Evaluation of a Skid Resistant Material at High Incident Intersection Locations

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ABSTRACT

High incident intersections have become an area of great focus for motorist's and pedestrian safety improvements within many municipalities. One of the problematic areas in high incident intersections is the subject of stopping effectively. In order to try and enhance stopping characteristics several test locations have been constructed using a methyl methacrylate / bauxite skid resistant material developed and applied by Lafrentz Road Marking at high incident intersections in Calgary and St. Albert, Alberta. These test sections were constructed in order to evaluate the product's effectiveness at improving pavement friction and reducing friction related incidents at the selected intersections.

The paper provides an overview of the four locations the skid resistant material was placed and their respective performance and wear characteristics over one winter in Calgary and after two years in the case of The City of St. Albert. The paper discusses the correlation between the various types of friction testing that was undertaken. The paper further explores how the material has changed the frictional values of the treated areas and what this means to the motorist. Finally, the paper provides a review of the placement operation as well as the performance and incident statistics for each of the locations where the skid resistant material was placed.

Introduction

Many cities and municipalities have started to investigate intersection incidents and what kind of treatments can be installed to help alleviate these issues without too much interaction or disruption to the drivers. In high traffic locations surface friction plays an important role in mitigating rear end collisions as well as increasing pedestrian safety. Stopping effectively or stopping distance plays a significant role on high incident intersections. Within this paper a newly developed methyl methacrylate / bauxite skid resistant surface material is investigated and four installations in two cities are evaluated. Key points that are discussed are how the material is performing in terms of surface frictional properties and durability as well as, incident history.

Skid Resistance and Intersections

The skid resistance of an asphalt pavement is of critical importance because it directly relates to the safety of motorists and their ability to stay on the road and be able to stop effectively. The frictional resistance between a vehicle's tire and the pavement surface constitutes skid resistance. Skid resistance can be affected by several factors including the environment, roadway surface characteristics, and roadway geometry. Possessing good all weather skid resistance and maintaining these frictional properties over time are critical to the driving public. There are many tools and methods available for measurement of skid resistance. Williams et al (1) discusses that skid resistance measures involve some sort of surrogate measure of friction which is primarily a measure of microtexture supplemented with a measure of texture and that the most commonly used device for measuring microtexture has been the British Pendulum Tester. Other skid resistance devices commonly used involve either a vehicle or trailer where a tire is used to produce the skidding condition. The FHWA Intersection Safety program (2) discusses the method of increasing the frictional characteristics on intersection approaches beyond what is attainable through traditional techniques is by using new high-friction surfacing systems utilizing resins and polymers combined with hard aggregates. This is the type of improvements that have been selected for these trial sections.

Lafrentz Road Marking Skid Resistant Material

<u>Development and Application of Material</u>

There are many different types of skid resistant materials available that use different binder systems. Some resin systems are quite hard and have not had great successes in Canadian climates with harsh snowplow activity. Methyl methacrylate materials have been used for a long period of time in Canadian environments as durable road marking materials with great success. A material was developed utilizing a two component MMA skid resistant material for Canadian climates which is called Lafrentz SRM. Several different types of aggregates can be used in the process: basalt, corundum, granite, and bauxite. Calcinated bauxite is generally the aggregate of choice in a 1-3mm sizing. Bauxite is chosen for its extreme hardness and superior wear characteristics.

The MMA/bauxite skid resistant treatment is installed by Lafrentz Road Marking crews by first preparing the asphalt surface scuffing up the surface. At intersections near the stop bar oils and other vehicular remnants seem to accumulate. Surface preparation is important to remove any of the contaminated asphalt and to ensure proper adherence and longevity of the material. Next a base layer of methyl methacrylate (MMA) is applied to the road surface at a thickness of 1-1.5mm as seen in Photo I. Calcinated bauxite is then spread evenly over the surface of the uncured MMA, embedding itself into the wet material, becoming bonded to the MMA once cured. After curing, the excess bauxite is then swept off and the surface is blown to remove any remaining dust. Finally, a thin layer of MMA resin is rolled over the bauxite, effectively sealing the surface. This works well as the nature of a MMA can create a monolithic repair bonding back to itself. Photo I and Photo II depict the installation process.


Photo I: First steps of application process of Lafrentz SRM MMA and bauxite


Photo II: Second steps removing excess bauxite and sealing surface with MMA resin

City of St. Albert SRM Trial Sections

Selection of Intersections

The City of St. Albert has a population of about 60,000 and a road network that consists of 782 lane km and 938 Intersections. A major North South corridor "St. Albert Trail" runs within the city. In 2009 there were 1,118 reported collisions on the network. Of these collisions 510 occurred at Signalized locations and 333 occurred at the top 14 collision locations. The 333 was comprised of 122 rear end collisions or 37%. In 2010, The City of St. Albert initiated an intersection safety initiative to address some of the high incident locations their transportation system had seen at these major arterial intersections. The past methodology on recognizing high collision locations included only a review of "quantity of collisions". This would result in repetitive locations being the Top 5 despite of any engineering adjustments and actions. By utilizing the data collected annually the city was able to create a new method which included Network Screening for each intersection location. This method looked at a weighted frequency which measured the collision severity. The factors that were included in their calculations were: Average Daily Volume, Average Collision Rate, and a Comparison of Similar Road Classification Intersections. The equation seen below in Figure I is the Critical Collision Rate.

$$R_c = R_a + k\sqrt{\left(\frac{R_a}{M}\right) + \frac{1}{(2M)}}\ \textit{Where:}$$

$R_c =$ Critical Collision Rate

$R_a =$ Average Collision Rate (calculated from similar Network Elements)

$M =$ Millions of vehicles entering into the intersection

k = Probability Constant (A value of 2.32 obtains a 99% confidence level

Figure I: Critical Collision Rate Equation

Utilizing this equation St. Albert was able to graph the critical collision rate versus intersection collision rates at arterial intersections which can be seen in Appendix A. From this graph three locations: St. Albert Trail at Hebert / Gervais Road, St. Albert Trail at Sturgeon Road / St. Anne St., and St. Albert Trail at McKenney Avenue / Bellerose Drive were chosen as potential candidates for the Skid Resistant Material trials. These locations were all in the Top 10 critical collision locations and two of them had intersection safety cameras. One of the purposes of the trial sections was to try and reduce the number of rear end collisions that occur at these locations.

Layout and Installation

Several different styles of placement of a skid resistant material were investigated each with their own merits. The first style that was looked at was placing the material across the entire width of the roadway and extending 30 meters back from the stop bars at the intersection which can be seen in Figure II. This method covered all of the possible vehicle types but in covering 222 square meters it is also the most costly. The second method looked at the perpendicular laneway. In this layout the amount of skid resistant material that was going to be present was deemed to be not significant enough even though the savings would be great. The third option was to install the SRM only in the wheel paths. The preferred installation method was that of the wheel path. The wheel path was determined to be less expensive than the solid laneway but still beneficial for multiple vehicle types while possessing a consistent stopping material. As well, there are some recognized cost savings in material and installation with this method. The material was placed on St. Albert Trail on the straight through lanes only

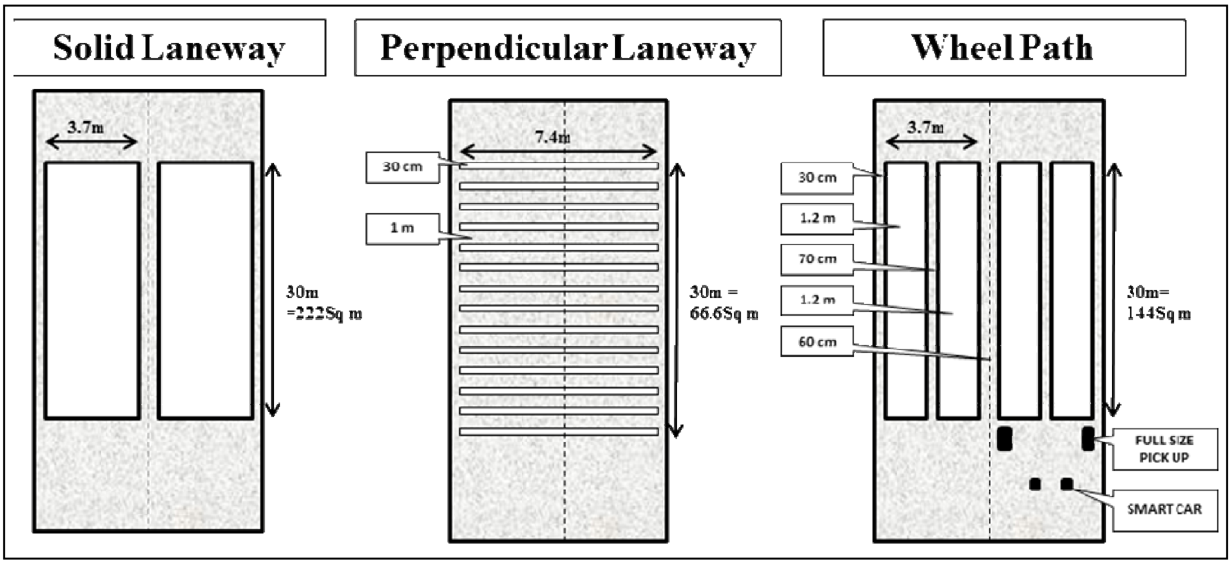


Figure II: Three Different Styles of Placing Skid Resistance Material

Each of the intersection locations that received this installation had three driving lanes in each direction on St. Albert Trail. The first location was placed in early June of 2010 on asphalt that was approximately one year old. The work was scheduled for night due to the extremely high volumes of traffic at these locations and was back in service by the morning. The following two locations were installed later in the 2010 season in October once paving operations had been completed. Photo III shows the material just after completion on the left and the following morning on the right. Skid marks can be seen in the second photo demonstrating the material was put to test right after installation.

Photo III: Post Installation Photo

Skid Test results and Monitoring

To study the skid resistance of the material two methodologies were employed. The First test methodology that was used in these tests was ASTM E303-93 Standard Test Method for Measuring Surface Frictional Properties Using the British Pendulum Tester. The test method states that the tests are to be taken with "sufficient water to cover the test area thoroughly and rewetting the test area after each swing." The tests were performed using a Wessex Skid Tester S885 as can be seen in Photo IV. For these tests both the asphalt and the skid areas were tested in each direction (North bound and Southbound) of travel in the wheel path lanes. The tests have been performed over the life cycle of the material first after initial construction was complete and then every spring thereafter. Table I shows the average values of the surface frictional properties of the different locations for both the asphalt and the skid resistant material. It can be seen that the skid numbers for the SRM are greater than that of the asphalt immediately prior to their installations. As well, after two winter cycles the skid numbers still seem to be enhanced when compared to conventional asphalt.

Location	**November 4, 2010**		**March 30, 2011**		**March 12, 2012**	
	BPN	**% Diff**	**BPN**	**% Diff**	**BPN**	**% Diff**
SAT @ Hebert						
Asphalt before SRM	**64**		**64**		**61**	
SRM	**77.42**	**21**	**80**	**25**	**75.5**	**24**
SAT @ St. Anne						
Asphalt before SRM	**59.25**		**65**		**63**	
SRM	**75.5**	**27**	**78.67**	**21**	**77.5**	**23**
SAT @ Bellerose						
Asphalt before SRM	**59**		**60**		**54**	
SRM	**81.38**	**38**	**74.67**	**24**	**64**	**19**
****All results are average value presented in BPN (British Pendulum Number)**						

Table I: Test Results Using the British Pendulum Tester

On March 15, 2011 The City of St. Albert, with the help of the City of Edmonton conducted traction tests along St. Albert Trail on the three MMA/bauxite surface treatment test sections. In performing the tests a Vericom VC4000 accelerometer was used to collect the following information: Average G, Peak G, stopping distance, stopping time, and vehicle speed. The target velocities for this testing were 30 km/h utilizing a Dodge Dakota with all-season radial tires and an anti-lock braking system. Traction data was collected on the new asphalt and on the MMA/bauxite anti-skid treatment. Appendix B Graph I demonstrates the differences between the coefficients of friction (G) generated on the MMA/bauxite test sections and on regular asphalt. Two of the asphalt data points were collected on a dry surface, the rest of the asphalt data and MMA/bauxite were on a wet surface. The coefficients of friction are seen to be higher for the MMA/bauxite over the asphalt. Table II below and Graph II in Appendix B show the differences in stopping distance on the MMA/bauxite compared to regular asphalt. On average, the MMA produced a 1.5m shorter stopping distance when braking at 30km/h over regular asphalt. Braking on the MMA generated higher coefficients of friction (higher G), and resulted in shorter stopping distances than regular asphalt under wet conditions. Overall, the MMA test sections provided better frictional properties than regular asphalt.

Test Surface	Average Stopping Distance (m)
Asphalt	**6.82**
MMA	**5.32**
Variance	**1.50**
Percent Variance	**22%**

Table II: Stopping Distance

Photo IV: Wessex Skid Tester S885

Material wear after the winter of 2010 had been noted to be less than 5% wear in 2 of the three locations. The newest locations with the new asphalt exhibited better wear characteristics over the first winter. The first installation location exhibited 25 – 30 % wear in a few of the locations near to the stop bar where inductive loops in the ground and surface preparation could have led to some of the premature failures. In early 2011 the location that showed this failure was repaired and seems to be standing up much better. In 2012 after two winter cycles the SRM material seems to be looking good in most locations still only showing less than 5% wear on the three locations. In the South bound lane of St. Albert Trail and St. Anne intersection lane number 2 seems to have some type of asphalt or binder that has been left behind on the SRM surface possibly from the previous year's construction season. Other than this the material has worked well through another winter cycle.

Incident History

The City of St. Albert has been collecting Collision data for several years now and is utilizing this data to help access their network and locations that need improvements. The trend for total collisions for the three locations has been downward since the installation of the SRM in summer 2010. Table III provides numerical results for Total Collisions as well as Property Damage, Injury, and Rear End Incidents which have also shown a similar trend since installation. It is still very early in the data gathering process to know whether this is just an anomaly or if the material is attributing to this trend. Further monitoring and analysis will be required for a better understanding of how the increase of frictional properties has affected the data.

Year	Total Collisions	Property Damage	Injury	Fatality	Rear End Incidents
2006	136	102	34	0	52
2007	139	97	41	1	48
2008	112	90	22	0	32
2009	116	99	17	0	47
2010	82	64	18	0	42
2011	75	58	17	0	37

Table III: Collision Data of all three locations

City of Calgary SRM Trial Section

Location and installation

In 2011 The City of Calgary also saw a need for the introduction of some safety initiatives at intersections. As the city looked at locations that needed improvements one such location jumped out where Lafrentz SRM was considered to be installed as a trial project. The Skid resistant material was installed before the stop bar on 16th Ave. NE in the west bound lanes at 19th street in September of 2011. This location had a mild downhill slope leading to a stop light. The stopping capability of the motorists going west bound before the stop bar and crosswalk needed some enhancement. Sixteenth Avenue comprises part of the Trans-Canada Highway (Highway 1) and has approximately 80,000 AADT.

The City of Calgary decided to go with a solid laneway application, as seen in Figure III, in the three straight through lanes for this location. The City was more concerned with coverage and long term durability over the extra cost of material for full coverage. Lafrentz Road Marking installed the SRM application during the nights so as not to disrupt the travelling public at this high traffic intersection. In service use of the SRM in Photo V shows the solid laneway application and skid marks from use.

Photo V: Solid Laneway Application of SRM

Skid results

The SRM material was tested utilizing two different test methods. The first method was using ASTM E303-93 Standard Test Method for Measuring Surface Frictional Properties Using the British Pendulum Tester. This is the same method and apparatus that was utilized to test The City of St. Albert's SRM locations. As well, the City of Calgary also used a Grip Tester MK2 D which is based on ASTM E2340 and provides a continuous wet/dry skid resistance measurement. The grip tester simulates Anti-Lock Braking System (ABS) as well shows strong correlation with other skid resistance equipment. When we look at the Table IV below we can see that indeed that skid resistance of the asphalt prior to the new SRM is significantly lower. Also, it is evident that the Grip Numbers and British Pendulum Numbers seem to be quite similar in representation of the frictional properties of the materials they are testing.

Location	October 2011		October 2011	
	GN*	% Diff	BPN**	% Diff
Inner Lane				
Asphalt before SRM	0.58			
SRM	1.00	72		
Middle Lane				
Asphalt before SRM	0.49			
SRM	0.99	96		
Outer Lane				
Asphalt before SRM	0.59		58.5	
SRM	0.99	68	91.2	56
*Results are average values presented in GN (Grip Number)				
** Results are average values presented in BPN (British Pendulum Number)				

Table IV: Skid Test Data on 16th Ave. NE (WBL) just before 19th Street

Performance

In reviewing the surface frictional properties found by the Grip Tester and British Pendulum Tester the frictional properties of the SRM have significantly gone above that of conventional asphalt. The skid resistant material was installed before the stop bar on 16th Ave. NE in the west bound lanes at 19th street in September of 2011. Westbound rear end collision data between the months of September to January for 2009, 2010, and 2011 were compared. In 2009 there were nine rear end incidents, in 2010 there were eight rear end incidents, and in 2011 there were only seven rear end incidents. It is very early to comment or draw any conclusions on the potential safety performance that the new skid resistant material could provide. Further monitoring of the area needs to be recorded and revisited after a one and two year period to get a better understanding of its performance. After a mild winter that Calgary had this last year the material seems to be holding up quite well and is not showing any signs of wearing or loss.

Conclusion

All four locations have exhibited benefit in their frictional properties with the installation of the Lafrentz Skid Resistant Material (SRM). Lyon and Persaud (3) noted that skid-resistance improvement projects can yield substantial safety benefits for both road segments and intersections. In The City of Calgary's installation it is still too early to notice any safety benefits other than the increased skid-resistance at this time. The initial incident data looks promising but further monitoring and analysis will be required. The City of St. Albert's intersections have started to show a decrease in the number of rear end collisions in the three intersections which is one of the goals that they hoped to achieve with the trial sections. Still two years of data is early in the evaluation process and continued monitoring will be performed. Skid results are still increased over conventional asphalt through the two winter cycles the SRM in St Albert has seen. The decrease in stopping distance that was seen in the City of St. Albert could be a great benefit to motorist and pedestrians in any high traffic intersection locations.

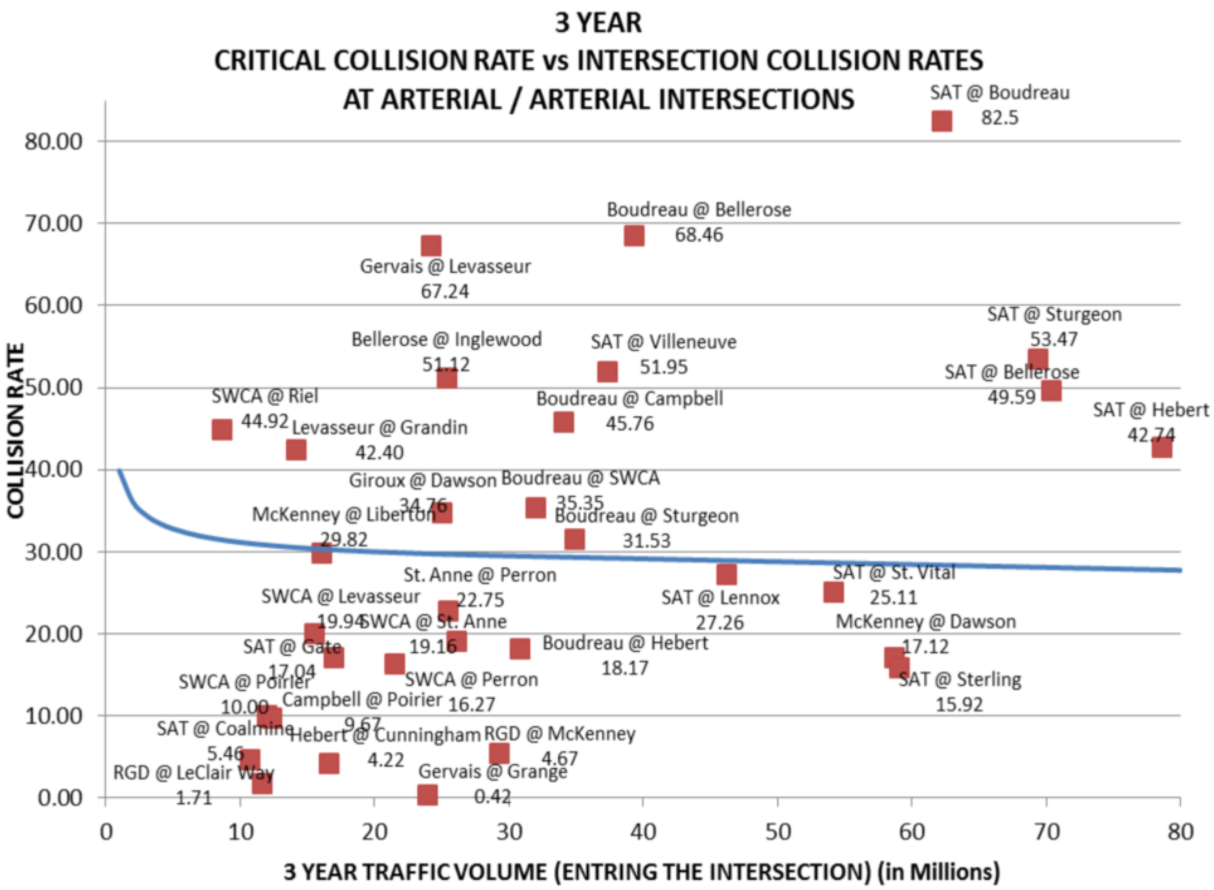
References

(1) Williams S, Becknell N, Hall K, "A Comparison of the Frictional Properties of 4.75 and 12.5 mm HMA Surface Mixes", Proceedings, Canadian Technical Asphalt Association, 54, 191-211 (2009).

(2) FHWA Intersection Safety Website "Low-Cost Safety Enhancements for Stop-Controlled and Signalized Intersections", http://safety.fhwa.dot.gov/intersection/resources/fhwasa09020/chap_5.cfm (2012)

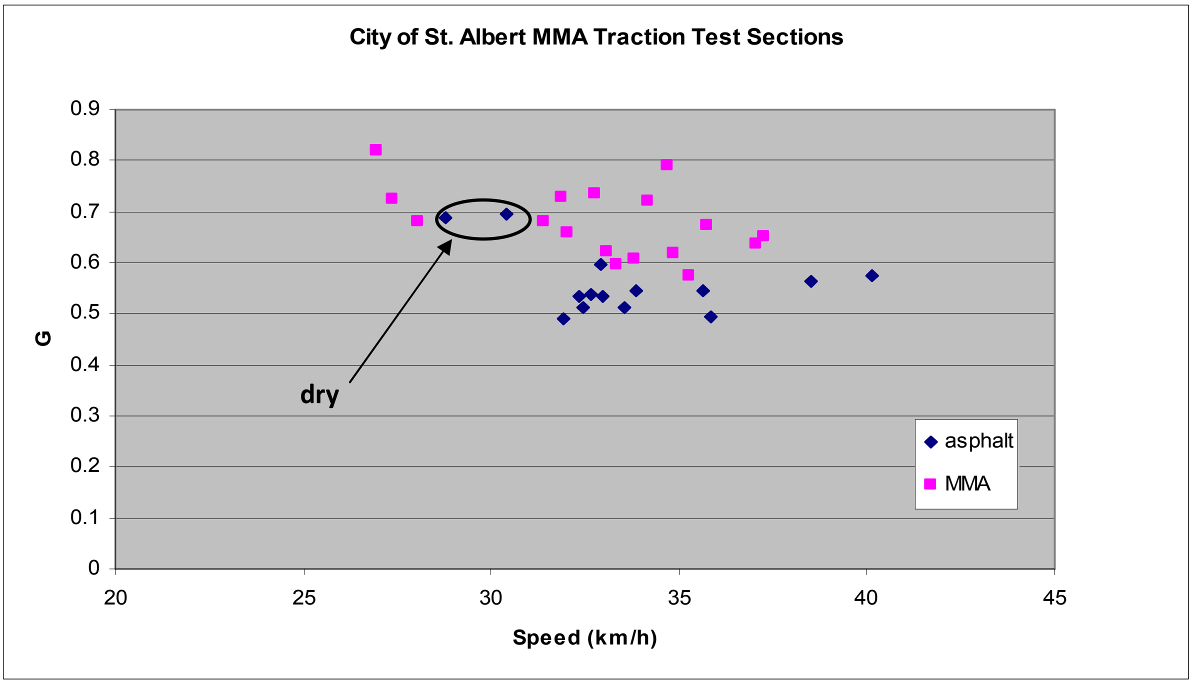
(3) Lyon, C and B. Persaud. 2008. "Safety Effects of a Targeted Skid Resistance Improvement Program." Transportation Research Board, Washington, DC. 135-140 (2008).

Appendix A

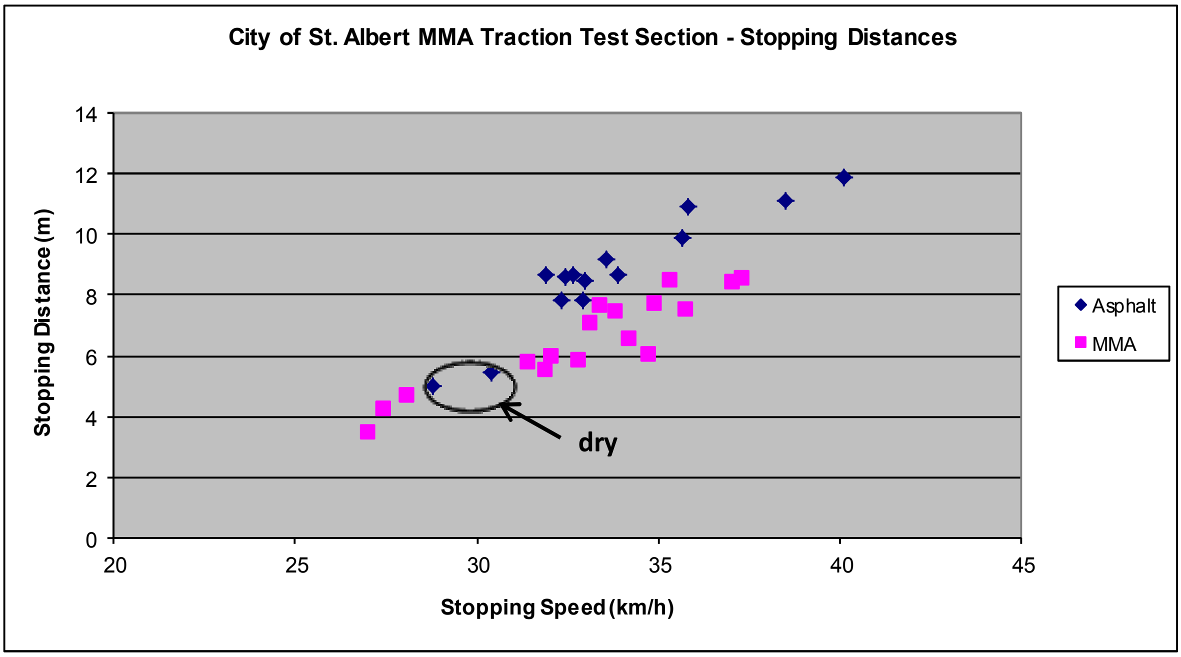


3 YEAR
CRITICAL COLLISION RATE vs INTERSECTION COLLISION RATES
AT ARTERIAL / ARTERIAL INTERSECTIONS
COLLISION RATE
3 YEAR TRAFFIC VOLUME (ENTRING THE INTERSECTION) (in Millions)
SAT @ Boudreau 82.5
Boudreau @ Bellerose 68.46
Gervais @ Levasseur 67.24
SAT @ Sturgeon 53.47
Bellerose @ Inglewood 51.12
SAT @ Villeneuve 51.95
SAT @ Bellerose 49.59
SWCA @ Riel 44.92
Levasseur @ Grandin 42.40
Boudreau @ Campbell 45.76
SAT @ Hebert 42.74
Giroux @ Dawson 34.76
Boudreau @ SWCA 35.35
McKenney @ Liberton 29.82
Boudreau @ Sturgeon 31.53
St. Anne @ Perron 22.75
SAT @ Lennox 27.26
SAT @ St. Vital 25.11
SWCA @ Levasseur 19.94
SWCA @ St. Anne 19.16
Boudreau @ Hebert 18.17
McKenney @ Dawson 17.12
SAT @ Gate 17.04
SWCA @ Perron
SAT @ Sterling 15.92
SWCA @ Poirier 10.00
Campbell @ Poirier 16.27
SAT @ Coalmine 5.46
Hebert @ Cunningham 9.67 4.22
RGD @ McKenney 4.67
RGD @ LeClair Way 1.71
Gervais @ Grange 0.42

Appendix B



Graph I: Coefficients of Friction generated braking on asphalt and MMA test sections



Graph II: Stopping distances as a function of stopping speed, on MMA and Asphalt