# Rubber Asphalt Mixes Using Warm Mix Technology

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**ABSTRACT**

Warm Mix Asphalt is a group of technologies that allow for the production and placement of asphalt mixes at temperatures 20 to 40°C lower than conventional hot mix asphalt. The move towards energy conservation has given the asphalt industry the incentive to explore warm mix technology.

Rubber mixes had been used in past but on an experimental basis, incorporating scrap tire rubber using two different methods, which are referred to as the wet process and dry process. In both cases, crumb rubber modifies the properties of the resultant mix to give a durable high performing pavement.

The County of Grey implemented its first asphalt rubber paving project in November 1991 and has subsequently laid more than 200 kilometres of its roads with rubber modification; recycling about 660,000 tires in the process. In an effort to improve on the performance and efficiency of their rubber asphalt mix paving process, as well as reap the benefits of warm mix asphalt, the County laid a total of 10,000 tonnes of mix using the Evotherm™ Warm Mix Asphalt Technology as at summer of 2009.

This paper describes the production, lay down and compaction, data on mix quality and discussion of overall experience.

**RÉSUMÉ**

Les enrobés bitumineux tièdes constituent un groupe de techniques qui permettent la production et la pose d’enrobés bitumineux à des températures 20 à 40°C plus bas que l’enrobé bitumineux à chaud conventionnel. Le mouvement vers la conservation de l’énergie a donné à l’industrie du bitume une bonne raison pour explorer la technique de l’enrobé tiède.

Les enrobés au caoutchouc ont été utilisés dans le passé mais sur une base expérimentale en incorporant du caoutchouc de vieux pneus avec deux méthodes différentes que l’on réfère comme procédé humide et procédé sec. Dans les deux cas, les particules de caoutchouc modifient les propriétés de l’enrobé résultant pour donner un revêtement durable de haute performance.

Le comté de Grey a réalisé son premier projet d’enrobé au caoutchouc en novembre 1991 et a par la suite posé plus de 200 kilomètres de route avec la modification au caoutchouc ; recyclant 660 000 pneus dans le procédé. Dans un effort pour améliorer la performance et l’efficacité de leur procédé de revêtement bitumineux au caoutchouc, aussi bien que récolter les avantages du procédé de l’enrobé tiède, le comté a posé un total de 10 000 tonnes d’enrobé avec le procédé d’enrobé tiède Evotherm™ à l’été 2009.

Cet exposé décrit la production, la pose et le compactage, les données sur la qualité de l’enrobé et discute de l’expérience en général.

## 1.0 INTRODUCTION

Warm Mix Asphalt (WMA) technology has recently become the new trend in the area of asphalt technology. Workers' health and safety, as well as environmental concerns have caused many people to look for different ways of producing asphalt concrete mixes that maintain physical properties and performance characteristics of traditional Hot Mix Asphalt (HMA) but are more worker and environmentally friendly [1].

The technology is now available to decrease HMA production temperature by 16 to over 55°C. These relatively new processes and products use various mechanical and chemical means to reduce the shear resistance of the mix at during construction while maintaining or improving pavement performance.

The development of these technologies began in Europe with the German Bitumen Forum in 1997. At that time, the Kyoto agreement concerning green house gas reduction was in the process of being adopted by countries of the European Union. Since then, a number of product and processes for HMA temperature reduction have been developed in both Europe and North America [2].

The processes currently available in North America include Aspha-min®, Advera®, Sasobit®, WAM Foam, Low Energy Asphalt (LEA), Evotherm®, Hypertherm™, and the Double Barrel Green® System.

The Evotherm® process is based on a chemical blend that includes additives to improve coating, workability, adhesion and emulsification [3]. Evotherm® can be delivered in the form of a high residue emulsion containing between 67 and 69 percent residue, a concentrated solution (DAT) or as an additive directly into the asphalt cement or as a liquid additive (3G) that is suitable for introducing at hot mix asphalt plant or asphalt cement terminal.

Evotherm 3G is available in a ready-to-use form and delivers the same performance as the Evotherm ET and DAT warm mix asphalt technologies. Evotherm 3G warm mix technology is the subject of this paper based on field evaluation of Rubber Asphalt Mix on County Road 7 in Grey County, Ontario.

Scrap rubber tires can be incorporated into asphalt paving mixes in a granulated form (Crumb Rubber), usually in the size range of 2.00 to 2.5mm (4 to 19 mesh) down to less than 0.6mm (30 mesh) using two different methods, which are referred to as the wet process and the dry process. The rubber, typically made from used tires either by grinding at ambient room temperature (ambient crumb) or after freezing with liquid hydrogen (cryogenic crumb) [4].

In the wet process, crumb rubber is added to the asphalt cement at the terminal or with an on-site mixer set-up at the HMA production plant and acts as asphalt cement modifier, while in the dry process granulated or ground rubber and/or crumb rubber is used as a portion of the fine aggregate. In both processes, crumb rubber is sometimes referred to as Crumb Rubber Modifier (CRM) because its use modifies the properties of the resultant asphalt mix product.

Rubber asphalt mixes or rubberized asphalt is a mixture of up to 2 percent by weight of rubber placed in an otherwise conventional asphalt mix and designed as dense-graded, open-graded or gap-graded paving mixtures. In the dry process, the rubber particles are blended with the aggregate prior to addition of the asphalt cement. The granulated rubber consists of rubber particles in size from 4.2 to 2.0mm (No.10 sieve).

## 2.0 BACKGROUND

Disposal of waste tire is an environmental concern in Ontario. According to Used Tires Program Plan prepared by Ontario Tire Stewardship in February 2009, the current scrap highway tire generation is about 13 million Passenger Tire Equivalent (PTE's) of which 0.8 million PTE's go to the landfills [5].


**Figure 1. Grey County, Ontario Location Map**

Grey County implemented its first asphalt rubber paving project in November 1991 and has since found that rubber modified asphalt allows the pavement to be more flexible and therefore more crack resistant with an estimated extended life of 20 years. Their success in the use of Rubberized Asphalt (RA) mixes has been attributed to their precise quality control and assurance over a Closed Loop Recycling Program.

Construction issues however do exist with their success; of great concern concerned the fumes emitted from RA mix production in the plant, haul truck and from paver hoop. Noticeable as well were the odours from RA; much stronger than regular HMA. Rubberized Asphalt was also harder to rake and manage by the paving crew. To address the above constructional issues, a WMA technology solution was proposed to and accepted by the County. In the summer of 2009, a trial road project was awarded and constructed.

## 3.0 PROJECT DESCRIPTION

The project is located on County Road 7, a two-lane rural highway, 6.7 to 7.4 metres in width plus shoulders that connects the communities of Kimberly on the southeast and Griersville on the North-westerly direction. As shown in Figure 2, the project extends from County Road 313 at Kimberley going North to the Town of Meaford ending at Provincial Highway 26 and carries 950 vehicles per day with low volume of truck traffic. The existing surface paved 1997 was removed and fine-graded to receive a 50mm layer of asphalt mix. The contract to pave 7.68 km of County Road 7 with HL 4 dense graded rubber warm mix asphalt was awarded to EC King Contracting of Owen Sound, Ontario.

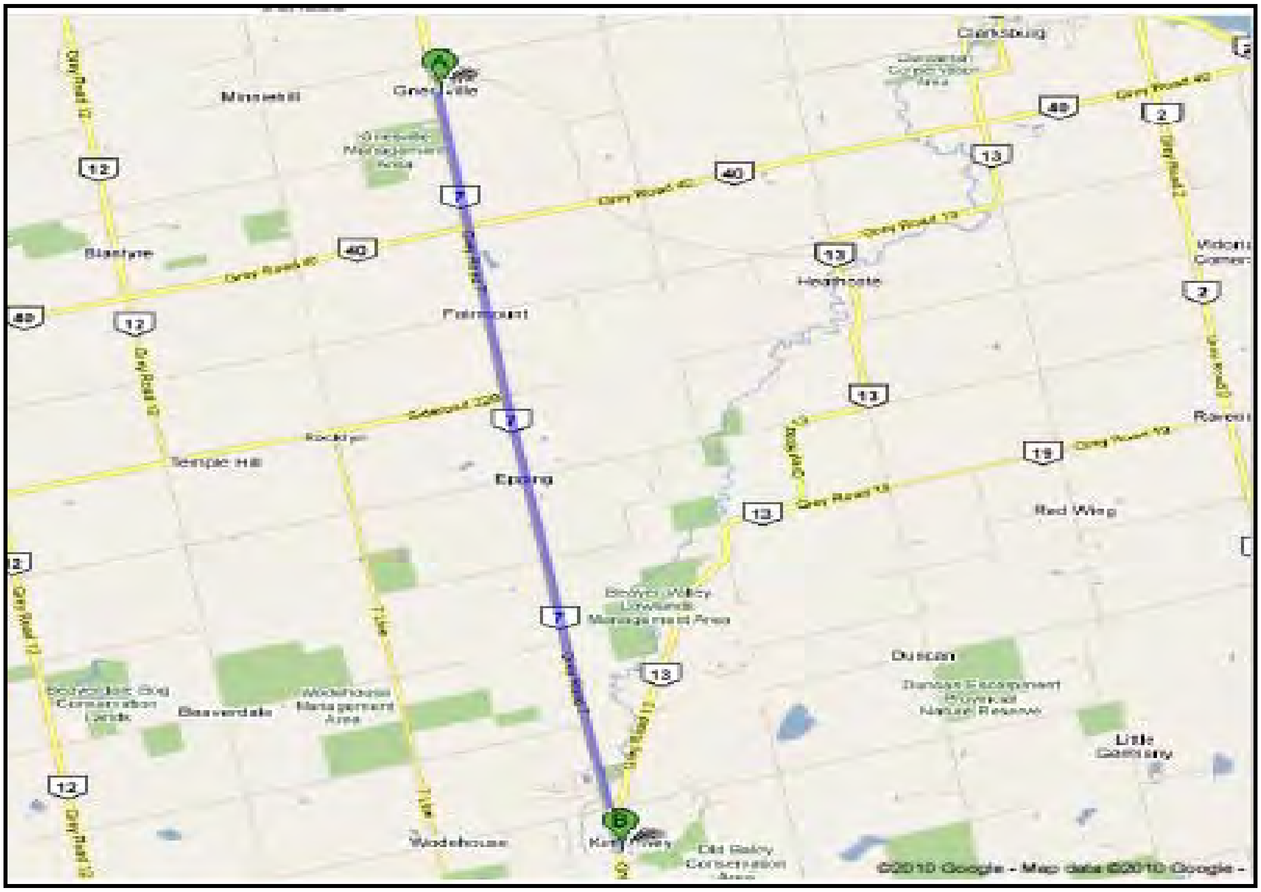


**Figure 2. Project Location – Grey County Road 7**

EC King Contracting produced and placed the Rubber Warm Mix (RWM) using Evotherm® technology on Grey County Road 7 from August 13th – 19th 2009. The project road is part of the County 2009 paving contracts approved by the County Council as an opportunity to reduce scrap tire problem, help to eliminate local environmental threat, and as a solution to cracking problems experienced within its asphalt road network. The RWM contains granulated crumb rubber produced utilizing the dry process with an average lift thickness of 50mm using Evotherm® technology placed on granular base prepared and compacted to required density.

The weather on the first day of paving and subsequent was overcast, with a high of 26°C. Throughout the paving process, it was hot but comfortable on the job-site. The paving crew and roller operators found the mix easy to rake, shovel and compact, with no appreciable fumes as further evidenced at the plant during production (Figure 3).

**Figure 3. Loading Trucks at Plant - No Fumes Observed during Production**

## 4.0 MIX DESIGN

The Marshall mix design method was used in developing the mix volumetric properties. The same Stability and Flow, air void, and Voids in Mineral Aggregates (VMA) specifications were achieved as an HMA mix of equal level and use (Table 1). The HL 4 RWM was designed on the fine side of the maximum density line (Figure 4) using aggregates from EC King Sydenham quarry and Chappels natural sand, with an optimum asphalt binder content of 6.30 percent of PG 58-28. The mix design was completed by McAsphalt Industries Limited, Scarborough, Ontario.

**Table 1. Laboratory Mix Design Data**

| Job Mix Formula Blend | Materials | |
|---|---|---|
| | **Source** | **Percentages (%)** |
| HL4 Stone | Sydenham | 20 |
| HL3 Stone | Sydenham | 25 |
| Asphalt Sand | Chappels | 43.5 |
| Screenings | Sydenham | 10 |
| Crumb Rubber | EnvironTech | 1.5 |
| PG 58-28 Evotherm | McAsphalt | 6.30 |
| **Physical Properties** | | |
| **Parameter** | **Selected** | **Specification** |
| Stability @ 60 $^{o}$C (N) | 6,603 | 5,800 min |
| Flow Index (0.25mm) | 16.5 | 8.0 min |
| Air Voids (%) | 4.0 | 3.5 – 4.5 % |
| Voids in the Mineral Aggregate, VMA (%) | 19.3 | 15.0 % min |
| Bulk Relative Density, BRD (kg/m3) | 2.324 | Not Applicable |
| Maximum Relative Density, MRD (kg/m3) | 2.422 | |

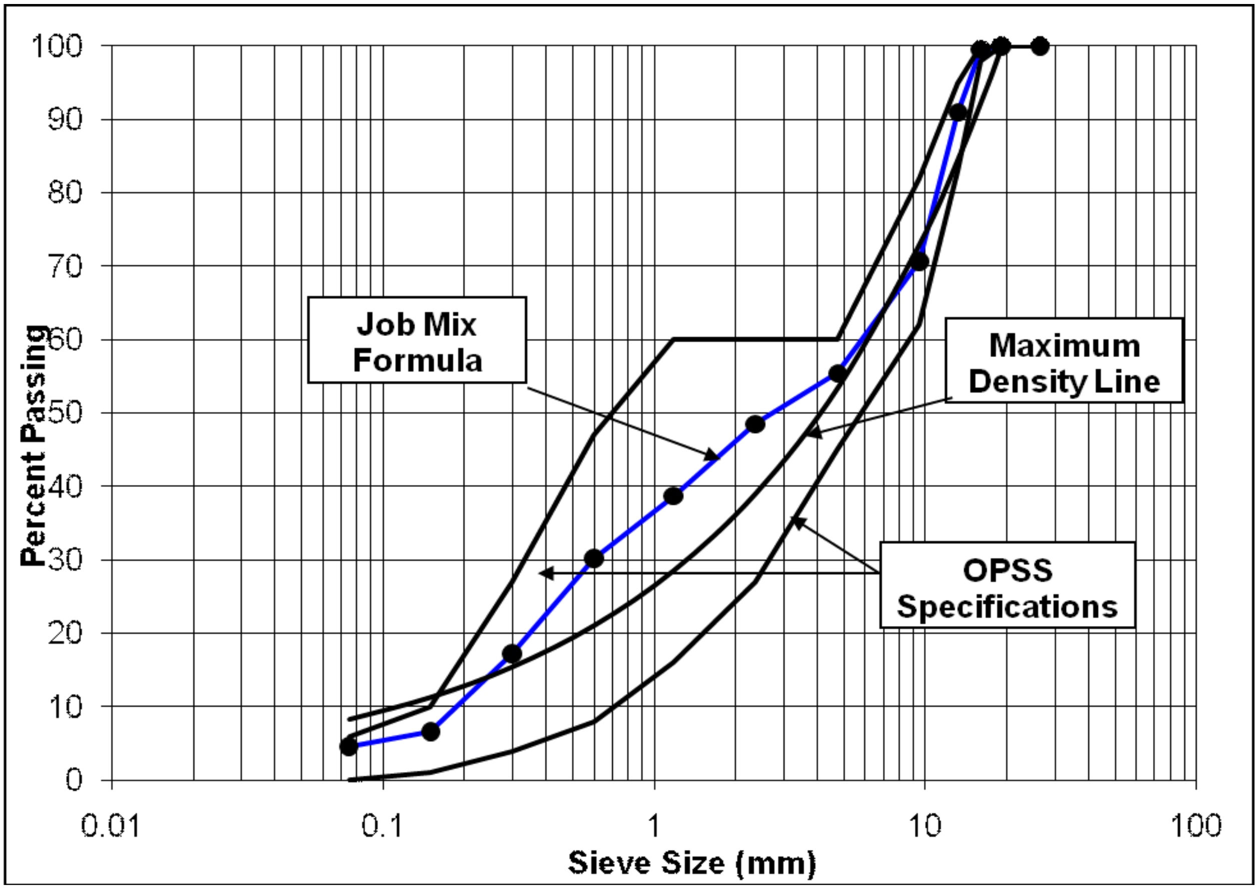


**Figure 4. Job Mix Formula Blend Chart**

## 5.0 MIX PRODUCTION

The EC King Contracting Sydenham asphalt plant which is a 170 tonne/hr batch plant produced a total of 3600 tonne of the mix over the period of four days. The average discharge temperature into the truck box was 122°C (Figure 5). On the average, hauling time recorded was 45 minutes from the plant to job site.


**Figure 5. Rubber Asphalt Warm Mix Temperature during Hauling**

In order to add the crumb rubber with the dry process mix, the reclaimed asphalt feeder system was utilized; the bags of crumb rubber were cut open and carried up to the Pugmill to be mixed with the aggregate (Figure 6). No problems were encountered during the production, with exhaust emissions significantly decreased and burner fuel consumption reduced at the lower mixing temperature levels.

**Figure 6. Crumb Rubber in Bags and Feed System**

## 6.0 PAVING PRODUCTION

As shown in Figure 7, the average discharge temperature of the first load into the Cedarapids rubber-tired paver hopper was 119°C, and there were no issues with discharge of mix into the hopper. Laydown and compaction was accomplished using traditional paver and roller. The mat flowed smoothly through the paver and under the screed (Figure 8) like regular HMA except that the placement temperature was significantly lower [6]. Almost no fumes or odours were noticed as well.


**Figure 7. Rubber Asphalt Warm Mix Temperature in Paving**

**Figure 8. Placing Rubber Asphalt Warm Mix**

The compaction train consisted of a 2003 Ingersoll Rand DD90 steel wheel vibratory roller for breakdown, a 2004 Bomag DUR24R rubber tire roller for intermediate compaction and a Bomag steel wheeled roller for finishing (Figure 9).

The handling and laydown of the mix was performed without any difficulties and the mix was still workable down to 80°C with the compaction specification readily met. Typically, the density of mix leaving the paver was recorded at 89 percent, with a second pass of the breakdown roller at a mix temperature of between 100 and 110°C, with test results from the nuclear density gauge indicating an average of 95 percent.  Further rolling at 85°C yielded an average density of 96 percent.

**Figure 9. Rubber Asphalt Warm Mix Breakdown and Intermediate Rolling**

Density checks showed that the mix could still be compacted further and the compaction train continued until the mat cooled down to below 80°C. The mix during placement showed minor signs of roller and tear marks on initial compaction, but after final breakdown compaction and finished rolling was completed these surface imperfections were eliminated. The finished mat seal up tight (Figure 10).

**Figure 10. Rubber Asphalt Warm Mix Finished Mat**

## 7.0 SUMMARY OF QUALITY TEST RESULTS

As part of the quality management presses, samples of the mix were taken and analyzed in the laboratory by EC King Contracting for quality control and AMEC for quality assurance purposes. Results obtained are summarized in Tables 2 and 3 and met with the Job Mix Formula (JMF) and specifications.

**Table 2. Marshall Properties Test Summary**

| Marshall Properties | Test Result Average | Mix JMF | Production Specs |
|---|---|---|---|
| Asphalt Cement (%) | 6.27 | 6.30 | 6.00 – 6.80 |
| Air Voids (%) | 3.9 | 4.00 | 3.0 – 5.0 |
| Voids in the Mineral Aggregate, VMA (%) | 18.2 | 19.3 | 15.0 min |
| Stability (N) | 6,612 | 6,603 | 5,800 min |
| Flow (0.25mm) | 12.4 | 16.5 | 8.0 min |

**Table 3. Gradation Test Summary**

| Sample | Job Mix Formula | QA Lab | QC Lab |
|---|---|---|---|
| **Sieves** | Results (% Passing) | | |
| 19 mm | 100 | 100 | 100 |
| 16mm | 99.5 | 99.0 | 99.2 |
| 13.2mm | 91.0 | 92.0 | 90.5 |
| 9.5mm | 70.7 | 74.3 | 70.2 |
| 4.75mm | 55.4 | 56.1 | 54.8 |
| 2.36mm | 48.5 | 46.0 | 46.0 |
| 1.18mm | 38.7 | 35.8 | 35.9 |
| 0.600mm | 30.2 | 27.6 | 28.2 |
| 0.300mm | 17.2 | 15.5 | 15.4 |
| 0.150mm | 6.6 | 5.2 | 5.5 |
| 0.75mm | 4.6 | 3.2 | 3.6 |
| **% AC Content** | 6.30 | 6.26 | 6.17 |

The WMA project was completed with very few problems and a visual inspection of the road completed in spring of this year (May 14, 2010) yielded no visible surface or structural defects. A detail follow-up inspection in the coming months will enable us to monitor and give a firm report on the life-cycle performance of the road.

## 8.0 CONCLUSION

The trial paving went well, indicating that Rubber Warm Mix using Evotherm® could be placed and compacted at reduced temperature as compared to regular Rubberized Asphalt mix, while meeting field compaction density and workability without segregation. In addition, construction and compaction of the longitudinal joint was achieved with little effort.

Visible fumes at the plant, haul truck, and paver hopper were virtually non-existent, while odour was eliminated by this process. As a bonus for the paving crew, Rubber Warm Mix Asphalt was easy to rake and work without the body temperature elevation they would have experienced working with regular Rubberized Hot Mix Asphalt.

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