# Current Asphalt Rubber Developments in Alberta

Chuck McMillan, M.Sc., P.Eng.,
Alberta Transportation

Allan Kwan, P.Eng.
Alberta Transportation

Hugh Donovan, P.Eng.
City of Edmonton

Peter Enslen, P.Eng.
City of Calgary

Bob Horton, P.Eng.
Strathcona County

Paper prepared for presentation
at the Recycling Materials for Use in Highway Design Session

of the 2003 Annual Conference of the
Transportation Association of Canada
St. John's, Newfoundland and Labrador

The authors wish to acknowledge the financial support of the Tire Recycling Management Association of Alberta in the completion of the trial projects and the ongoing research related to the asphalt rubber trials.

Abstract

Asphalt rubber involves the use of rubber crumb from recycled tires in various hot-mix pavement and seal applications. The use of asphalt rubber has been around for over 50 years, yet its supported use in North America tends to be concentrated in a small number of U.S. states. The U.S. ISTEA legislation in 1991 led to the requirement for evaluating rubber in asphalt applications as a condition for federal funding. Although that U.S. legislation was repealed it did result in numerous trial sections throughout the U.S. which are now reaching an age where performance can be evaluated and the experience used to more closely consider life cycle costs. The use of asphalt-rubber in Canada has typically been trial sections, which have not performed adequately to provide the needed incentive to make asphalt rubber a mainstream product.

In 2001 the Tire Recycling Management Association of Alberta (TRMA) and Alberta Transportation established a steering committee to once again examine the potential for using asphalt rubber in pavements in Alberta. Alberta Transportation and the Tire Recycling Management Association of Alberta, in conjunction with the cities of Calgary and Edmonton and Strathcona County, initiated a project to look at the feasibility of adopting asphalt rubber pavement technology in Alberta. Asphalt rubber has been used successfully in numerous states including Arizona, California, Texas and Florida in highway and street pavement rehabilitation for several decades. Four asphalt rubber trial sections were successfully constructed in Alberta in 2002 using the technology as currently used in Arizona.

This paper provides a brief overview of the various methods used to incorporate recycled tire rubber into asphalt concrete pavements and seals and a short synopsis of the experience of agencies with the asphalt rubber wet process in pavement applications. Processes which used crumb-rubber as a part of the aggregate are described. Additionally, a summary of the current methods considered the most successful and a review of current Alberta work is presented

Work undertaken in 2002 in Alberta includes the construction of four trial projects in four different road jurisdictions. This paper describes the phases and factors that contributed to the completion of the Alberta trial projects.

## 1.0 Introduction

Recycled tire rubber has been used in North America since the 1930s(1) to produce asphalt rubber. Experience reported from various agencies tends to be mixed with significant success being reported by Arizona, California, Texas and Florida highway agencies. Agencies in Canada, including Alberta, have also constructed numerous trials which utilized recycled tire rubber in asphalt or asphalt mixtures.

As the reported use of asphalt rubber tends to be concentrated in the warmer states noted, it has raised issues of whether the colder Canadian climate is conducive to the performance of asphalt rubber. Asphalt rubber also introduces a significant increase in cost which road authorities must rationalize within the life cycle costs (LCC) of the project, and the very real constraints on dollars for all rehabilitation work.

Potential benefits of asphalt rubber reported from U.S agencies are lower LCC as a result of thinner layer thicknesses, reduced reflective cracking and/or longer service lives. Gap graded and open graded mixtures are also potentially quieter than dense graded mixtures with the same traffic; asphalt rubber in these mixtures has been reported to result in measurably less road noise.

## 1.1 Background

The Asphalt Rubber 2000 conference held in Portugal in 2000 had a direct impact on initiating the current Alberta asphalt rubber project. In 2001 the Tire Recycling Management Association of Alberta (TRMA) and Alberta Transportation established a steering committee to look at the potential for utilizing asphalt rubber in Alberta. In addition to TRMA and Alberta Transportation representatives, the Cities of Calgary and Edmonton, and Strathcona County represent owner agencies on the committee. Further, the University of Alberta (UofA), the Alberta Roadbuilders and Heavy Construction Association (ARHCA) are represented on the committee. Further involvement of industry (Husky Energy) and academia (University of Calgary, (UofC)) have also participated on the committee. EBA Engineering Consultants Ltd (Consultant) was retained to provide project management services and technical input to the committee.

The successful applications of asphalt rubber being reported in the literature suggested that asphalt rubber production could be a value-added use for recycled tires, and one that could potentially lower life cycle costs for road authorities. A review of the practices of other agencies indicated that significant quantities of asphalt rubber has been placed and has performed well over the last two decades since asphalt rubber was last trialed in Alberta. In order to determine whether such benefits could be realized in Alberta's specific climatic and paving conditions, it was decided that trial pavement sections in Alberta would be required to evaluate the current asphalt rubber technology and to generate some made-in-Alberta performance data.

## 1.2 Objectives of Paper

The objective of this paper is to provide an overview of recent asphalt rubber work undertaken in Alberta, including the construction of four trial asphalt rubber projects. The paper is written by the four owners of the projects and is intended to provide an owner's perspective to the potential of this technology.

## 2.0 Overview of Asphalt Rubber Processes

There are generally considered to be three basic processes which may utilize recycled tire rubber or crumb rubber modifier (CRM) in the production of different types of asphalt concrete pavements. These processes are known as the dry process, the terminal blend process, and the wet process. Although the wet process is the only process considered in Alberta's recent trials, a short definition of each process, as used within this paper, is presented below.

The dry process uses CRM as an aggregate; it is not pre-mixed in the asphalt cement but into the hot mix. This process has been known by the trade name of PlusRide™. The literature reports mixed success with this process. A 1985 trial by Alberta Transportation suggested some benefit from this process although the pavement failed prematurely due to what was believed to be construction related issues.(2)

Terminal blend asphalt rubber is produced at a refinery or terminal and trucked to the job site. This process usually uses a finer gradation of rubber crumb and significantly less rubber crumb than the wet process. The University of Calgary has reported some success with terminal blend trials and the U.S. Turner Fairbanks site reports chemically modified (stabilized) crumb rubber blends which would fall into this category(3).

The asphalt rubber wet process is as defined by the American Society for Testing and Materials (ASTM) in ASTM D8 as " *a blend of asphalt cement, reclaimed tire rubber and certain additives in which the rubber component is at least 15% by weight of the total blend and has reacted in the hot asphalt cement sufficiently to cause swelling of the rubber particles*".

ASTM D6114 specifications for Asphalt rubber specifies the required properties for the asphalt-rubber blend as shown in Table 1.

**Table 1 ASTM Specifications for Asphalt Rubber Binder**

| **Binder Designation** [A] | | **Type I** | **Type II** | **Type III** |
|---|---|---|---|---|
| Apparent Viscosity, 175°C cP (ASTM 2196) | Min<br>max | 1500<br>5000 | 1500<br>5000 | 1500<br>5000 |
| Penetration, 25°C, 100g, 5s | min<br>max | 25<br>75 | 25<br>75 | 50<br>100 |
| Penetration, 4°C, 200g, 60s | Min | 10 | 15 | 25 |
| Softening Point, °C | Min | 57.2 | 54.4 | 51.7 |
| Resilience, 25°C, % | Min | 25 | 20 | 10 |
| Flash Point, °C | Min | 232.2 | 232.2 | 232.2 |
| Thin Film Oven Test Residue<br>Penetration Retention, 4°C : % of original | Min | 75 | 75 | 75 |

[A] ASTM provides recommendations for asphalt rubber binder type based on climatic conditions. For average monthly maximum ambient temperatures of 27°C or lower and average monthly minimum ambient temperatures of -9°C or lower at Type III is recommended. For average monthly maximum ambient temperatures of 43°C or lower and average monthly minimum ambient temperatures of -9°C or greater a Type II is recommended. Alberta climatic conditions would be suited for a Type III AR binder.

The ASTM D6114 specification also has the following requirements for the ground recycled tire rubber:

- Less than 0.75% moisture, and free flowing
- Specific gravity of 1.15 ± 0.05
- No visible nonferrous metal particles
- No more than 0.01% ferrous metal particles by weight
- Fiber content shall not exceed 0.5% by weight (for hot mix binder applications)
- Recommends no rubber particles retained on the 2.36 mm sieve

(Note that Rubber gradation may affect the physical properties and performance of asphalt rubber hot mix).

## 3.0 Synopsis of Asphalt Rubber Performance

Over the last several decades significant work has been undertaken with asphalt rubber in seal applications. More recently, in the last two decades, asphalt rubber in hot mix asphalt applications has been increasingly constructed by various agencies. This work is especially apparent in some U.S. states such as Arizona, California, Texas, and Florida. This section provides a brief overview on the experience of others.

The State of California Department of Transportation (Caltrans) recently reported on the use of asphalt rubber within their state highway projects in their Asphalt Rubber Usage Guide(1). Within the guide, Caltrans identifies the numerous research efforts undertaken to evaluate the performance of asphalt rubber within their state. Caltrans reports the use of predominantly gap graded asphalt rubber mixes, and some use of open graded asphalt rubber mixes. Caltrans has conducted trials using asphalt rubber with dense graded aggregates and have concluded that such mixtures are not well suited for asphalt rubber binders because of the lower binder content in such mixtures compared to the gap- and open-graded mixtures. This conclusion suggests that the performance of asphalt rubber mixtures rely at least partially on the increased binder contents afforded by high VMA mixtures.

Caltrans' Flexible Pavement Rehabilitation Manual(4) identifies an equivalency for gap graded or open graded asphalt rubber mixtures up to 2 times the thickness of a conventional dense graded mixture. Based on the Caltrans manual, the equivalency is applicable for conventional pavement thicknesses of 60mm to 120mm. This means that the Caltrans guide allows a required 60mm overlay to be replaced by a 30mm gap graded asphalt rubber mixture or a required 120mm overlay to be replaced by a 60mm gap graded asphalt rubber mixture. This equivalency as reported is considered valid by Caltrans for designs based on structural need or reflective cracking requirements, it does not, of course apply to design thicknesses required to address smoothness. Such reductions in pavement thickness are applied to rehabilitation only and do not apply to new construction.

Caltrans also report on the use of asphalt rubber in sealcoat applications. They report the advantage of asphalt rubber seals being longer life and increased resistance to reflective cracking. Caltrans uses seals as a wearing surface and as interlayers and suggest that they can be effective in minimizing reflective cracking as well as minimizing overlay thickness if reflective cracking is primary distress mode and structure is sufficient. The Caltrans Flexible Pavement Rehabilitation Manual provides for a structural contribution of the seal when overlain by either asphalt rubber or conventional dense graded mixtures.

The Caltrans guide also notes that construction using asphalt rubber mixtures can be more challenging specifically related to compaction and the high mix temperatures required to be used for compaction. Potential odor and emission issues are also referenced in the Caltrans guide and it is concluded that asphalt rubber presents no significantly different issues than conventional mixtures. Although somewhat increased emissions with asphalt rubber are noted, this is attributed to higher mix temperatures rather than the presence of the rubber crumb.

The Arizona Department of Transportation (ADOT) have reported performance results using open graded asphalt rubber mixes[5]. The ADOT experience includes the use of asphalt rubber in seal applications from the late 1960s to the present. ADOT constructed their first asphalt rubber mix in 1988.

A study undertaken in Arizona in the 1970's looked at the ability of various treatments to retard reflective cracking. The observations from that study[6,7] identified 5 approaches as resulting in a significant reduction in reflective cracking. Of the identified treatments, asphalt rubber seal coat placed as a membrane treatment under an asphalt concrete friction course. Of interest, another of the 5 treatments found to be significant was the use of 200/300 penetration asphalt in an asphalt mixture. Alberta Transportation regularly uses 200-300 asphalts on lower traffic highways.

The Arizona Department of Transportation constructed their first asphalt rubber open graded mixture in 1988. In 1990 a trial project on I-40 was undertaken in Arizona using asphalt rubber open graded mixtures over cracked PCC pavements. Although this experience is somewhat limited relative to the potential service life of asphalt pavements on Alberta highways, it is a longer period than the pavement was expected to perform by the project designers, and is similar to expectations of the City of Edmonton, for example, whom normally use a 10 year design period. Based on this project, ADOT experience suggests that gap and open graded mixtures are notably superior in resisting reflective cracking from underlying PCC pavement than dense graded conventional mixtures placed much thicker than the asphalt rubber mixtures[8].

ADOT generally uses the open graded mixture as the final wearing surface at a thickness of 25mm; gap graded asphalt rubber mixtures are used up to 50mm in thickness.

Texas recently reported[9] on the use of crumb rubber for seal applications using terminal blended asphalt rubber and have indicated good results relative to the stability of the material. This further use of rubber in asphalt provides additional potential for the utilization of crumb rubber products in other road applications. A 1998 article in the Texas Transportation Researcher[10] reported on prior work in Texas using similar asphalt rubber mixing processes.

The positive aspects of asphalt rubber are summarized in a brief presentation by J. Lundy, of Oregon State University, that looked at asphalt rubber in Arizona, California and Texas. While the presentation cites good success in California and Arizona, and mixed success in Texas, the presentation concludes that asphalt rubber is successfully and widely used in the south central and southwest U.S.[11].

The National Center for Asphalt Technology (NCAT) undertook a study for the Florida Department of Transportation in 1989[12]. Their study concentrated on evaluating the use of asphalt rubber with the normal (fine) gradations typically used by FDOT. Therefore, the asphalt rubber used by FDOT are typically of much lower rubber content than is the case for asphalt rubber defined in the introduction to this paper as the wet process.

Of significance, NCAT concluded that asphalt rubber could be used in dense graded mixtures and achieve acceptable results. This type of application may be pursued in Alberta in the future.

Alberta Transportation had constructed asphalt chip seals in the late 1970's but no significant performance gains were observed. Some reportedly failed prematurely and other sections, intended as stress absorbing membranes, did not provide measurable reduction in reflective cracking. The Alberta Transportation experience with PlusRide™ placed in 1985 also ended prematurely which was attributed to low asphalt contents[(2)]. The high cost of the rubber asphalt resulted in no further work being pursued until about 1993 when the consultant was commissioned to look at the feasibility of asphalt rubber in Alberta[(13)]. Alberta Transportation, the Cities of Edmonton and Calgary, and the Consultant (EBA Engineering Consultants Ltd.) jointly sponsored this study. The study involved laboratory testing to look at potential mix options. However, the study concentrated on typical Alberta dense graded mixtures and concluded that the use of asphalt rubber binder (produced as the wet process) would not be feasible with typical Alberta dense graded mixes. The study also identified that the dry process would be limited to about 1% CRM with normal dense graded mixes.

A study by the Department of Transportation in Oregon[(14)] provided a good overview of both Oregon projects and other asphalt rubber projects in Washington, Virginia, Colorado, Ontario and Alaska. The conclusions of the Oregon study indicated that the dry process was at best inconsistent, that the wet process asphalt rubber with open graded mixes had varying performance and terminal blended asphalt rubber produced as a performance based asphalt had the best results. The conclusions presented reinforced the need for Alberta road agencies to develop their own experience.

## 4.0 Alberta 2002 Trial Projects

### 4.1 Approach

The Alberta asphalt rubber steering committee agreed to pursue the construction of rubber asphalt trial sections if considered warranted based on a review of the current practices and experience.

Based on recommendations from the Consultant, the Alberta Asphalt Rubber Steering Committee (AARSC) elected to pursue the wet process in general conformance with the practice of the Arizona Department of Transportation. In addition to available literature, as noted previously, discussions with ADOT and Arizona contractors identified that their practice of gap graded or open graded mixtures were the most proven approach and likely the most probable to produce good results. In addition, Alberta Transportation's previous work did not support pursuing dense graded asphalt rubber mixtures nor the dry mix processes.

For the Alberta projects, a gap graded aggregate was decided upon based on a review of Arizona's and other jurisdiction's experience as well as on a review of materials locally available (it was considered that selecting gradations which were not too atypical would have a greater chance of success). Superpave mixtures previously placed by Alberta Transportation and aggregates available in both the Calgary and Edmonton markets were found to exist that could readily produce gap graded materials that conformed closely to the ADOT specifications for mineral aggregate. ADOT specifies a mineral admixture in their specifications to address stripping potential. Consistent with conventional Alberta projects an admixture was not used for the trial projects.

It should be noted that Alberta Transportation has had some concerns with the openness of Superpave mixtures placed in the province and studies have shown that these gradations are significantly more permeable than dense graded mixtures[(15)]. As a further anecdotal observation in Alberta, a trial of an open graded mix undertaken by Strathcona County failed after five years. Historically there has been some concern of the ability of open graded mixtures to perform as well as dense graded mixtures in cold climates where salt and sanding occurs and there are large number of freeze thaw cycles. However, there has also been no technical reason for pursuing these types of mixtures in the past and as a result very little work has been done in Alberta. This will be an area requiring more research in the future.

The Consultant undertook tentative mix designs in 2001 using aggregates identified for potential projects. These mix designs were undertaken without the benefit of an asphalt rubber binder design; a nominal 20% rubber was blended into the asphalt cement and used for the mix designs. As the trial projects were identified and actual materials identified Law Engineering and Environmental Services Inc. of Phoenix Arizona was contracted to design both the asphalt-rubber binder proportions and the asphalt rubber gap graded mixture. For the Calgary project, the original mix design was considered to be representative and was used without further confirmational work being done.

The asphalt binder manufacturing was contracted by the TRMA to International Slurry Systems (ISS) of Chandler, Arizona. The contract required ISS to blend and provide the asphalt rubber binder to each of the two proposed asphalt mix plants (one in Calgary and one in Edmonton) which would in-turn produce and place the asphalt rubber gap graded mix.

The City of Calgary produced material in their own plant and the material was placed with their own paving crews. The ISS equipment was connected to the City of Calgary batch plant to provide the asphalt rubber binder to the plant.

The three Edmonton area projects were tendered and contracted as a single contract to E Construction for mixing and placing the mix on each of the three Edmonton area trial sites. Timelines were specified in an effort to coordinate the work between the two separately contracted entities.

A testing program was undertaken before and after the placement of the asphalt rubber and conventional mixtures and included Falling Weight Deflectometer, visual distress mapping, and radar thickness measurements. As well, video was recorded at the test sites to document the pavement condition before and after construction. Sound testing was also completed following construction to determine the potential noise reduction benefit of the asphalt rubber gap graded mix.

To assist in the assessment of the asphalt rubber trials two University contracts were awarded. The University of Alberta (UofA) was contracted to evaluate the construction and initial performance of the trial sections, based on test data collected by the consultant.

Arizona State University (ASU) was contracted to evaluate the Alberta asphalt rubber mixture (from the Edmonton area projects) and compare it to a ‘typical’ dense graded mixture that was used as the control mix for the City of Edmonton work. Further comparison of the Alberta asphalt rubber mixtures to other asphalt rubber mixes previously tested by ASU is also expected to provide insight as to the characteristics of the Alberta mixes relative to those placed in other jurisdictions.

## 4.2 Project Descriptions

Each of the four participating agencies selected projects within their jurisdictions, these projects are summarized below:

***Project 1 City of Calgary***

The City of Calgary selected a portion of 112 Avenue NW to pave with the asphalt rubber mixture. This section of 112 Avenue is a two lane roadway with a rural cross section. The existing pavement structure was 215 mm of asphalt concrete pavement (ACP) over a nominal 90 mm granular base. The roadway is located in a semi industrial area near gravel pits and the city waste management facility. The 20 year Design ESALs were estimated as 1.96 million.

A nominal 75 mm thickness of gap graded asphalt rubber mix was placed between station 111 and 222 and 40 mm was placed between 222 and 333. The overlay need determined by the City was an experience based design of 75 mm. The remaining portion of 112 Avenue (from station 333 to 999) was paved by the City with a mix utilizing recycled shingles. There is no control section on this project using a conventional mix although the shingle mix did conform to all City of Calgary specifications for conventional surface overlay asphalt (Mix B in Standard Specifications Roads Construction).

***Project 2 City of Edmonton***

The city of Edmonton selected to pave a portion of 137$^{th}$ Avenue with the asphalt rubber mixture.

In Edmonton, 137$^{th}$ avenue is a four lane divided arterial roadway with an urban (curb and gutter) cross-section. The existing pavement structure consisted of 100mm of hot mix asphalt overlying 150mm of concrete base overlying 150mm of cement treated granular sub-base. The section of roadway selected was originally constructed between 1963 and 1965. The roadway is designated as a truck route arterial roadway with an AADT of 26,500 and approximately 10% truck traffic. Design ESALs for 137$^{th}$ Avenue were determined by the City to be 1.27 million based on a 10 year design period. Prior to placing the asphalt rubber and control mixes, the pavement exhibited significant longitudinal and transverse reflective cracking from the joints of the concrete base below the asphalt layer.

A nominal 50 mm thickness of gap graded asphalt rubber mix was placed in the east bound lanes (EBL) between km 0.0 (127$^{th}$ St) and km 0.80 and 100mm was placed between km 0.80 and km 1.60 (113A St). The existing pavement was milled to a depth of 50mm prior to the placement of the asphalt rubber mix. The overlay need determined by the City of Edmonton was based on their Dynaflect testing and the deflection based design method normally employed. The west bound lanes (WBL) were paved with the City's conventional ACO mix at a thickness of 100mm; the WBL section will be used as the control section for performance comparison purposes.

***Project 3 Strathcona County***

Strathcona County selected to pave portions of the 17$^{th}$ St and Baseline Road intersection.

In Strathcona County, 17$^{th}$ St is a 2 lane rural cross section roadway (4 lane urban cross section for the trial section locations at the intersection) and Baseline Road is a six lane urban cross section with a raised median at the locations selected for the placement of the asphalt rubber mix.

The existing pavement structure on the main section (17th street) varied with 180 mm of ACP in the inner lane and 380mm ACP in the outer lane over up-to 370mm of base material. Both roadways carry significant truck traffic. The sections selected by the County included the left turn bay of the EBL of Baseline road, and portions of both the north and southbound lanes of 17th St.. Sections were milled prior to placing the asphalt rubber mix and in some sections were preceded with a 40mm lift of dense graded asphalt concrete mix meeting the County's ACS mix specifications with a polymer modified asphalt (PG 64-34). The milling depth was equal to the depth of material placed, therefore there was no net increase in pavement thickness. Twenty-year design ESALs of 11.5 million were determined for 17th St, while the Baseline turning bay design ESALs were not determined. The project limits on 17th St. were from km 0.135 to km 1.004.

In the NBL, a 60mm thickness of asphalt rubber was placed from km 0.135 to km 0.255(120m), the remainder of the NBL 100mm of conventional dense graded mix with a polymer modified asphalt (PG 64-34). In the SBL a 30mm lift of the asphalt rubber mix was placed over a 40mm lift of dense graded mix from km 0.135 to km 0.378 (243m); from km 0.413 to km 0.623 (210 m) a 60mm lift of asphalt rubber gap graded mix was placed over a 40 mm lift of the dense graded asphalt concrete; and from km 0.854 to km 1.004 (150 m) a 60mm lift of asphalt rubber gap graded mix was placed. The eastbound to north bound turning lane on Baseline road was paved with 60mm of asphalt rubber gap graded mix over 40 mm of dense grade asphalt mix using the referenced polymer modified asphalt. In all sections the existing pavement was milled prior to placing new materials.

***Project 4 - Alberta Transportation***

Alberta Transportation included the asphalt rubber gap graded mixture as part of a larger overlay section on highway 630:02 (Hwy 630).

Hwy 630 is a two lane rural highway with an AADT of 1500 vehicles per day and 20 year design ESALs of 0.21 million. The existing pavement structure consisted of 100 mm of ACP over a 270 mm granular base. The trial sections were constructed at the east end of the project where the existing structure condition was relatively uniform. The pavement exhibited significant longitudinal cracking and a relatively low frequency of low temperature transverse cracks.

A nominal 80mm asphalt rubber gap graded mixture was designed as two lifts between km 28.100 and km 28.600 (500m) with a single 40 mm lift of the asphalt rubber mix placed between km 27.600 and 28.100 (500 m). As a control section, 500m was designed between km 27.100 and 27.600 to have a single 40 mm lift of Alberta Transportation Type 5 dense graded asphalt concrete pavement. The next 11 km was paved with an 80 mm overlay of which the 500m from km 26.600 to 27.100 was identified as a control section for the project.

## 4.3 Asphalt Rubber Binder Design

The asphalt cement used for this project was 150-200A in conformance to Alberta Transportation Specification 5.7.

The rubber crumb used for the Alberta trial projects was from recycled truck tires supplied by a local Edmonton company (Alberta Environmental Rubber Products). The rubber gradation was intended to meet Type B gradation in accordance with Arizona specifications as shown in Table 2.

**Table 2 Crumb Rubber Gradation Requirements**

Type B (Arizona)

| Sieve Size | Percent Passing |
|---|---|
| 2.00 mm | 100 |
| 1.18 mm | 65 – 100 |
| 600 μm | 20 – 100 |
| 300 μm | 0-45 |
| 75 μm | 0 |

Law Engineering and Environmental Services Inc (Law Engineering) in Phoenix Arizona undertook the rubber-asphalt binder design and the mix design(s). The rubber crumb provided to the consultant was determined to be coarser than the specification limits for the fine material, with some +2.0 mm material as-well; however, the asphalt-rubber design was carried out with this material as it was considered representative of the material available.

**Table 3 Crumb Rubber Gradation as Tested for Design**

| Sieve Size | Percent Passing |
|---|---|
| 2.36 mm | 100 |
| 2.00 mm | 99 |
| 1.18 mm | 30 |
| 600 μm | 0.5 |
| 300 μm | 0.2 |
| 75 μm | 0.0 |

As ASTM indicates that the rubber gradation can affect the performance of the hot mix, future work needs to assure that the gradation of the CRM is confirmed on a continuous basis during production of the asphalt rubber. Further, future work will need to consider quality assurance programs to check for fiber content, and ferrous or nonferrous metal contents.

The design binder had a total CRM of 19% (by weight of total binder) (23.5% by weight of asphalt cement). The design was conducted to meet Arizona Type II requirements. A Type III was specified in the construction contract; and these results indicate the asphalt rubber does meet the ASTM Type III requirements. The properties of the asphalt rubber binder determined for the design are shown in Table 4.

**Table 4 Alberta Asphalt Rubber Properties**

| Test Performed | Minutes of Reaction | | | | | Specified Limits |
|---|---|---|---|---|---|---|
| | 60 | 90 | 240 | 360 | 1440 | |
| Viscosity, Haake at 177°C cP | 2200 | 2700 | 3200 | 3500 | 2900 | 1500-4000 |
| Resilience at 25°C, % Rebound | 41 | - | 49 | - | 45 | 25 min |
| Ring and Ball Softening Point, °C | 62.8 | 63.3 | 64.4 | 67.5 | 65.8 | 54.4 min |
| Penetration at 4°C, 200g, 60 sec. | 30 | - | 32 | - | 37 | 15 min |

Note: the binder design was conducted to Arizona specifications, these match ASTM requirements

## 4.4 Asphalt Rubber Concrete Mix Designs

The three projects in the Edmonton area placed a single mix. The asphalt rubber mix designs for the three Edmonton area projects had an optimum asphalt rubber binder content of 9.8% by weight of dry aggregate (8.9% by weight of total mix). The rubber asphalt content used as the starting target for the Calgary project was 8.2% by weight of dry aggregate.

The design parameters are shown in Table 5 and the design gradations are shown graphically in Figure 1.

**Table 5 Design Results**

| Parameter | Edmonton Area Designs | Calgary Design |
|---|---|---|
| Asphalt Content (wt dry agg) | 9.8% | 8.2% |
| Air Voids | 5.5% | 5.5% |
| VMA | 23.4% | 19.8% |
| Voids Filled | 76.4% | 72.2% |
| Stability | 11 kN | 10.5 kN |
| TSR | 0.75 | |
| Flow | 4.75 mm | 4 mm |
| MTD (Gmm) | 2.306 | |
| Density | 2174 kg/m$^3$ | 2247 kg/m$^3$ |
| Coarse/Fine | | 60/40 |
| | | |

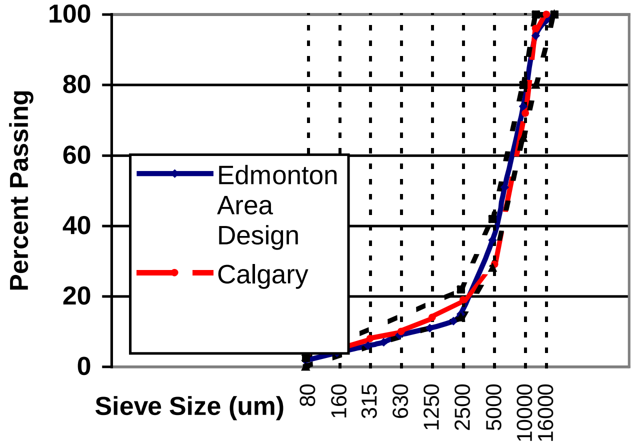


**Figure 1 Design Gradations**

The mix design for the Edmonton projects was performed by Law Engineering and was undertaken using the materials produced for the projects. The Calgary design was performed by EBA Engineering as a preliminary design prior to the rubber-asphalt binder design, and was considered as a starting point without further confirmation. Note also that the gradation for the Calgary project design exceeded the specification requirement (used for the Edmonton projects) on the 80 µm sieve with 4.1% passing versus a specification limit of 0 to 2.5%.

The mix designs for the control sections on each project were specific to the agency. The City of Edmonton utilized an ACO mix specification, Alberta Transportation’s control mix was a Type 5 specification. The work in Strathcona County utilized polymer-modified asphalt for the dense graded ACS materials placed. The City of Calgary placed a mix that incorporated a small amount of waste asphalt shingle, which conformed to its Mix B asphalt concrete specification, as a control section.

## 4.5 Pavement Structure Designs

Each agency followed their normal practice to determine the structural need for their respective pavement sections. The design thicknesses were reported as part of the project descriptions. This Section discusses the process used.

***Project 1 City of Calgary***

The City of Calgary design was experience based and did not consider structural testing per se. The City of Calgary practice is to design for a 15 year pavement life.

***Project 2 City of Edmonton***
The City of Edmonton base their structure design on Dynaflect deflections and use both the AASHTO and Asphalt Institute methods to determine an appropriate overlay thickness. The City of Edmonton uses a 10 year design period for their pavement designs.

***Project 3 Strathcona County***
Strathcona County design was based on a coring and testing program undertaken in 2000 that identified that the pavement structure was adequate for the then estimate 20 year design ESALs. The AASHTO method was used as the basis for the design review.

***Project 4 Alberta Transportation***
Alberta Transportation pavement designs are based on analysis of FWD deflections in accordance with the AASHTO (93) design guide and the department's internal pavement design manual. Alberta Transportation typically uses a twenty-year design period for a rehabilitative overlay.

As previously noted, as part of the data collection process undertaken for this project FWD deflections were obtained for all projects. This will allow a consistent design methodology to be applied to examine existing pavement strength on a common basis as the analysis of these trial projects progresses. The Consultant conducted AASHTO based calculations for all projects based on FWD deflection data and layer thicknesses measured using radar to determine an estimate of the existing modulus values.

## 4.6 Construction

The construction of the three Edmonton area projects used a single contractor and a single mix design; construction observations generally apply equally to all three Edmonton area projects. The Calgary project used a different mix design and different asphalt plant and paving crew. Some observations are specific to the Calgary trial project.

Asphalt rubber production using the Arizona equipment involved assuring the 150-200A asphalt was heated to 175°C prior to the mixing process. The design quantity of rubber and asphalt (19% rubber/81% asphalt cement or 23.5% rubber crumb by weight of asphalt cement) were then mixed together in the shear mixer portion of the asphalt rubber blending plant. Mixing of the asphalt and rubber crumb was completed and then the material was pumped into the reaction tank and held for a maximum time with viscosity measurements made by the contractor each hour as specified. The second tank contained two separate compartments and allowed asphalt rubber binder to be drawn from one partition while material was held in the other compartment. Reported results indicated that the asphalt rubber viscosity ranged from 1700 cP to 3100 cP prior to being incorporated in the mix, which is within the specified range of 1500 – 4000 cP.

Smoke emissions at the plant and paver were observed to be more visible than for normal mix production, likely due to the high mix temperatures. Some crew members indicated the fumes were bothersome, although most did not. As previously noted, there are no known health issues related to using asphalt rubber mixtures. The mixing temperature for Edmonton area projects was ~165°C with a lay down temperature of ~145°C.

Roller pick up problems were noted during mix placement and resulted in the rolling being delayed until the mix cooled enough to prevent this problem. The resulting compaction results indicate that the high rolling temperatures may be needed in order to achieve compaction.

No QA checks were made on the rubber crumb during production of the asphalt rubber binder. The material had been determined to not comply with the gradation requirements as noted in the asphalt rubber design section, however this was expected based on pre-construction samples.

***Project 1 City of Calgary***

The City of Calgary experienced a number of problems and shutdowns at the batch-plant site which were believed to be related to the introduction of the asphalt rubber into the plant.

The City of Calgary asphalt rubber mix was placed on June 26$^{th}$ and 27$^{th}$, 2002. At the target asphalt rubber binder content of 8.2% air voids were about 1% below the targeted 5.5% air voids. The first three Marshall tests were relatively consistent with asphalt rubber binder contents of 8.1, 7.7 and 8.2% and corresponding voids of 4.6, 4.4 and 4.1% respectively. The fourth Marshall sample with an asphalt rubber binder content of 8.0% showed uncharacteristically low air voids of only 2.7%. However, the final Marshall sample for the Calgary work was 7.2% asphalt rubber binder content, which resulted in 5.2% air voids, closer to the design target. Overall the gradations for the Calgary project were cleaner than design. Reported mix temperatures were 180°C at the paver.

Average compaction was 95.4% of Marshall Density for asphalt rubber mix placed in Calgary.

Table 6 and Figures 2 and 3 show the materials results for the asphalt rubber gap graded mixture.

***Projects 2,3, and 4 Edmonton Area***

The asphalt rubber feed into the Edmonton contractor's drum plant was direct into the plant. The plant electronics were tied into the asphalt rubber plant to control asphalt rubber flow into the mix. Unlike Calgary, this process seemed to be accomplished with no problems encountered.

The Strathcona County asphalt rubber mix was placed June 29$^{th}$ and the asphalt rubber mix for the City of Edmonton project was placed June 30$^{th}$ ,July 1$^{st}$ and July 2$^{nd}$ 2002. The Alberta Transportation asphalt rubber mix was placed July 3$^{rd}$ 2002.

Placement of the mix was relatively straight-forward. The mix was observed to be significantly 'stickier' than conventional asphalts (although probably similar to highly polymer modified asphalts) which led to build up on equipment. Hand work of the gap-graded asphalt rubber mixture was also problematic, but this difficulty is considered to be expected for this type of gradation and modified asphalt.

Blaw Knox pavers were utilized (two on 137 Ave, a PF 510 and a PF 180H, the 510 was used on the highway work) and two steel wheel rollers with a smaller steel wheel roller used for small areas on 137 Ave.

Paving on 137$^{th}$ was completed at night, and the specification to only pave at >14°C was waved by on-site personnel. Paving was shut down when the ambient temperature reached 9°C due to an observed lack of workmanship being achieved at the lower ambient temperatures.

Quality assurance undertaken on the project identified a binder content issue early in the project. The Edmonton area projects were constructed with an asphalt rubber binder content of ~10.5% compared to the design of 9.8% and the adjusted target of 9.3%**.** Asphalt rubber content and corresponding Marshall air voids for the Edmonton projects varied significantly between tests and suggests poor control of asphalt delivery to the plant. The final day of production on Hwy 630 had the least variation and relatively uniform asphalt content and Marshall air voids. Some of the variation noted may also be attributed to variations in the sample gradations. Overall, each of the three projects averaged ~1% less Marshall air voids than the design and would be considered to be over-asphalted based on conventional practice.

The level of compaction for the Edmonton area projects varied from about 94% to 96% in terms of average values for the three separate projects. A minimum value of 97% of Marshall density had been specified in the contract.

Table 6 and Figures 2 and 3 show the materials results for the asphalt rubber gap graded mixture.

## 4.7 Performance Observations

Although the rubber asphalt mixes have been in-place for less than a year a number of performance observations have been made.

Formal crack surveys are yet to be conducted to compare areas with specific crack mapping conducted prior to placement of the asphalt rubber and control section pavements. These surveys will be undertaken in the summer of 2003.

The City of Edmonton, City of Calgary, and Alberta Transportation projects have experienced reflective cracking in both the asphalt rubber mix and conventional mix sections.

Asphalt rubber mixtures on $17^{th}$ St (Strathcona County) and $137^{th}$ Ave (City of Edmonton) have both experienced rutting. On the City of Edmonton project, the observed rutting only occurs at the approach to the signalized intersection at 113a Street and is considered minor and much less problematic than almost 30 mm of rutting which occurred in a section of the control mix within one week of paving. (Although it is believed that the majority of the control section rutting was due to opening to traffic too soon.)

On the Strathcona County project rutting of the rubber asphalt section up to 30 mm has been measured near the stopping conditions, and reduced significantly at distances from the stop conditions. The rutting in the conventional mix (with modified asphalt) is only slightly less at similar stopping conditions. The rutting on the Strathcona County project was evaluated by removing a slab of pavement from the roadway. Observations suggest that it was not the asphalt rubber mix that had experienced the permanent deformation, but the older lower lifts of dense graded materials.

Overall, performance to-date is not significantly different from the other mixtures placed on the projects. It is considered that it is still too early for the observed performance to be definitive as to the potential of the asphalt rubber gap graded mixtures to provide improved pavement performance compared to conventional agency mixes.

Noise testing conducted on the three Edmonton area projects showed a reduction in noise of approximately 4 dB. This level of reduction is considered significant and is in agreement with the results reported by others.

## 4.8 Complementary Studies

### 4.8.1 University of Alberta

The University of Alberta has been contracted to undertake a review of the project with the intent of fully documenting all aspects of the design and construction and providing conclusions relative to the potential success of the these trial projects.

### 4.8.2 Arizona State University

Arizona State University has been contracted to undertake physical testing of the asphalt rubber gap graded mix placed on the Edmonton area projects and compare it to both a conventional mix and asphalt rubber materials placed in other jurisdictions. In addition, the ASU work includes characterization of the Asphalt rubber binder.

Physical testing being performed at ASU includes Complex modulus, static creep, repeated load permanent deformation, indirect tensile creep and strength, fatigue testing of flexural beams and triaxial shear strength testing. Testing will be conducted on both the asphalt rubber gap graded mix and the City of Edmonton ACO mix used as the control section for the City project.

## 5.0 Costs

Although project costs for a trial project of this nature are difficult to quantify in a meaningful way, there are costs directly associated with the asphalt rubber gap graded mix which can be quantified independent of the nature of the project. These quantifiable costs include the cost of the rubber crumb ($250/t of rubber crumb) and the additional cost associated with an increase binder demand for the gap graded mix (~ 3% increase in binder demand compared to conventional dense graded mixes equating to ~$7.50/t of mix). Note that the increase in binder is both asphalt and rubber, which must not be counted twice. Since the rubber crumb cost is approximately equal to current asphalt costs, the net increase in binder cost is considered to be approximated by the calculated ~$7.50/t. It is recognized this value varies depending on assumed asphalt contents for conventional mixes.

Other costs which are more difficult to quantify in the absence of significant experience are the cost of producing the gap graded aggregate and the costs associated with the asphalt rubber blending equipment.

Based on experience with Superpave mixes in Alberta, Alberta Transportation has estimated a $1/t premium for these mixes throughout the province. This premium includes a cost premium for the aggregate and a cost reduction for the reduced asphalt demand of typical Superpave mixtures. Based on this experience Alberta Transportation expects that the aggregate premium is in the order of $2.50/t of aggregate. In the City of Edmonton, the cost premium is considered to be significantly greater, as much as $15/t of aggregate. Although the cost premium doesn’t necessarily address the aggregate conservation issue of rejecting fines which in rural areas often have no market, it is considered an economic premium for these types of mixtures in Alberta. The additional costs for equipment are known for the trial projects, but are not considered representative of work that would be carried out on a production basis. In all, an increase in cost of approximately $5/t for asphalt rubber gap graded mix is an estimated production cost at this time. (Actual costs on the trial projects was in excess of $10/t for the binder production alone).

Potential savings which are being pursued as a part of this research effort include the potential to reduce structural overlay thicknesses and achieve equivalent pavement life, while also achieving lower noise levels.

In the simplest terms, and based on the dollar values identified above, the increase capital cost of asphalt rubber gap graded mixtures can be cost justified if they can be used at a lesser thickness than the conventional mix they are replacing; this reduced thickness to achieve an economic break-even based on capital costs, would be in the order of 30 to 50%.  Whether such performance equivalencies can be obtained is in-part, the purpose for which these trial projects were undertaken.

## 6.0 Summary and Conclusions

1. The process followed by the Alberta asphalt rubber steering committee to undertake the trial projects discussed in this report resulted in a significant growth of understanding of asphalt rubber in Alberta.  However, it is obvious that there is still much to learn about the design, construction and performance of this material.

2. The construction of the relatively small trial sections resulted in more construction variation than is desirable for trial sections that will be used to predict the performance capabilities of the asphalt rubber gap graded mixtures in Alberta.

3. Work at ASU will serve to quantify the potential of the asphalt rubber produced in Alberta to perform relative to mixtures produced in other jurisdictions.

4. The performance to-date of the asphalt rubber trial sections has shown that the product does not prevent reflective cracking in the specific applications in which they were placed.  Any reduction in frequency or severity of cracking will be quantified as part of future monitoring of the projects.

5. The trial projects successfully demonstrated that the asphalt rubber gap graded mixtures, while requiring some additional care and attention in handling, could be placed with conventional equipment and methods.

6. A review of costs associated with the asphalt rubber gap graded mixtures showed that a reduction in overlay thickness of 50% will be required in order to achieve equivalent capital costs.  Although it is too early to speculate on performance life of asphalt rubber gap graded mixtures in Alberta, a substantial increase in service life in the absence of reduced structural thickness of the overlay would be required to justify the additional capital cost.

7. Alberta is pursuing additional work for the 2003 construction season.  It is considered that such additional work will allow for more experience to be gained and provide further projects for performance monitoring.

## References


1. CalTrans, Asphalt Rubber Usage Guide, State of California Department of Transportation, Materials Engineering and Testing Services-MS #5, January 2003.

2. Carter, T., PlusRide Asphalt, Rubberized Road Surface Compound, Hw 47 Test Section, Alberta Transportation Internal Report, 1987.

3. Chollar, B., Memon, M., CMCRA: Where the Tire Meets the Road, From the Turner Fairbanks Highway Research Center, www.tfhrc.gov/pubrds/spring97/crum.htm

4. Flexible Pavement Rehabilitation Manual, California Department of Transportation, June 1, 2001

5. Way, G.B., OGFC Meets CRM, Where the Rubber Meets the Rubber, 12 Years of Durable Success, Proceedings of the Asphalt Rubber 2000 Conference, November, 2000, pp15-31

6. Way, G.B., Prevention of Reflective Cracking in Arizona Minnetonka – East (A Case Study), Arizona Department of Transportation, May 1976

7. Way, G.B., Prevention of Reflective Cracking Minnetonka – East (1979 Addendum Report), Arizona Department of Transportation, August 1979

8. Way, G.B., Flagstaff I-40 Asphalt rubber Overlay Project – Ten Years of Success, Proceedings of the Asphalt Rubber 2000 Conference, November, 2000, pp641-658

9. Memon, G.M., Chollar, B.H., Asphalt Rubber Chip Seal Project In Texas and the Viscosity Buildup Study of Chemically Modified Crumb Rubber Asphalt (CMCRA), Proceedings of the Asphalt Rubber 2000 Conference, November, 2000, pp628-639

10. The "Cure" for Pavement ills, Texas Transportation Researcher, Volume 34, Number 2, 1998

11. Lundy, J. Use of Ground Tire Rubber in Asphalt, Oregon State University, presentation from http://cwest.orst.edu/news/construction/presentations/lundy.pdfv

12. Roberts, R.L., et al, Investigation and Evaluation of Ground Tire Rubber in Hot Mix Asphalt, National Center for Asphalt Technology, Auburn University, Alabama, 1989

13. EBA Engineering Consultants Ltd., Study to Investigate The Use of Recycled Tire Rubber In Asphalt Concrete, Alberta Transportation report ABTR/RD/RR/-94/03, 1994

14. Hunt, E.A., Crumb Rubber Modified Asphalt Concrete in Oregon, Final Report SPR 355, March 2002.

15. Johnston, A., Gavin, J., Palsat, D., An Evaluation of the Permeability Characteristics of Superpave Coarse Mixtures In Alberta, Proceedings of the Canadian Technical Asphalt Association, 2001.

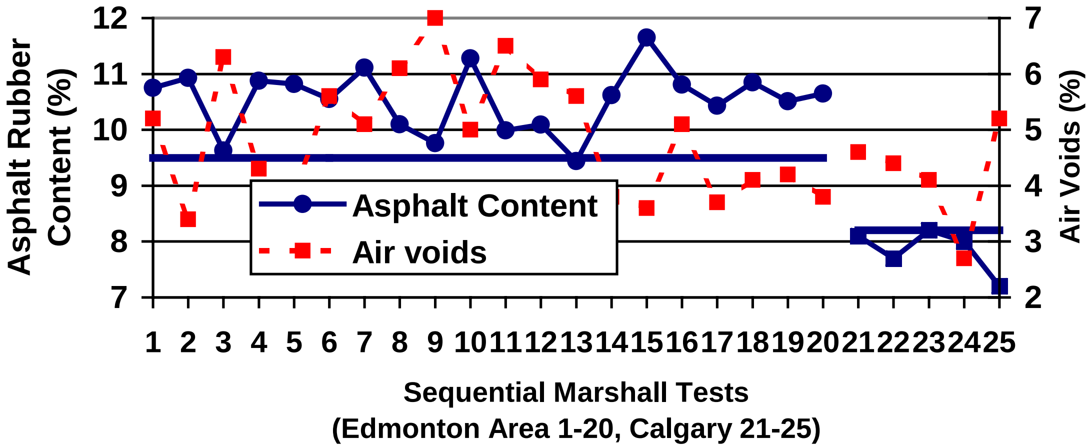


**Figure 2 Asphalt Rubber Binder Content and Marshall Air Voids**

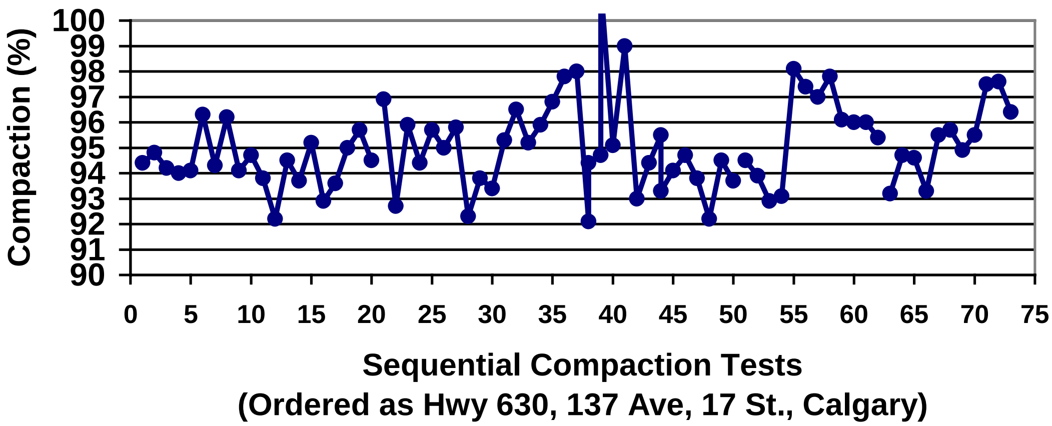


**Figure 3 Asphalt Rubber Mix Compaction**

**Table 6 Asphalt Rubber Quality Assurance Results**

| Sample Number | Marshal Density | Asphalt Content (% Dry Agg) | Air Voids | Gradation % Passing µm | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 16,000 µm | 12,500 µm | 10,000 µm | 5,000 µm | 2,500 µm | 1,250 µm | 630 µm | 315 µm | 160 µm | 80 µm |
| **City of Calgary 112 Avenue** | | | | | | | | | | | | | |
| M-1 | 2236 | 8.1 | 4.6 | 100 | 90 | 75 | 26 | 13 | 10 | 8 | 6 | 4.0 | 2.5 |
| M-2 | 2267 | 7.7 | 4.4 | 100 | 92 | 75 | 27 | 14 | 10 | 8 | 7 | 5.3 | 3.6 |
| M-3 | 2255 | 8.2 | 4.1 | 100 | 93 | 76 | 29 | 14 | 10 | 9 | 7 | 4.6 | 3.2 |
| M-4 | 2287 | 8.0 | 2.7 | 100 | 94 | 83 | 34 | 19 | 14 | 12 | 9 | 5.4 | 3.3 |
| M-5 | 2247 | 7.2 | 5.2 | 100 | 90 | 69 | 22 | 12 | 9 | 7 | 6 | 4.0 | 2.7 |
| **City of Edmonton 137 Avenue** | | | | | | | | | | | | | |
| M-9 | 2159 | 10.55 | 5.4 | 100 | 94 | 78 | 40 | 16 | 12 | 10 | 8 | 5.4 | 3.2 |
| M-10 | 2157 | 11.11 | 4.9 | 100 | 94 | 79 | 43 | 17 | 13 | 11 | 8 | 5.6 | 3.3 |
| M-11 | 2157 | 10.10 | 5.6 | 100 | 92 | 78 | 40 | 16 | 12 | 10 | 8 | 5.6 | 3.4 |
| M-12 | 2144 | 9.76 | 6.9 | 100 | 94 | 77 | 38 | 15 | 11 | 9 | 7 | 4.8 | 2.9 |
| M-13 | 2155 | 11.28 | 4.8 | 100 | 96 | 81 | 43 | 17 | 13 | 11 | 8 | 5.3 | 3.1 |
| M-14 | 2151 | 9.99 | 6.3 | 100 | 95 | 78 | 40 | 16 | 12 | 10 | 8 | 5.0 | 3.0 |
| M-15 | 2161 | 10.09 | 5.9 | 100 | 95 | 78 | 41 | 16 | 12 | 10 | 8 | 5.1 | 3.0 |
| M-16 | 2185 | 9.44 | 5.3 | 99 | 92 | 69 | 33 | 14 | 11 | 10 | 8 | 5.2 | 3.2 |
| M-17 | 2197 | 10.62 | 3.8 | 100 | 95 | 79 | 41 | 16 | 12 | 10 | 8 | 5.2 | 3.2 |
| M-18 | 2176 | 11.65 | 4.1 | 100 | 95 | 79 | 40 | 17 | 12 | 10 | 8 | 5.0 | 3.2 |
| **Strathcona County – 17th Street and Baseline Road** | | | | | | | | | | | | | |
| M-6 | 2163 | 10.75 | 4.4 | 100 | 93 | 79 | 41 | 17 | 12 | 10 | 8 | 5.2 | 3.0 |
| M-7 | 2198 | 10.93 | 3.6 | 100 | 94 | 79 | 40 | 17 | 12 | 10 | 8 | 5.0 | 2.9 |
| M-8 | 2163 | 9.63 | 6.3 | 100 | 93 | 76 | 35 | 15 | 11 | 10 | 7 | 4.7 | 2.7 |
| M-24 | 2179 | 10.88 | 4.0 | 100 | 95 | 79 | 42 | 17 | 13 | 11 | 8 | 5.3 | 3.1 |
| M-25 | 2189 | 10.82 | 3.4 | 100 | 94 | 78 | 40 | 18 | 13 | 11 | 8 | 5.3 | 3.0 |
| **Alberta Transportation – Highway 630** | | | | | | | | | | | | | |
| M-19 | 2162 | 10.81 | 5.2 | 100 | 96 | 79 | 41 | 17 | 13 | 11 | 8 | 5.2 | 3.0 |
| M-20 | 2205 | 10.43 | 3.3 | 100 | 95 | 77 | 40 | 17 | 12 | 10 | 8 | 5.2 | 3.1 |
| M-21 | 2186 | 10.85 | 3.4 | 100 | 94 | 78 | 42 | 18 | 13 | 11 | 8 | 5.4 | 3.2 |
| M-22 | 2191 | 10.51 | 3.3 | 100 | 94 | 78 | 39 | 17 | 12 | 10 | 8 | 5.2 | 3.1 |
| M-23 | 2195 | 10.65 | 3.7 | 100 | 94 | 78 | 40 | 16 | 12 | 10 | 8 | 5.1 | 2.9 |