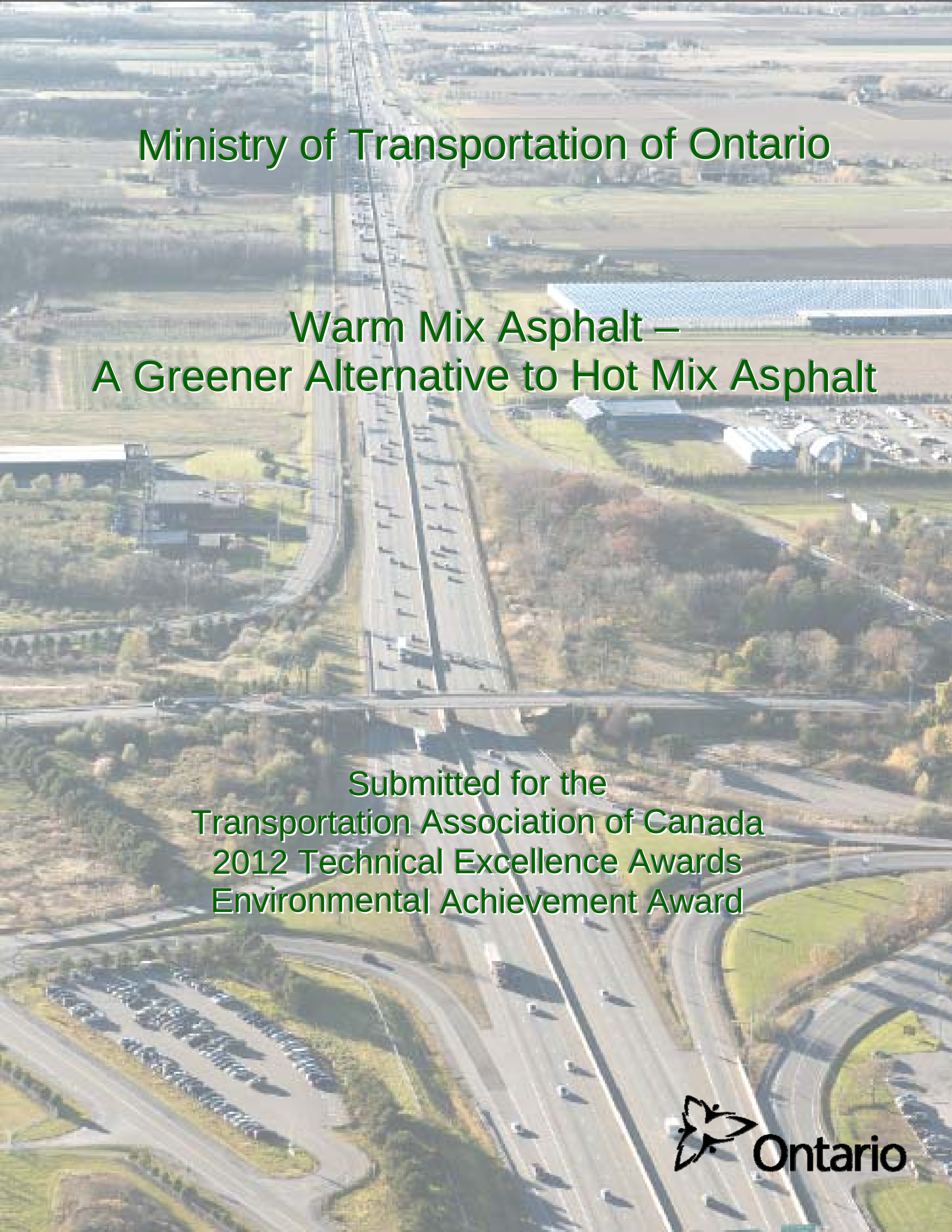

Ministry of Transportation of Ontario

Warm Mix Asphalt – A Greener Alternative to Hot Mix Asphalt

Submitted for the
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Introduction

The Ministry of Transportation of Ontario's (MTO) priorities include improving Ontario's highway infrastructure and integrating the principle of sustainability into ministry programs, policies, and operations. The commitment to protect and preserve the environment and encourage the sustainable use of resources on all projects is reflected in the mandate of the MTO Provincial Highways Management (PHM) division "to deliver a provincial highway network that is safe, provides mobility for people and goods, and promotes economic, environmental and social sustainability." MTO has a strong history of research, development, and implementation of innovative green pavement technologies. One recent initiative that has been successfully implemented is the use of Warm Mix Asphalt (WMA) on MTO construction projects.

Warm Mix Asphalt is defined as a group of technologies that allow for a reduction in the temperatures at which asphalt mixes are produced and placed relative to traditional Hot Mix Asphalt (HMA). WMA is produced and placed at temperatures 20º to 50º C less than conventional HMA. The production and paving of asphalt at these reduced temperatures generates fewer emissions and requires less energy while maintaining or enhancing pavement performance.

MTO began preliminary research on the application of WMA to Ontario roads in 2006, followed by initial WMA trial contracts in 2008. Between 2008 and 2009, MTO placed a total of 7,000 tonnes of WMA on five MTO contracts. Expanding upon its initial success, MTO constructed 10 WMA contracts in the year 2010, placing a total of 63,000 tonnes of WMA. To evaluate the environmental benefits of WMA, MTO required additional tests and measurements be performed on several of the 2010 contracts. These included emissions measurements at both the asphalt manufacturing plant and paving site, temperature measurements of the WMA during production and paving, and additional tests to assess WMA pavement performance (see Figure 1). In these trial contracts, WMA paving occurred at temperatures 10º to 30º lower than conventional HMA without any adverse effects on asphalt properties (see Figure 2). The WMA trials were successful and supported increased WMA usage. As a result, MTO decided to target 10% WMA use on contracts completed in 2011. In addition, MTO decided to include larger tonnages of WMA than in previous years, and to use WMA in both the binder course and surface course layers.

Queen Elizabeth Way Warm Mix Asphalt Pavement Rehabilitation Contract

The Queen Elizabeth Way (QEW) WMA pavement rehabilitation contract involved the placing of approximately 67,000 tonnes of WMA, making it the largest WMA paving contract completed in Canada to date. This contract is larger than all of MTO's 2010 WMA trial contracts combined. The total value of the contract was approximately $7.6 million. The project was located on a 15.6 km section of the QEW within the Towns of Grimsby and Lincoln in the Region of Niagara along the south-western shore of Lake Ontario (see Figure 3). The QEW is a major freeway connecting the Greater Toronto Area (GTA) with the Niagara Peninsula, including an international border crossing at Fort Erie-Buffalo. The traffic volumes on the section of QEW included in this project exceed 80,000 vehicles per day including approximately 14% commercial vehicles.

The project involved paving three mainline lanes and two asphalt shoulders along the Niagara-bound direction of the QEW from east of Casablanca Boulevard to Victoria Avenue, including all interchange ramps and crossing roads within the contract limits (see Figure 4). While most of the previous MTO WMA contracts included only surface course paving, this project used WMA for both the binder and surface course layers. Mainline rehabilitation involved milling 50 mm of the existing pavement and paving with 40mm Superpave (SP) 12.5 mm surface course over 50 mm SP 19.0 mm binder course. Pavement rehabilitation on the ramps and side roads involved milling 50 mm and paving with 50 mm SP 12.5 mm. The work began on July 5, 2011 and was completed on October 27, 2011. Paving operations were carried out at night using two-lane closures and echelon paving (see Figure 5).

Contributions Made to the Protection and Enhancement of the Environment

The use of WMA on highway paving contracts has a number of significant environmental advantages including the following:

1. Reduced Fuel Consumption at the Asphalt Plant

The production of WMA results in a significant reduction of energy consumption at the asphalt plant. WMA does not need to be heated to the same temperature as HMA, so less energy and fuel is required for its production. Studies on WMA have reported overall energy savings ranging from 20% to 35% at the asphalt plant with an average fuel savings of 23% (Croteau and Tessier, 2008, D'Angelo et. al, 2008, Prowell et. al 2009, Prowell et. al, 2011). It has been estimated that a fuel saving range of 20% to 35% corresponds to approximately 1.5 to 2.0 litres of fuel per tonne of asphalt (Croteau and Tessier, 2008). Using this range as a guideline, the estimated fuel savings resulting from the use of WMA on the QEW project alone would amount to approximately 100,500 to 134,000 litres of fuel, the equivalent to taking 18,650 to 25,000 vehicles off the highway for one day. This does not account for the energy savings associated with the incorporation of recycled asphalt pavement into the asphalt.

2. Reduced Emissions at the Asphalt Plant

The primary contribution to Greenhouse Gas (GHG) emissions reduction using WMA technology is from emissions savings generated from the lower fuel combustion requirement. Secondary GHG emission reduction associated with WMA technology is the lower GHG emissions during production of WMA mix at a lower temperature. MTO measured several GHG emission parameters on several 2010 WMA contracts, including Carbon Dioxide (CO_2), Carbon Monoxide (CO), Oxides of Nitrogen (NO_X), Sulphur Dioxide (SO_2), Volatile Organic Compounds (VOC), and Particulates. In general, the results from those contracts indicated slightly lower emissions for WMA relative to conventional HMA. Significant GHG emission reductions were observed on several WMA contracts, such as Contract 2010-2025 completed on Highway 10 in MTO's Central Region (see Figure 6). Based on a 20% to 35% reduction in $CO_{2\ \text{equivalents}}$ corresponding to the reduction in fuel consumption, it is estimated that GHG emissions would be reduced by 4.1 to 5.5 kg of $CO_{2\ \text{equivalents}}$ per tonne of WMA relative to conventional HMA (Croteau and Tessier, 2008). Using this range of values, the estimated reduction in GHG emissions resulting from using WMA on the QEW project would amount to approximately 274,700 to 368,500 kg of $CO_{2\ \mathrm{equivalents}}$. MTO has not yet measured GHG emission reductions in this range on its WMA contracts. But it is expected that production emissions in Ontario will further decrease to levels reported in other studies once production facilities are able to produce WMA with greater efficiency.

3. Reduced Asphalt Fumes at Paving Site

The paving of WMA results in a significant reduction of asphalt fumes at the paving site. This reduction in asphalt fumes is clearly visible during WMA placement (see Figure 7). Based on tests conducted by MTO on 2010 WMA contracts, dust was reduced by 30% behind the paver and 85% at the location of the paver operator. Similarly, benzene soluble fraction was reduced by 63% behind the paver and 72% at the location of the paver operator. The measured opacity values of HMA were roughly triple that of WMA at both locations (see Table 1). This reduction in asphalt fumes provides better working conditions for paving crews, and provides particular benefit to the public on paving contracts completed in dense urban areas.

4. Potential for Higher Recycled Asphalt Pavement Content

The ability to incorporate larger quantities of recycled asphalt pavement (RAP) into asphalt mixes is a significant environmental benefit of WMA. WMA facilitates a higher rate of asphalt recycling than conventional HMA due to its higher workability which permits the coating and compaction of RAP materials at lower temperatures. WMA trials in the U.S. have been conducted with up to 50% RAP (Prowell et. al, 2011).

The recycling of aged asphalt pavement is environmentally sustainable and supports the provincial objectives for the conservation of non-renewable natural resources, the reclamation and reuse of existing resources, and the diversion of reusable material from landfill. The use of RAP also saves energy through reduced processing of virgin asphalt materials and reduced transportation of new materials to the paving site. The savings in terms of energy, transportation, and new materials translates into potential cost savings for contractors and highway agencies.

In the QEW project, MTO incorporated 15% RAP in the SP 12.5 mm surface course and 20% RAP in the SP 19.0 mm binder course. This equates to a savings of approximately 11,350 tonnes of virgin aggregate and 493 tonnes (3,121 barrels) of asphalt binder for this project. As MTO continues to expand its use of WMA, it is anticipated that a higher proportion of RAP will be incorporated into future WMA contracts to maximize the economic and environmental advantages of WMA.

5. Reduced Fuel Consumption and Vehicle Emissions Associated with User Delay in Construction Zones

The use of WMA may also reduce the user delay costs, fuel consumption, and GHG emissions associated with construction lane closures. The temperature of WMA subsequent to compaction is lower than conventional HMA and closer to service temperature, so it is possible to re-open lanes to traffic sooner.

6. Potential for Improved Long-Term Pavement Performance

The use of WMA provides the environmental, economic, and social benefits outlined above without compromising the long-term performance of the asphalt pavement. In fact, WMA has the potential to provide superior pavement performance, thus reducing the overall life-cycle cost of the pavement relative to conventional HMA. The following are some of the factors that may contribute to the improved performance of WMA.

Improved Compaction and Joint Quality: WMA has been shown to improve the compactibility of asphalt mixes even under adverse conditions. This improved compactibility can improve the quality of the asphalt pavement joints. The average compaction of WMA samples tested on MTO WMA trial contracts was equal to or better than that of HMA. For the QEW project, the contractor obtained a financial bonus on the basis of excellent compaction test results.

Reduced Asphalt Binder Aging: The lower temperatures at which WMA is produced and placed will result in reduced asphalt binder oxidation, aging, and hardening. Reduced asphalt binder aging will result in a longer service life for WMA relative to HMA.

Comparable Resistance to Permanent Deformation: WMA has comparable resistance to rutting relative to conventional HMA. MTO conducted Hamburg Wheel Track Testing for the WMA trial contracts and found that the Hamburg rut depths were comparable between WMA and HMA.

Improved Resistance to Thermal Cracking: Thermal cracking is a common form of asphalt pavement deterioration on Canadian roads. WMA provides improved resistance to thermal cracking relative to HMA due to less binder aging.

Potential to Extend the Paving Season: WMA provides superior workability relative to conventional HMA. The increased workability of WMA permits the placement and compaction of WMA at lower temperatures, which can extend the available paving season in colder climates. For example, European case studies have reported that WMA has been produced, placed, and properly compacted at ambient temperatures as low as
-3ºC (D’Angelo et. al, 2008).

Longer Haul Distances: WMA permits longer haul distances from the plant to the paving site. Increasing the initial production temperature of HMA to compensate for extended transportation time is not feasible as it results in damage to the asphalt binder. However, the initial temperature of WMA mixtures can be increased with no additional damage to the asphalt binder while maintaining acceptable workability for placement and compaction at the paving site. This will result in improved long-term asphalt performance for paving projects that are located a long distance from an asphalt plant. In addition, the longer haul distances eliminate the need for low efficiency mobile asphalt plants on paving contracts in remote locations.

Based on the above, WMA can provide improved long-term performance relative to HMA that will translate into reduced maintenance/rehabilitation costs, material usage, GHG emissions, and environmental impacts over the life cycle of the pavement.

Innovation

WMA is an innovative technology that has been introduced to North America in the past decade. There are still many aspects of the technology that remain to be studied, and new WMA technologies are being developed every year. Through the WMA initiative, MTO is leading the research and implementation of WMA in Ontario with its partners.

One objective of the MTO WMA initiative is to conduct research to better understand the environmental and engineering benefits of WMA in the Ontario context. Since 2008, MTO has implemented 25 WMA trial contracts with a combined total tonnage exceeding 300,000 tonnes. On several WMA paving contracts, MTO has included the requirement for contractors to take emissions and temperature measurements during production and paving of WMA, as well as providing additional asphalt samples to test WMA pavement performance. MTO is also developing a comprehensive performance monitoring program for WMA pavements to evaluate their long-term performance in the field. The information obtained from these tests and studies will be invaluable to informing future WMA use in Ontario.

MTO has steadily increased its use of WMA on highway paving contracts, culminating with the 67,000 tonne WMA paving contract on the QEW through Niagara Region. MTO specified WMA on 10% of its paving contracts in 2011. This commitment provided the asphalt industry with the incentive and opportunity to invest and build confidence in WMA. MTO is also committed to working with the asphalt industry to develop WMA specifications and best practices guidelines through its work with the WMA Task Group.

Financial Implications

To evaluate the overall effectiveness of WMA, it is important to consider not only its environmental and performance benefits, but also its economic cost relative to HMA.

The bid price for WMA on the 2010 WMA trial contracts was between 2% to 16% higher than conventional HMA. However, these bid prices included the costs of additional testing and emissions measurement as well as the WMA additives. In addition, these contracts involved relatively small quantities of WMA that did not provide the benefit of economies of scale.

The QEW WMA pavement rehabilitation project was a large paving contract that did not include the additional testing and emission measurement requirements of the 2010 WMA trial contracts. This project included only WMA, so a direct comparison with the bid price of HMA on the same contract was not possible. However, when compared to average bid prices for conventional HMA on other 2011 paving contracts in Central Region, the cost of the WMA binder course was approximately 24% less than conventional HMA, while the cost of the WMA surface course was approximately 9% more than conventional HMA. Based on the relative quantities of binder and surface course, this reflected an overall cost neutrality between WMA and HMA for this particular project. It is expected that in future contracts the cost of WMA will continue to decrease as contractors realize the financial benefit of reduced energy consumption in the production of WMA.

Overall Applicability to Transportation and the Need for WMA to be disseminated to Other TAC Members and the Transportation Community as a Whole

Based on the overall economic, environmental, and social benefits of WMA, it is clear that there is a significant benefit to expanding its use among highway agencies across Canada. MTO has been and will continue to encourage the use of WMA in Ontario by leading the WMA Task Group, entertaining cost-neutral WMA change proposals from contractors, developing specifications for WMA, and specifying WMA on more MTO contracts.

The WMA Task Group is composed of members from MTO, Ontario Hot Mix Producers Association (OHMPA), and Ontario Good Roads Association (OGRA). The WMA Task Group was formed to leverage the available experience in WMA and provide a forum to deal with challenges in an equitable manner. The WMA Task Group has several specific objectives including:

- Compile a WMA state-of-the-practice guide
- Adopt mix design procedures for various WMA technologies
- Establish contractor guidelines for WMA use
- Develop educational materials to promote the use of WMA
- Provide recommendations to improve current WMA specifications

The work completed by the WMA Task Group will facilitate the expansion of WMA use in Ontario.

MTO will continue to encourage the use of WMA through the development of construction and material specifications for its highway construction contracts. An “Appendix C” to Ontario Provincial Standard Specification (OPSS) 310 – Construction Specification for Hot Mix Asphalt has been created that includes supplementary requirements for using WMA in municipal contracts. This appendix provides municipalities with the ability to tender WMA projects by referencing the appendix in the contract documents.

Finally, MTO will continue to encourage the use of WMA on MTO paving contracts. Building on the success of the WMA trial contracts, MTO committed to specifying WMA on 10% of its contracts for the year 2011. By doing so, MTO provided the asphalt industry with the incentive and opportunity to invest and build confidence in WMA. MTO, in consultation with the WMA Task Group, is currently developing a permissive specification for WMA that would allow contractors to bid either HMA or WMA on paving contracts. It is anticipated that this permissive specification will significantly increase the use and reduce the cost of WMA in Ontario.

Conclusion

MTO completed a 67,000 tonne WMA paving contract on the QEW in 2011, making it the largest WMA paving contract to date in Canada. The use of WMA provides the following environmental, performance, and economic benefits:

- Reduced fuel consumption at the asphalt production plant in the range of 20% to 35% (1.5 to 2.0 litre of fuel/tonne)
- Reduced GHG emissions at the asphalt production plant in the range of 4.1 to 5.5 kg $CO_{2\ \mathrm{equivalent}}$ /tonne
- Reduced asphalt fumes behind the paver including 30% reduction in dust, 63% reduction in benzene soluble fraction, and 64% reduction in opacity
- Potential to include up to 50% Recycled Asphalt Pavement in the WMA mix
- Potential to reduce user delay, fuel consumption, and GHG emissions in construction zones due to less asphalt cooling time required
- Potential for improved pavement performance resulting in less maintenance/rehabilitation and lower overall life-cycle cost of pavement structure
- Overall construction cost neutrality relative to conventional HMA with the potential for WMA costs to decrease as its use in Ontario expands

Based on the WMA tonnage and RAP percentages used in the QEW paving contract, the estimated material and emission savings were approximately 100,500 to 134,000 litres of fuel, 274,700 to 368,500 kg $CO_{2\ \mathrm{equivalent}}$ of GHG emissions, 11,350 tonnes of virgin aggregate, and 493 tonnes (3,121 barrels) of asphalt binder. Given that MTO paved over 2.8 million tonnes of asphalt in 2010, expanding the use of WMA in Ontario will result in substantial environmental benefits and material savings without compromising long-term pavement performance and cost.

References:

1. Anderson, R.M., Baumgartner, G., May, R., and Reinke, G. (2008). "Engineering Properties, Emissions, and Field Performance of Warm Mix Asphalt Technologies: interim Report", NCHRP 9-47, Transportation Research Board.
2. Croteau, J.M. and Tessier, B. (2008). "Warm Mix Asphalt Paving Technologies: a Road Builder's Perspective", Transportation Association of Canada, Ottawa, Canada.
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4. Prowell, B.D., Hurley, G.C., Frank, B. (2011). "Warm Mix Asphalt: Best Practices 2nd Edition", Quality Improvement Series Publication 125, National Asphalt Pavement Association, Lanham, MD.
5. Prowell, B.D., Kvannak, A., Hurley, G., West, R., Kreich, T., Osborn, L., Frank, B., Peregrine, K., and Jones, D. (2009). "Engineering Properties, Emission, and Field Performance of Warm Mix Asphalt – Draft Interim Report – State-of-the-Practice", NCHRP 9-47A, Transportation Research Board.

Appendix – Photos and Figures

Figure 1: Emissions Measurements Taken at the Asphalt Plant and Asphalt Paver

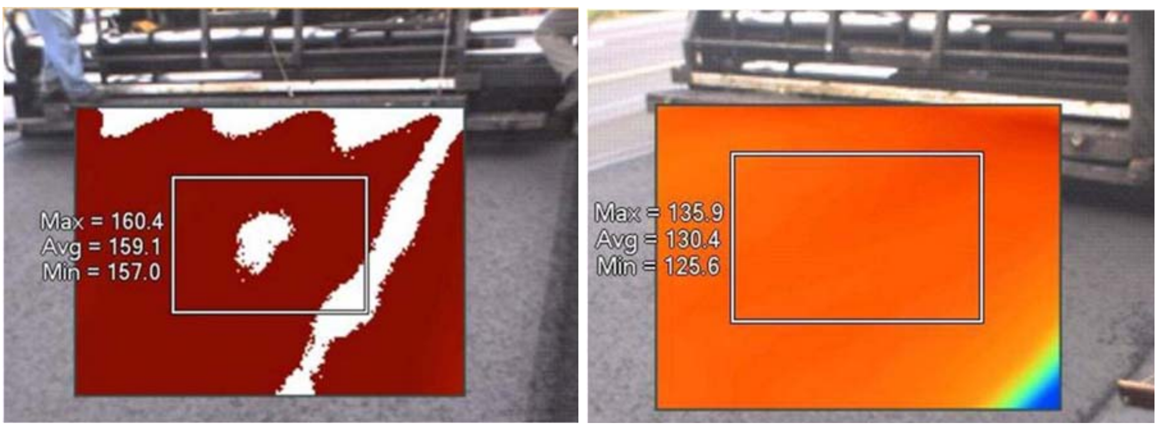

Figure 2: Asphalt Temperature Measurements behind the Paver (HMA vs. WMA)

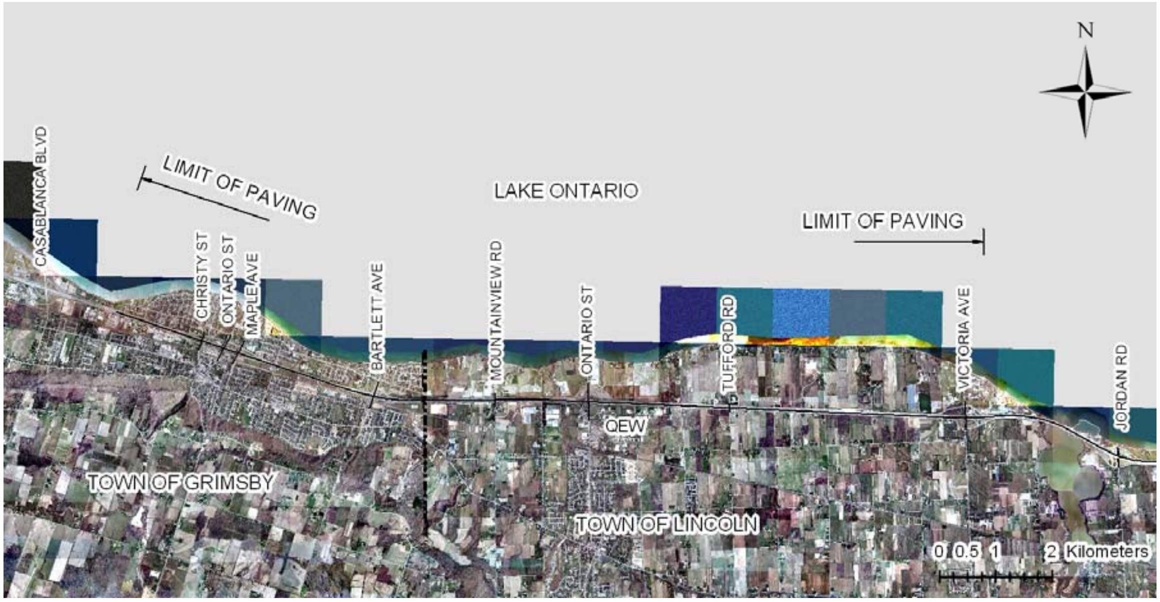

Figure 3: QEW Warm Mix Asphalt Pavement Rehabilitation Contract Limits


Figure 4: Typical View of QEW Looking East from the Christie Street Underpass

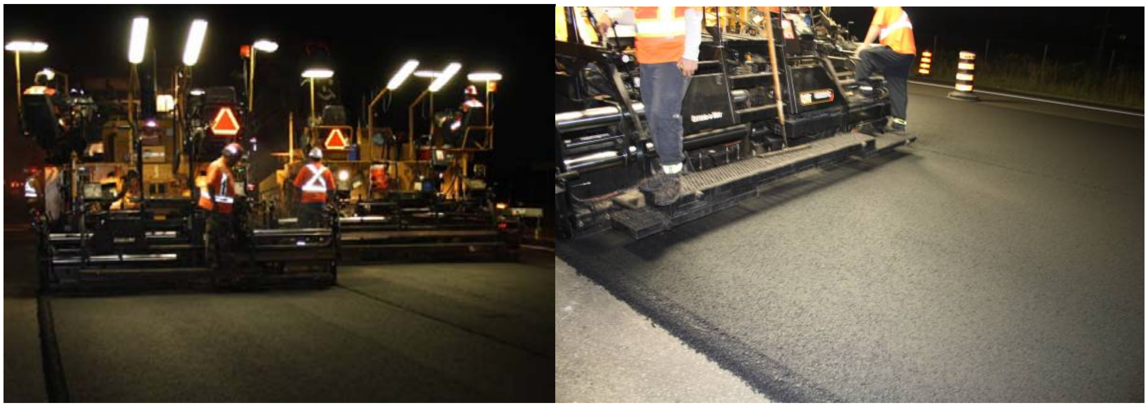

Figure 5: Echelon Night Paving of Warm Mix Asphalt on QEW Contract

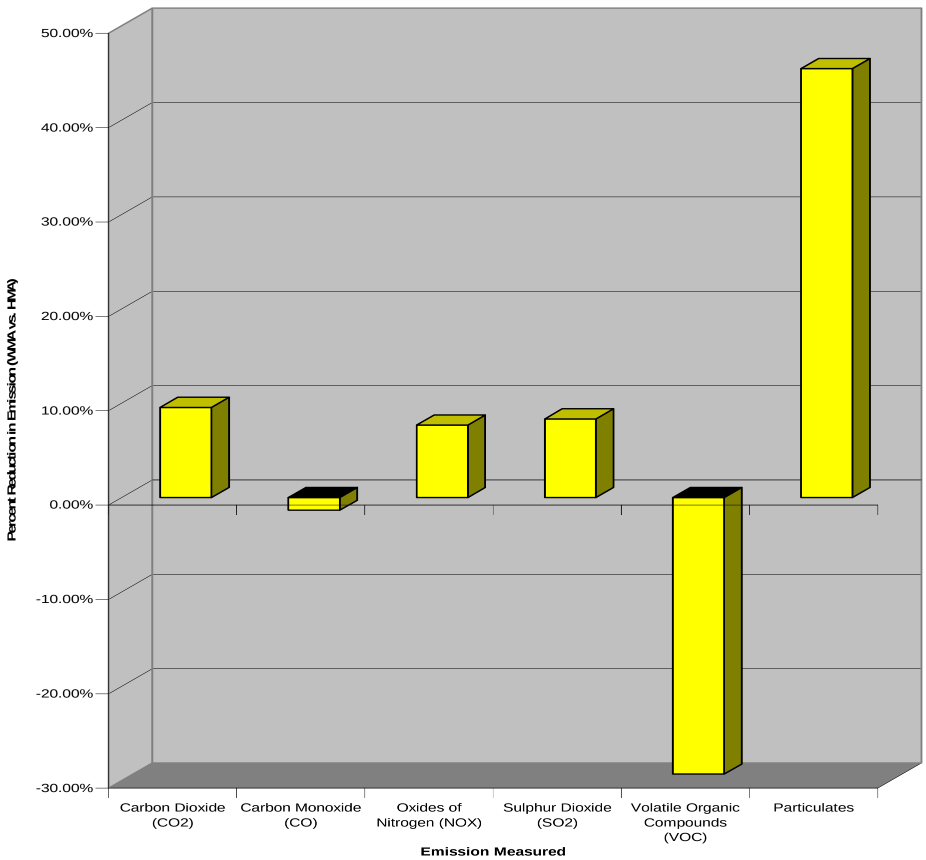

Figure 6: Warm Mix Asphalt GHG Emissions Reduction Measured at the Asphalt Plant for the Highway 10 Paving Contract

Table 1: Asphalt Fume Reduction Measured at the Asphalt Pavers for the Highway 10 Paving Contract

Sampling Location	Total Dust[1]		Benzene Soluble Fraction[1]		Opacity (%)	
	HMA	WMA	HMA	WMA	HMA	WMA
Rear of Paving Vehicle	0.63	0.44	0.200	0.074	18.2	6.6
Operator of the Paving Vehicle	0.73	0.11	0.330	0.090	20.0	8.3
Exposure Limit	10.00		0.500		20.0	

[1]Dry Reference Concentration mg/Rm^3) at 25º and 1 atmosphere

Figure 7: Visible Asphalt Fumes at the Asphalt Paver (HMA vs. WMA)

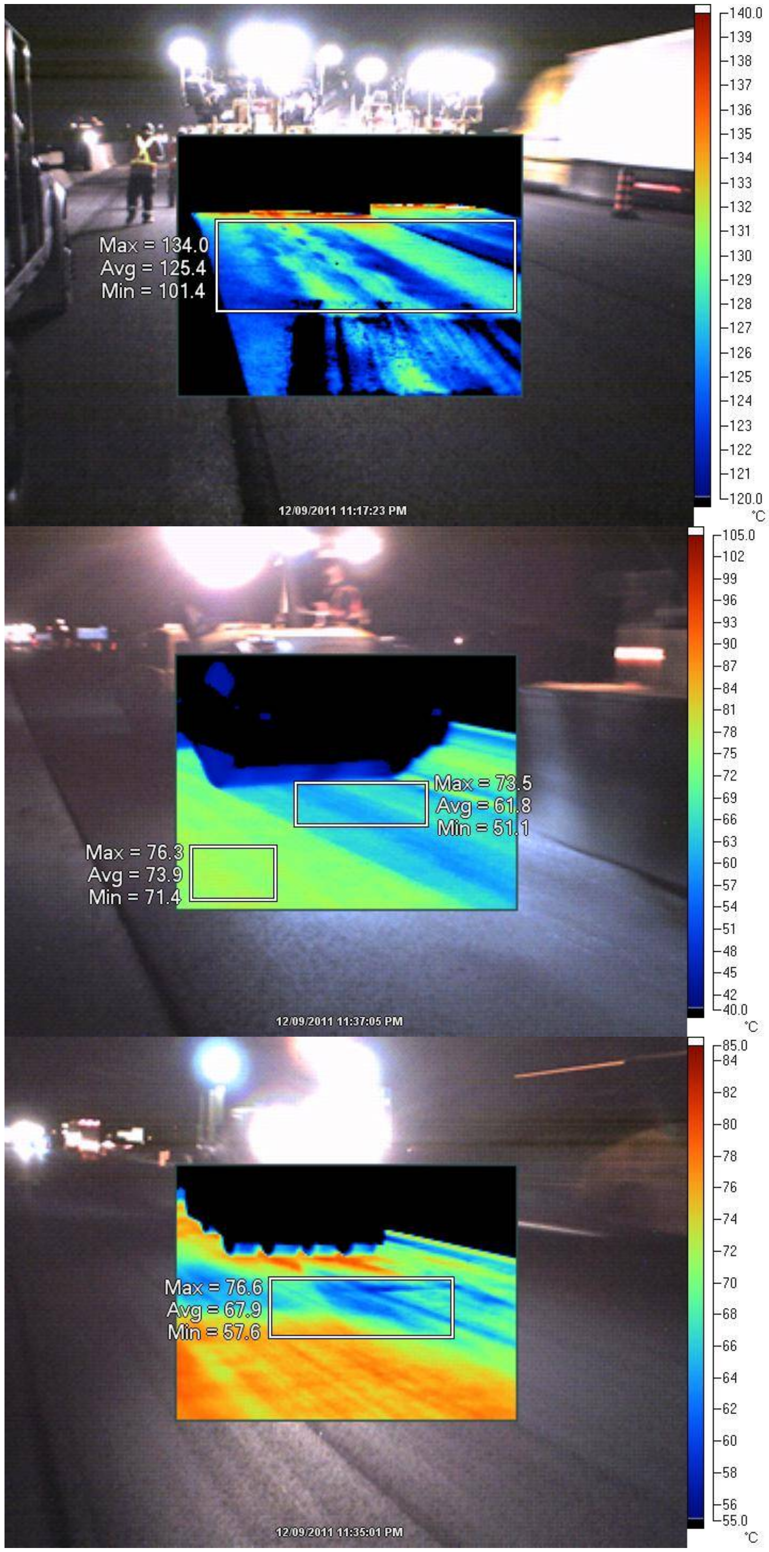

Figure 8: Thermal Imaging behind the Asphalt Paver, Breakdown Roller, and Rubber Tire Roller on the QEW Contract*

***Note that the scale on thermal images varies**