Successful Implementation of Warm Mix Asphalt in Ontario

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ABSTRACT

Warm Mix Asphalt (WMA) has proven to be an innovative green technology that improves the environmental sustainability of Hot Mix Asphalt (HMA) by reducing emissions and conserving energy while maintaining or enhancing pavement performance through improved compaction.

Approximately 500,000 tonnes of WMA have been paved on Ministry of Transportation of Ontario (MTO) roadways since 2008. WMA technologies that have been used include both chemical and organic additives. While WMA has many benefits, it also has challenges that are being addressed by a joint task group comprised of members from MTO and the asphalt paving industry. In 2010, MTO built several WMA test sections along with HMA control sections to evaluate the performance and environmental benefits of WMA. Emission measurements were conducted at the asphalt plants as well as at the paving sites for both WMA and HMA mixes. Laboratory investigations included moisture sensitivity testing on production samples, Hamburg wheel track testing, coating, compactability, and Flow Number. MTO is monitoring the performance of the WMA pavement sections based on the distress data obtained by MTO's Automated Road Analyzer (ARAN).

Pavement performance of WMA has been comparable to HMA, with slightly better joint quality. Given the positive experience with WMA, MTO adopted a permissive specification in 2012 allowing the contractors to use WMA in lieu of HMA. In conjunction with this specification, the desire to grow the WMA market has prompted MTO to continue to build WMA projects in 2013 and 2014, by specifying its use.

This paper presents quality assurance and emissions data collected during construction of our WMA projects. The paper also discusses laboratory test results as well as pavement condition data collected for each of the WMA pavement test sections.

INTRODUCTION

The Ministry of Transportation of Ontario (MTO) has a strong history of research, development, and implementation of innovative pavement technologies. One successful initiative is Warm Mix Asphalt (WMA) that was first trialed by MTO in 2008.

WMA is defined as a group of technologies that allow for a reduction in the temperatures at which asphalt mixtures are produced and placed, relative to traditional Hot Mix Asphalt (HMA) [1]. This reduction usually varies from 20 to 40 degrees Celsius. Producing and paving asphalt at these lower temperatures generates fewer emissions and requires less energy than HMA while maintaining or enhancing pavement performance. Due to the environmental and performance benefits, WMA is considered an "innovative green" technology that supports MTO's strategic plans.

WMA technologies can also be used as a compaction aid, allowing the asphalt to be produced at normal HMA temperatures and still achieve adequate compaction when laid at lower than normal temperatures for early and late season paving.

There are numerous WMA technologies available in North America and the list is growing rapidly. These technologies can be divided into three broad categories:

- Organic processes,

- Chemical processes, and
- Foaming processes.

Organic and chemical processes involve adding organic or chemical additives respectively to the asphalt mix. On the other hand, foaming processes either inject water into the mix or add water-bearing agents to 'foam' the asphalt. All categories allow production and paving of asphalt at lower temperatures than HMA.

The many benefits of using WMA as an alternative to HMA include:

- Potential cost-savings, as lowering production temperature reduces fuel consumption
- Improved compaction and better joint construction
- Less potential for cracking due to reduced asphalt binder aging
- Reduced green house gas emissions during production and paving
- Improved worker safety due to lower material temperatures
- Potential to extend the paving season due to increased workability at lower temperatures
- Increased workability at lower temperatures facilitates longer haul distances from the asphalt plant to the construction site
- Potential for higher reclaimed asphalt pavement (RAP) content

WARM MIX ASPHALT SPECIFICATION

MTO has developed two types of specifications for WMA usage; mandatory specification for use in WMA trial contracts and permissive specification allowing contractors to use either WMA or HMA.

Both specifications include additional requirements from that of regular HMA, including:

- Provide the name of the WMA technology; complete name and address of the WMA supplier; type and dosage of WMA additives; WMA technology supplier's established recommendations for usage; and Material Safety Data Sheets.
- Requires supporting technical documents stating that the selected WMA technology is a proven process with technical merit, demonstrated past performance, satisfactory laboratory test results, and demonstrated recyclability.
- Requires Superpave mix design according to Appendix X2 of AASHTO R 35-12 requiring test results for Flow Number (AASHTO TP79), Coating (AASHTO T195), Compactability (as described in AASHTO R35), and moisture sensitivity (AASHTO T283).
- Moisture Sensitivity Test (AASHTO T283) on the WMA samples taken during production.

MTO-INDUSTRY WARM MIX ASPHALT TASK GROUP

MTO, in collaboration with the asphalt industry, formed a warm mix asphalt task group in 2010 to further investigate WMA and improve MTO's specification. Main objectives of the task group are as follows:

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

To achieve the objectives of the task group, various working sub-groups were established.

WARM MIX ASPHALT CONTRACTS

MTO began its early research for use of WMA in 2006, and constructed its first WMA test section in 2008 along a 500m stretch of Highway 15 near Smiths Falls, Ontario (Southwest of Ottawa).

In 2010, MTO paved 63,000 tonnes of WMA on ten WMA contracts. Most of the 2010 contracts included a HMA control section. The technologies used included either chemical or organic additives.

To evaluate WMA technology, the following additional requirements were included in the 2010 contracts:

- Emission measurements at the asphalt manufacturing plant as well as the paving site [2]. Parameters measured included: CO, CO_2, NO_x, SO_x, Volatile Organic Compounds (VOC), and Total Particulate Matter (TPM).
- Temperature measurements of the WMA during production and paving.
- Maximum allowable paving temperature of 125^{o}C.
- Additional HMA and WMA samples for Hamburg Wheel Track Test.

The 2010 contracts were built with minimal challenges and prompted MTO to further invest in WMA technology considering larger size contracts. In 2011 alone 250,000 tonnes of WMA was paved on MTO highways in 11 contracts. Total WMA quantity paved on MTO highways between 2008 and 2013 has amounted to approximately 500,000 tonnes. WMA was used in the surface course as well as the binder course layers. Many of the MTO's warm mix contracts incorporated 10 to 20% RAP.

Warm mix asphalt contracts revealed the following challenges:

- Costs – organic and chemical additives made WMA marginally costlier than HMA
- Lack of knowledge/experience with WMA
- Effectiveness of different technologies – not all are the same
- Ensuring long term performance including moisture susceptibility
- A Mix design procedure was needed to cover all different WMA types and evaluate the mix for potential rutting
- Recyclability – needed to ensure that RAP resulted from WMA pavement could be safely re-used in the new asphalt mix
- Restrictions/adjustments at the asphalt plant – production of WMA required adjustments to the burner and flights. Some plants encountered clogging of material on the conveyor belts when tried to lower the production temperature
- Combination with antistrip additive – needed to ensure that the WMA additive was compatible with the antistrip additive when antistrip was needed

EVALUATION OF WARM MIX CONTRACTS

WMA Temperature

The temperature readings from the 2010 contracts indicated that WMA was paved at temperatures 10 to 30^{o}C lower than HMA without any adverse effect on the mix workability or compaction. An infrared camera was used to take thermal images from the pavement surface behind the paver and at the rollers (Figure 1).

Emissions

Asphalt plant stack emissions were measured for one 2008 and eight of the 2010 WMA contracts. Six contracts used natural gas and the remaining three contracts used fuel oil or diesel as fuel at the asphalt plants. Figure 2 shows the results of CO_2 emissions during production of WMA and HMA mixes. Carbon dioxide is one of the main greenhouse gases produced in the burning of fossil fuels. In asphalt mix production, carbon dioxide is produced mainly by the combustion of fuel to heat up the asphalt cement, to dry the aggregates and to power the delivery vehicles. Similar trends were observed for other emissions parameters. Although the asphalt production emissions measured in the asphalt plant were not significantly different, they were slightly lower for WMA. Emissions concentrations were significantly higher for diesel fuel compared to when natural gas was used as the fuel. Natural gas is normally considered to be the cleanest fuel source and produces far less air pollutants than diesel or oil.

For many trials, CO and VOC for WMA emissions were higher than for HMA; it is expected that this is due to incomplete combustion. Incomplete combustion is mainly caused by improper tuning of the burner.

On the paving sites, asphalt fumes were measured for five of the 2010 contracts. The results indicated that the opacity (visible smoke) levels of WMA were as low as one-third that of HMA (Figures 3 and 4). Furthermore, the dust and benzene soluble fraction were also measured and the results were significantly lower for WMA as shown in Figure 5.

With increased WMA use in Ontario, it is anticipated that the plant burners will be properly tuned up for WMA production which will reduce incomplete combustion and reduce stack emissions.

Hamburg Wheel Track Test

MTO owns a modified Hamburg Wheel Track device that is equipped with a pair of treaded pneumatic tires to apply the load to the specimens (Figure 6). The tires have a 4-ply rating and are inflated to 345 kPa. The tire tread width is 70 mm. Each tire applies a 642 N load to a specimen submerged in a water bath at 60°C. The test involves application of a total of 20,000 load passes to the specimens while continuously recording the rut depths. Production samples of HMA and WMA mixes were collected from the 2010 contracts and mixes were compacted in the laboratory for Hamburg testing. Hamburg rut depths were largely comparable between WMA and HMA with some rut depths actually lower for the WMA, as illustrated in Figure 7.

Field Compaction

On MTO contracts, field compaction is calculated as a percentage of the maximum theoretical specific gravity of the mix. In general, the average field compaction results for WMA was either equal to or better than HMA as shown in Figure 8.

MTO is currently investigating the impact of allowing a lowered ambient paving temperature for premium surface course mix when WMA is used. In a 2013 contract where a premium WMA surface course was specified, the allowable minimum ambient paving temperature was lowered from 12°C to 7°C. The paving occurred in November with ambient temperatures varying from 4°C to 13°C. Table 1 provides compaction results for eight sublots that were paved prior to winter shut down. As evident in Table 1, adequate compaction was achieved while paving at ambient temperature as low as 4^{o}C. An average lot compaction of 94.4% resulted in compaction bonus for this lot.

Tensile Strength Ratio (TSR)

Production samples of WMA were collected and tested for moisture sensitivity according to AASHTO T283. The TSR results for WMA were significantly variable with values ranging from 44 to 100 percent (Figure 9). Although the AASHTO T283 test is known for its poor repeatability, the variability of the TSR results for WMA samples are probably also due to a combination of other factors including variations in production temperatures (resulting in different levels of aging), and improper blending of the warm mix additive or anti-strip additives with the asphalt cement. In a similar study, conducted recently MTO evaluated moisture sensitivity of HMA production sample according to AASHTO T283 procedure and the data variation was not so significant.

Costs

Overall, WMA has been priced almost equal to HMA. For estimation purposes, MTO allows for 5% extra cost for WMA over HMA due to the cost of the WMA additive and additional mix design testing requirements. Given the environmental benefits and potential performance improvements, the life cycle cost of WMA is expected to be equivalent to HMA.

PAVEMENT PERFORMANCE

MTO owns an Automated Road Analyzer (ARAN) which is a high speed vehicle capable of measuring pavement roughness, rutting, cracking, and macro-texture (Figure 10). ARAN is equipped with a pair of RoLline laser sensors that measure pavement roughness along wheel paths in terms of International Roughness Index (IRI). A Laser Crack Measurement System (LCMS) determines crack width, depth and extend. LCMS also measures wheelpath rutting and calculates macro-texture.

ARAN 2013 cracking data were used to evaluate pavement performance of the test sections, after three years of service (except for Highway 15 that was built in 2008). Figures 11 and 12 show the extent of slight and moderate severity longitudinal cracking on the WMA and HMA sections, respectively. In general, WMA test sections exhibit fewer longitudinal cracks than HMA sections. Most of the longitudinal cracks are along the centreline construction joint. Figure 13 shows extent of slight severity transverse cracking. For most of the jobs, WMA sections contain fewer transverse cracks than HMA control sections. Figure 14 shows better performance for WMA sections based on the extent of slight severity alligator cracking. Typical images of WMA test sections are given in Figures 15 and 16.

SUMMARY AND CONCLUSIONS

This paper reports on MTO’s successful experience with warm mix asphalt including evaluation of WMA pavement test sections in comparison to the HMA control sections. Overall, field and laboratory evaluations indicated that WMA was a viable alternative to HMA with improved performance and environmental savings.

The following conclusions can be drawn:

- WMA can be paved at temperatures 10 to 30^{o}C lower than HMA without any adverse effect on mix properties or compaction.

- Without proper tuning of the plant burner, the emissions savings are not achievable at the asphalt plant. However, lower production temperatures will result in significant reduction of asphalt fumes and visible smoke at the paving site.
- Hamburg wheel track test indicated similar performance for rutting and moisture sensitive between WMA and HMA.
- WMA proved to be an effective compaction aid. Many of the WMA contracts received a compaction bonus. Use of warm mix additives provides a better chance to achieve compaction during early and late season paving when ambient temperatures fall a few degrees below the allowable limit (but still above freezing temperatures).
- Although TSR results on production WMA samples were significantly variable, no signs of moisture damage have been observed on the warm mix contracts or from the wheel track rut testing. However, monitoring of the WMA pavements should continue until they are 5 or 7 years old.
- Given the environmental benefits and potential performance improvements, the life cycle cost of WMA is expected to be equivalent to HMA

GOING FORWARD

- For 2014, MTO is estimating to pave over 400,000 tonnes of warm mix asphalt.
- MTO will continue monitoring the performance of WMA pavements.
- MTO/Industry WMA Task Group will continue collaborations to provide recommendations for improvements to the WMA specification.
- MTO is participating in FHWA Specific Pavement Study-10 (SPS-10) that involves construction of WMA test sections for long term pavement performance monitoring.

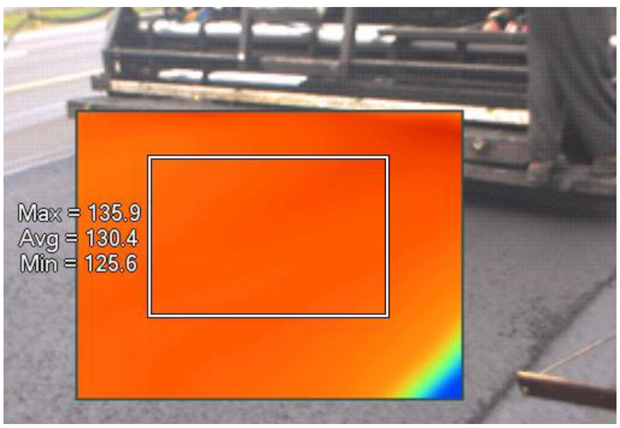
REFERENCES

1. Prowell, B.D. and G.C. Hurley, Warm-Mix Asphalt: Best Practices, Quality Improvement Series 125, National Asphalt Pavement Association, 2007.
2. National Asphalt Pavement Association (NAPA), Documenting Emissions and Energy Reductions of WMA and Conventional HMA, 23 August 2006.

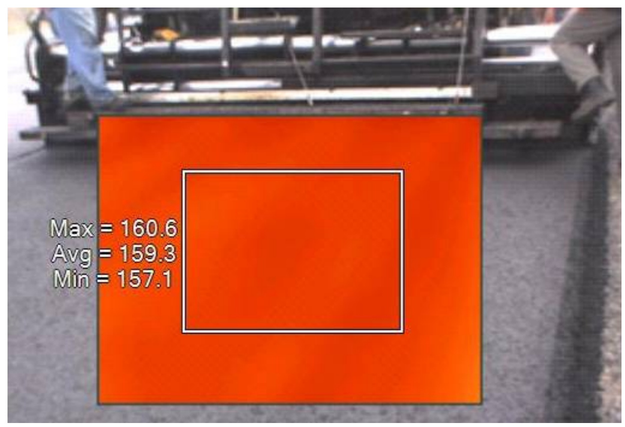
Table 1 -
Adequate compaction was achieved for a premium surface course mix when minimum allowable ambient paving temperature was lowered from 12°C to 7°C

Paving Date (2013)	Sublot #	Ambient Temperature (°C)	Mix Paving Temperature (°C)	Lift Thickness (mm)	In-situ Compaction (%)
November 4	1	5	142	58	93.6
November 4	2	4	146	52	94.2
November 5	3	9	156	51	95.2
November 6	4	13	149	53	92.7
November 7	5	7	137	69	93.5
November 14	6	6	132	65	96.5
November 15	7	6	136	52	93.3
November 15	8	6	136	53	95.8

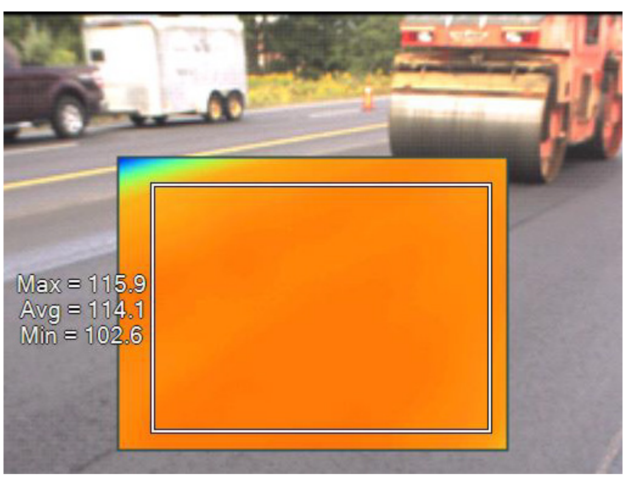
Each sublot typically consists of up to 500 tonnes of asphalt mix



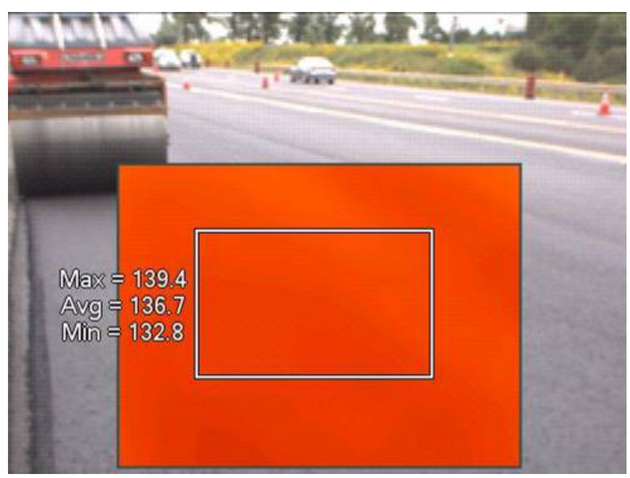
WMA



HMA



WMA



HMA

Figure 1 -
Thermal images from WMA and HMA paving sites showing significantly cooler temperatures for WMA

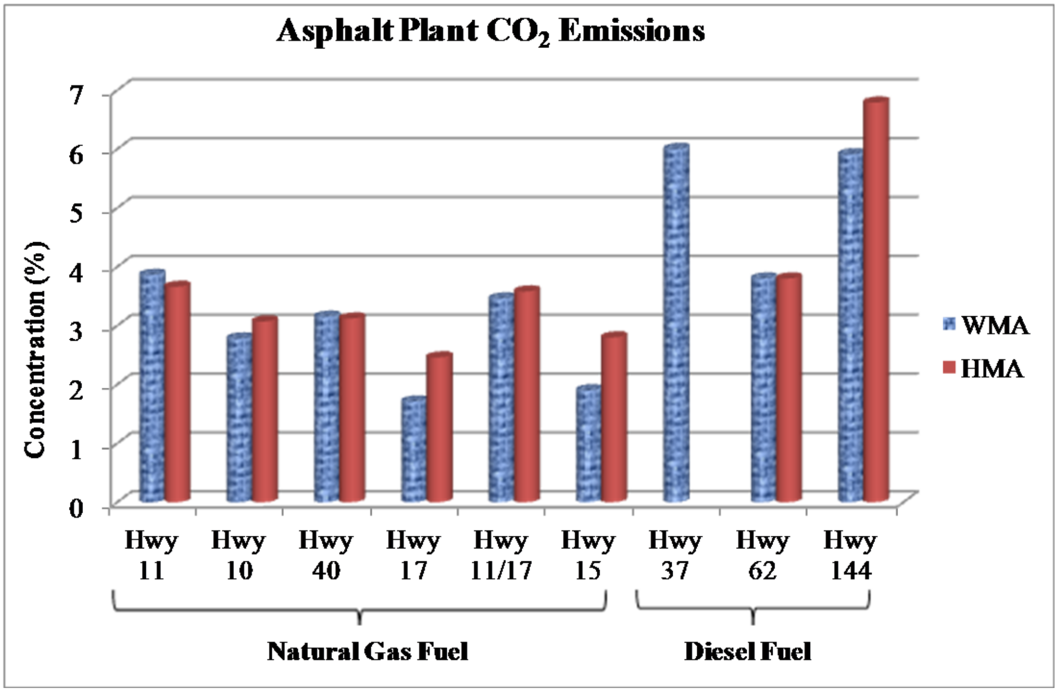


Figure 2 -
Carbon dioxide emissions at the asphalt plants

Figure 3 -
Warm mix asphalt paving site - No visual emissions

Figure 4 -
Warm mix asphalt night paving - No visual emissions

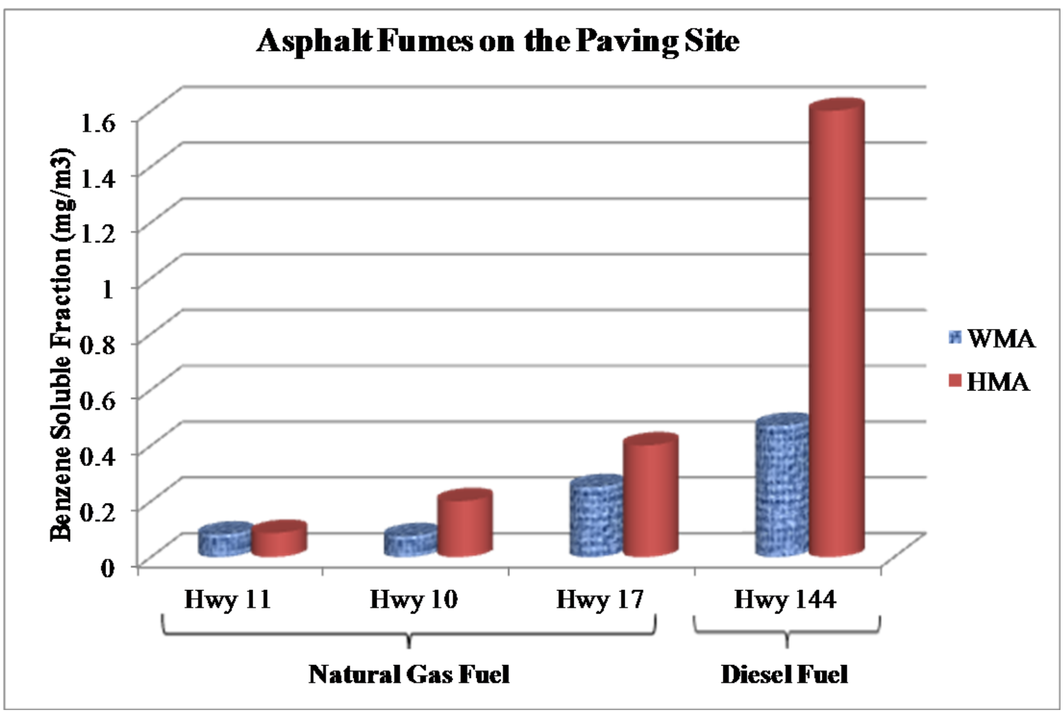
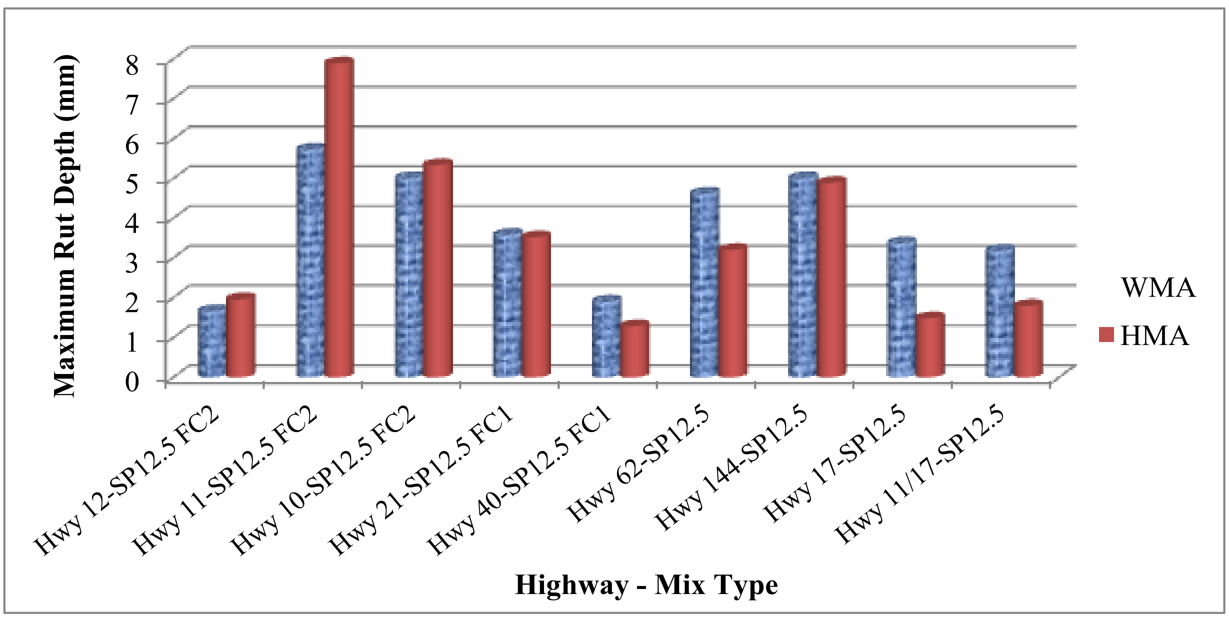


Figure 5 -
Asphalt emissions on the paving site behind the paver

Figure 6 -
MTO's modified Hamburg wheel track testing machine equipped with pneumatic tires



SP12.5=Superpave mix with Nominal Maximum Aggregate Size of 12.5mm
FC1 = the coarse aggregate in the mix is supplied from the MTO's Designated Sources for Materials (DSM) list
FC2 = Both the coarse and fine aggregates in the mix are supplied from the MTO's Designated Sources for Materials (DSM) list

Figure 7 –
Hamburg wheel track test results on the production samples

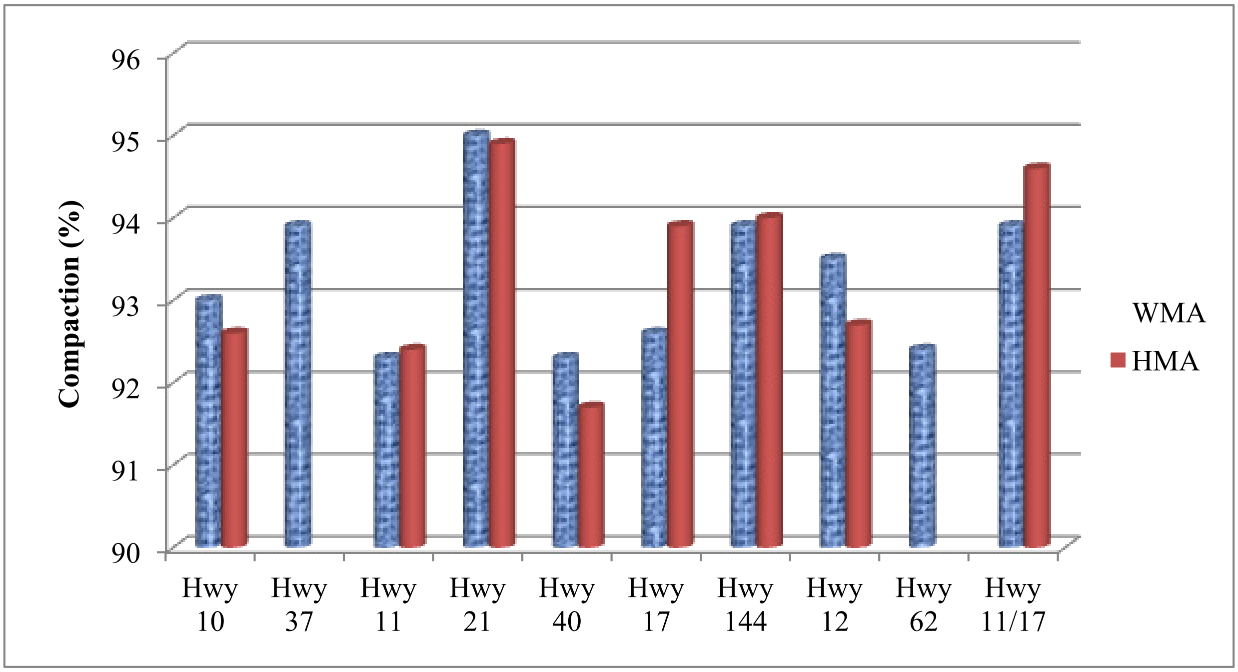


Figure 8 –
Average field compaction results

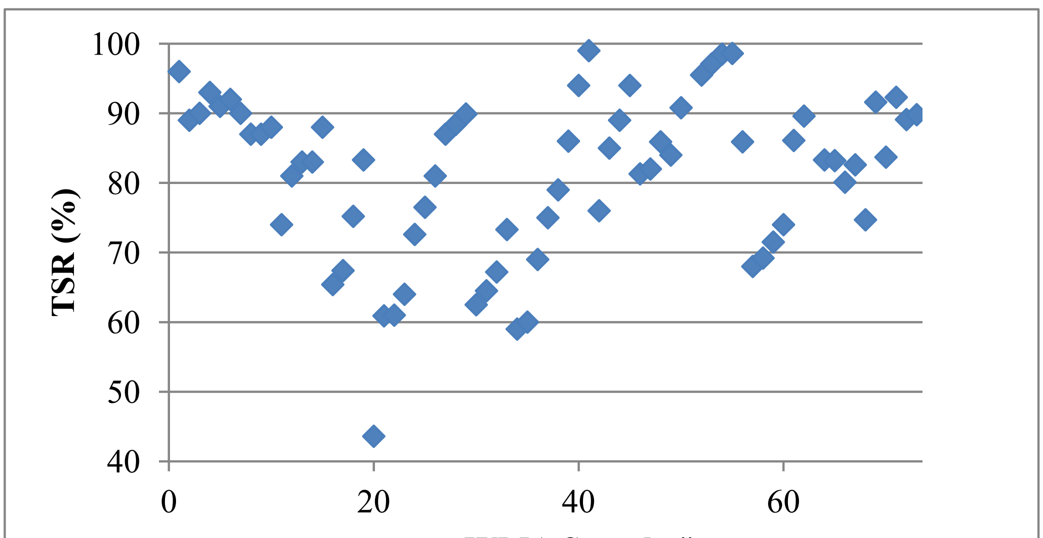


Figure 9 –
Tensile Strength Ratio results on production samples of WMA

Figure 10 –
Latest generation of MTO's ARAN (Automated Road ANalyzer)

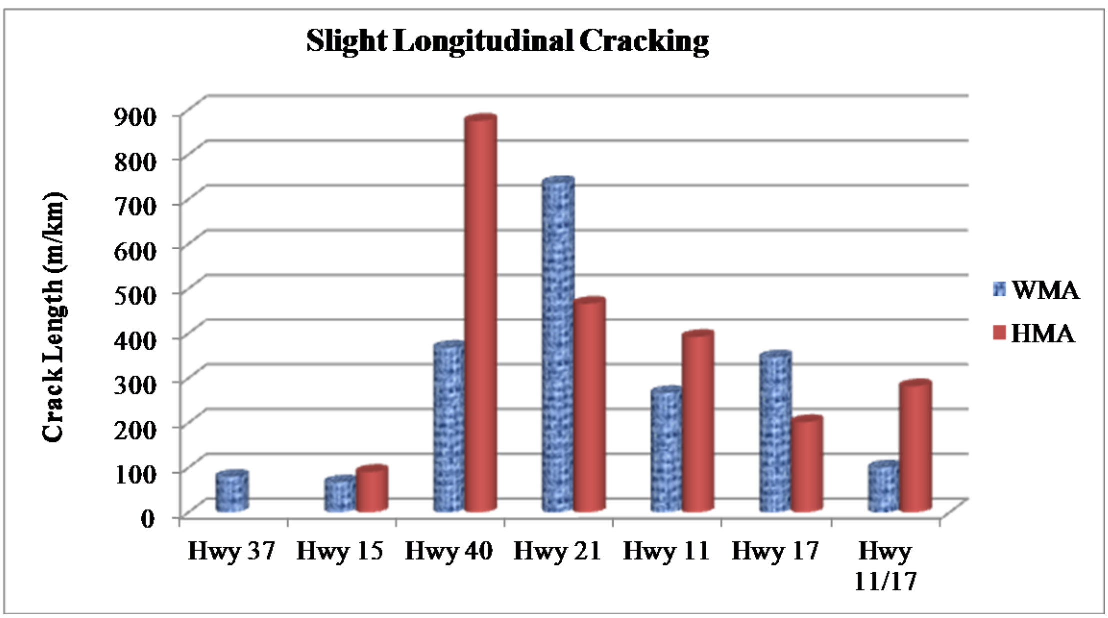


Figure 11 –
Extent of slight severity longitudinal cracking on the WMA and HMA sections

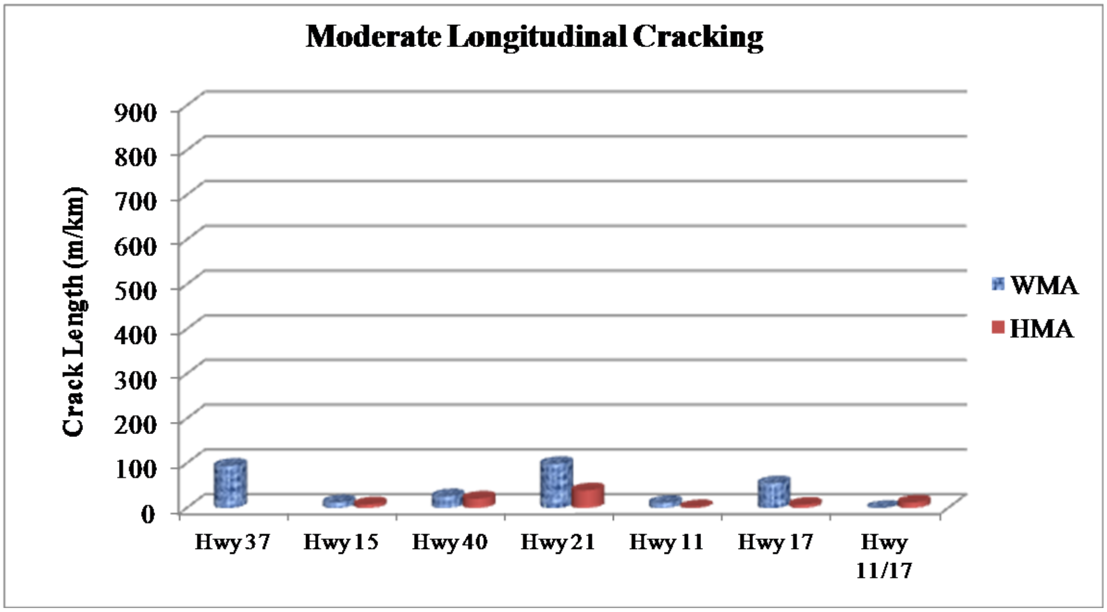


Figure 12 –
Extent of moderate severity longitudinal cracking on the WMA and HMA sections

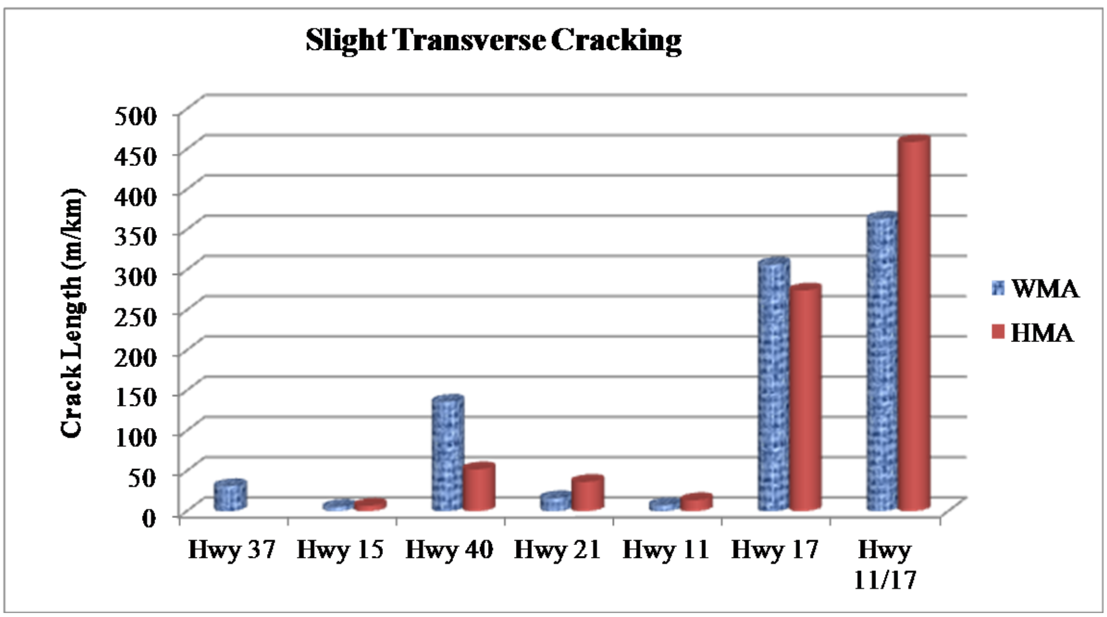


Figure 13 –
Extent of slight severity transverse cracking on the WMA and HMA sections

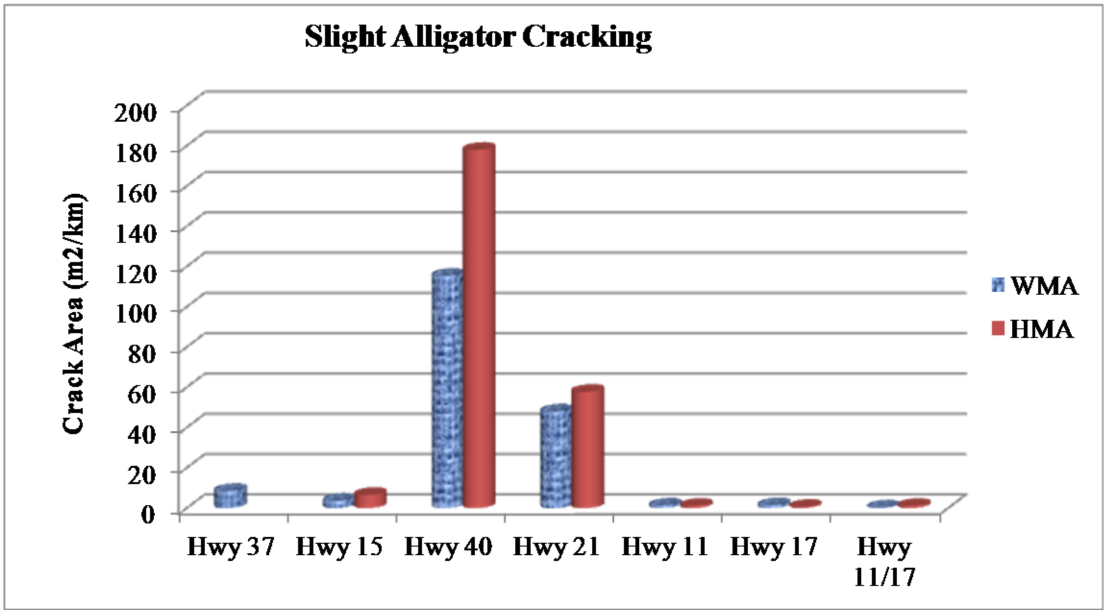


Figure 14 –
Extent of slight severity alligator cracking on the WMA and HMA sections

WMA **HMA**

Figure 15 –
Typical pavement condition on Highway 15 (paved in 2008)

WMA **HMA**

Figure 16 –
Typical pavement condition on Highway 11 (paved in 2010)