B.22 summarizes mix design information and core testing results for these modified asphalt mixtures. Core testing results shows discrepancy between testing results and mix design requirements. Stability results of core samples are lower and flow values are higher than the mix design requirements.
### Table B.20: Properties of Original and Extracted Modified Binder in Calgary Intersections

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Penetration @ 25°C (dmm)</td>
<td>150</td>
<td>105</td>
<td>99</td>
</tr>
<tr>
<td>Kinematic Viscosity @ 13 °C (mm²/s)</td>
<td>1039</td>
<td>507</td>
<td>1208</td>
</tr>
<tr>
<td>Dynamic Viscosity @ 60°C (Pa.s)</td>
<td>797</td>
<td>237</td>
<td>897</td>
</tr>
<tr>
<td>% Retained penetration 25°C (dmm)</td>
<td>-</td>
<td>-</td>
<td>66</td>
</tr>
<tr>
<td>Aging Index Viscosity@ 60°C</td>
<td>-</td>
<td>-</td>
<td>1.13</td>
</tr>
</tbody>
</table>

### Table B.21: Aggregate Gradation for Calgary PMA Mixture

<table>
<thead>
<tr>
<th>Sieve Size (mm)</th>
<th>32 mm &quot;A&quot; Modified Mix</th>
<th>19 mm &quot;D&quot; Modified Mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Passing</td>
<td>Limits</td>
<td>% Passing</td>
</tr>
<tr>
<td>32</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>25</td>
<td>97.3</td>
<td>94-100</td>
</tr>
<tr>
<td>19</td>
<td>88.7</td>
<td>87-92</td>
</tr>
<tr>
<td>12.5</td>
<td>73.0</td>
<td>70-76</td>
</tr>
<tr>
<td>9.5</td>
<td>61.7</td>
<td>59-65</td>
</tr>
<tr>
<td>4.75</td>
<td>47.6</td>
<td>44-50</td>
</tr>
<tr>
<td>2.36</td>
<td>33.9</td>
<td>31-37</td>
</tr>
<tr>
<td>1.18</td>
<td>24.1</td>
<td>21-27</td>
</tr>
<tr>
<td>0.60</td>
<td>18.2</td>
<td>15-21</td>
</tr>
<tr>
<td>0.30</td>
<td>12.1</td>
<td>9-15</td>
</tr>
<tr>
<td>0.15</td>
<td>8.0</td>
<td>5-11</td>
</tr>
<tr>
<td>0.075</td>
<td>5.3</td>
<td>5-7</td>
</tr>
</tbody>
</table>
Table B.22: PMA Core Testing Results (August 1988)

<table>
<thead>
<tr>
<th>Mix Type</th>
<th>PMA &quot;A&quot; Mix</th>
<th>PMA &quot;A&quot; Mix</th>
<th>PMA &quot;D&quot; Mix</th>
<th>PMA &quot;D&quot; Mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>35 m E of east curb of 19 Street on 16 Ave WB lane</td>
<td>120 m E of east curb of 19 Street on 16 Ave WB lane</td>
<td>120 m E of east curb of 19 Street on 16 Ave WB lane</td>
<td>120 m E of east curb of 19 Street on 16 Ave WB lane</td>
</tr>
<tr>
<td>Binder content (% by total mass)</td>
<td>4.4</td>
<td>4.4</td>
<td>5.5</td>
<td>6.0</td>
</tr>
<tr>
<td>Density (kg/m³)</td>
<td>2450</td>
<td>2370</td>
<td>2415</td>
<td>2391</td>
</tr>
<tr>
<td>Stability (N) 75 blows</td>
<td>12,300</td>
<td>14,400</td>
<td>10,600</td>
<td>14,000</td>
</tr>
<tr>
<td>Flow (250µm)</td>
<td>16.6</td>
<td>12.2</td>
<td>17.5</td>
<td>14.2</td>
</tr>
<tr>
<td>VMA (%)</td>
<td>11</td>
<td>13.9</td>
<td>12.8</td>
<td>14.3</td>
</tr>
<tr>
<td>Air Voids (%)</td>
<td>2</td>
<td>5.0</td>
<td>1.5</td>
<td>2.0</td>
</tr>
<tr>
<td>Film Thickness (µm)</td>
<td>5.7</td>
<td>7.9</td>
<td>6.8</td>
<td>9.1</td>
</tr>
</tbody>
</table>

Performance Evaluation

Table B.23 shows rut measurements at the intersection of 16 Avenue and 19 Street for different lanes after rehabilitation.

Table B.23: Rut Measurement After Rehabilitation

<table>
<thead>
<tr>
<th>Year</th>
<th>Time after Rehabilitation (Year)</th>
<th>Rut (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Westbound</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Left Lane</td>
</tr>
<tr>
<td>1990</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>1991</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>2003</td>
<td>17</td>
<td>17</td>
</tr>
</tbody>
</table>

*Rut depth observed at stop line

Based on rutting data, during the first five years after rehabilitation all lanes of westbound showed a good performance in terms of rutting resistance. However, all lanes of eastbound showed a high rutting.

In July of 2003, this section of pavement was revisited to evaluate its performance. It was observed that the westbound of this intersection still exhibited good performance. There were some longitudinal cracks, but surface texture showed little wear and no raveling. The eastbound direction of this section showed severe rutting was present.
The eastbound direction of this intersection is located at the peak of a steep-grade hill which causes higher pressure on the pavement due to truck acceleration and deceleration. These factors could be the main reasons for high rutting on eastbound lanes of this intersection.

B.6.2 Macleod Trail SE from 5 to 7 Avenue (1986)

Macleod Trail northbound is a major artery into the city centre from the south part of Calgary. This intersection is located within the downtown core and receives high volume of traffic. Prior to the placement of the PMA, this section of pavement was badly worn. This intersection has heavy traffic during daily rush hours with a significant volume of bus traffic in each of the curb lanes.

Table B.24 illustrates pavement structure layers at this intersection before rehabilitation with PMA in 1986. The last conventional overlay was placed in 1984, which concludes the conventional asphalt pavement lasted only 2 years at his intersection.

<table>
<thead>
<tr>
<th>Layers</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silty clay (mm)</td>
<td>300</td>
</tr>
<tr>
<td>Well graded stone (mm)</td>
<td>100</td>
</tr>
<tr>
<td>Mix A (mm)</td>
<td>250</td>
</tr>
<tr>
<td>Mix C (mm)</td>
<td>25</td>
</tr>
<tr>
<td>Mix C (mm)</td>
<td>25 (1984*)</td>
</tr>
</tbody>
</table>

* Year of last overlay
Material and Mix Design

PMA Grade-I binder, similar to the previous section, was used in the mix placed on Macleod Trail in 1986. Properties of this binder are listed in Table B.25.

Table B.25: PMA Binder Properties

<table>
<thead>
<tr>
<th>Binder Properties</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penetration @ 25°C (dmm)</td>
<td>153</td>
</tr>
<tr>
<td>Softening point °C</td>
<td>54</td>
</tr>
<tr>
<td>Kinematic Viscosity @ 135 °C (mm²/s)</td>
<td>910</td>
</tr>
<tr>
<td>Dynamic Viscosity @ 60 °C (Pa.s)</td>
<td>688</td>
</tr>
</tbody>
</table>

Construction of MacLeod Trail from 5 to 7 Avenue

This intersection was paved in August of 1986. Approximately 50 mm of the surface material was milled, an asphalt-rejuvenating product was added to the recycled asphalt and the material was relaid. The section was then overlaid with 50 mm thin lift overlay of polymer-modified asphalt (PMA).

Table B.26 presents the results of the analysis of core samples taken during paving and required specification. Table B.27 presents recovered aggregate gradation from core samples taken during rehabilitation in 1986, one year after rehabilitation, and in 1992. The recovered aggregate gradation results confirmed the specified limit six years after rehabilitation. Results in Table B.28 indicate that PMA binder did not harden significantly, which could be due to its modification. The original penetration test on the binder was 153 dmm and it dropped 29% after one year and 46% after six years of service.

Table B.26: Testing Results for Core Sample Taken During Paving

<table>
<thead>
<tr>
<th>Property</th>
<th>NB Lanes of 6 Avenue</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binder content (% by total mass)</td>
<td>6.4</td>
<td>-</td>
</tr>
<tr>
<td>Density (kg/m³)</td>
<td>2338</td>
<td>-</td>
</tr>
<tr>
<td>Stability (N) 75 blows</td>
<td>9,000</td>
<td>8,050 min</td>
</tr>
<tr>
<td>Flow (250μm)</td>
<td>15.3</td>
<td>10-16</td>
</tr>
<tr>
<td>VMA (%)</td>
<td>15.8</td>
<td>18 min</td>
</tr>
<tr>
<td>Air Voids (%)</td>
<td>3.4</td>
<td>2 - 4</td>
</tr>
</tbody>
</table>
Table B.27: Aggregate Gradation from Core Samples

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>% Passing Core extracted 1986</th>
<th>% Passing Core extracted 1987</th>
<th>% Passing Core extracted 1992</th>
<th>City of Calgary Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.5</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>9.5</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>94-100</td>
</tr>
<tr>
<td>4.75</td>
<td>79</td>
<td>77.5</td>
<td>78</td>
<td>84-90</td>
</tr>
<tr>
<td>2.36</td>
<td>61</td>
<td>59.7</td>
<td>61</td>
<td>59-65</td>
</tr>
<tr>
<td>1.18</td>
<td>49</td>
<td>49.1</td>
<td>49</td>
<td>45-51</td>
</tr>
<tr>
<td>0.60</td>
<td>32</td>
<td>34.6</td>
<td>34</td>
<td>32-38</td>
</tr>
<tr>
<td>0.30</td>
<td>16</td>
<td>17.2</td>
<td>19</td>
<td>17-23</td>
</tr>
<tr>
<td>0.15</td>
<td>11</td>
<td>11.8</td>
<td>14</td>
<td>8-14</td>
</tr>
<tr>
<td>0.075</td>
<td>7.6</td>
<td>8.8</td>
<td>11</td>
<td>6-8</td>
</tr>
</tbody>
</table>

Table B.28: Core Testing Results of PMA from Macleod Trail

<table>
<thead>
<tr>
<th>Binder Properties</th>
<th>Original 1986</th>
<th>June 18, 1987 5 and 7 Avenue</th>
<th>September 9, 1992 5 and 7 Avenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penetration @ 25°C (dmm)</td>
<td>153</td>
<td>108</td>
<td>83</td>
</tr>
<tr>
<td>Kinematic Viscosity @ 135°C (mm²/s)</td>
<td>910</td>
<td>-</td>
<td>1202</td>
</tr>
<tr>
<td>Dynamic Viscosity @ 60°C,(Pa.s)</td>
<td>688</td>
<td>-</td>
<td>664</td>
</tr>
<tr>
<td>% Retained penetration @ 25°C</td>
<td>-</td>
<td>70.6</td>
<td>54.3</td>
</tr>
<tr>
<td>Aging Index Viscosity @ 60°C</td>
<td>-</td>
<td>-</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Rut Measurement After Rehabilitation

The latest data for rut depth measurements, collected on 2003, at 5 Avenue is presented in Table B.29. The centre lanes of this section of pavement have rutted while the outside lanes showed minimal depth of rutting after 17 years of service. Overall this section has performed well.

Table B.29: Rut Depth Measurements (mm) After Rehabilitation for Macleod Trail at 5 Avenue

<table>
<thead>
<tr>
<th>Rut for Lane 1 (mm)</th>
<th>Rut Lane 2</th>
<th>Rut Lane 3</th>
<th>Rut Lane 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>36</td>
<td>34</td>
<td>Minimal</td>
</tr>
</tbody>
</table>
B.6.3 McKnight Boulevard and Barlow Trail Intersection (1998)

This intersection is situated on two of Calgary's major thoroughfares, Barlow Trail and McKnight Boulevard. Barlow Trail serves as the main entrance road for the airport, while McKnight Boulevard is a major connector for Calgary east to west. This section of pavement is subject to extremely high traffic loading due to its vicinity especially on McKnight Boulevard as it leads to Deerfoot Trail.

There was not any information available regarding the material and pavement distresses before overlay. The City of Calgary decided to rehabilitate this section of pavement with PMA in 1998.

Rut Measurements After Rehabilitation

In July of 2003, rut depths were measured at two locations of this intersection and are presented in Table B.30.

The surface texture of westbound pavement of McKnight Boulevard was very good and there was not any ravelling and cracking. Almost the same situation was found on Barlow Trail northbound which performed very well with no ravelling and cracking, the surface texture was also very good and rut depths at this point were very minimal on both lanes. Overall, this intersection is performed well with PMA.

<table>
<thead>
<tr>
<th>Location</th>
<th>Left Lane</th>
<th>Centre Lane</th>
<th>Right Lane</th>
</tr>
</thead>
<tbody>
<tr>
<td>McKnight Boulevard Westbound</td>
<td>17</td>
<td>19</td>
<td>11</td>
</tr>
<tr>
<td>Barlow Trail Northbound</td>
<td>7</td>
<td>-</td>
<td>9</td>
</tr>
</tbody>
</table>

B.6.4 Glenmore Trail and Barlow Trail Intersection (1999)

This intersection serves heavy trucks, as it is located next to a number of truck stops. The presence of a large number of trucks makes this pavement section susceptible to severe rutting. This section was overlaid in 1999 with PMA. Information regarding distresses survey before overlay, material, and history of this section was not available.
Rut Measurements After Rehabilitation

In July of 2003, rut depths were measured at this intersection in order to obtain an overall view of pavement performance. Rutting measurements are shown in Table B.31. After four years of service, this pavement did not performed very well. The surface texture was beginning to deteriorate and ravelling was presented but there was no cracking.

<table>
<thead>
<tr>
<th>Location</th>
<th>Left Lane</th>
<th>Right Lane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glenmore Trail Eastbound</td>
<td>21 mm</td>
<td>30 mm</td>
</tr>
<tr>
<td>Barlow Trail Northbound</td>
<td>22 mm</td>
<td>46 mm</td>
</tr>
</tbody>
</table>

B.6.5 16 Avenue (Trans Canada Highway) and Bowfort Road Intersection (2003)

This intersection is located at the top of a hill and is subject to extremely high traffic volumes, especially heavily loaded trucks. PMA mixture was placed at this section of pavement in June of 2003. There was no information available regarding history, material and pavement condition before rehabilitation.

Rut Measurements after Rehabilitation

After one month on July 30, 2003, rut depths were measured to evaluate short-term performance of PMA at this intersection. The rut depths between 2 to 15 mm at various points of intersection were observed.

Although one-month pavement evaluation does not give a general view of the performance, this section of pavement exhibited poor performance. The surface texture is still in good condition, but in some area asphalt binder has bled to the surface. Binder content was 5.8% and it could be the cause of bleeding. This section of pavement was paved during the hottest week of summer, increasing susceptibility to rutting of this mix immediately after construction.