USAGE OF EMULSION MIXES TO MITIGATE THE EFFECT OF SUBGRADE MOVEMENTS

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ABSTRACT

The standard pavement structure in Canada consists of layers of manufactured materials laid onto an often-heterogeneous roadbed soil. The upper portion of the roadbed soil is commonly exposed to frost action. Differential frost heaving of frost-susceptible roadbed soils may lead to distortion and subsequent cracking of the pavement upper layers. Complete excavation of frost-susceptible material is not economically viable in all cases. Emulsion mixes have been used successfully to follow roadbed soil movement without cracking. Laboratory and field observations indicate that emulsion mixes have membrane-like mechanical properties rather than the slab-like properties of standard hot bituminous mixtures. Furthermore, emulsion mixes are not as susceptible to thermal cracking as regular standard hot bituminous mixtures. Emulsion mixes are used as base layer in a pavement structure as well as surfacing courses. They are produced in cold mix plants as well as with mix-pavers. The aggregate gradation of these mixes may be open or dense. The experience acquired over the last 25 years in Ontario has contributed to define the conditions under which these emulsion mixes may be produced and used. This paper presents an overview of emulsion mixes as well as the work carried out on York/Durham Line 30 in York Region.

RÉSUMÉ

La chaussée type traditionnelle au Canada est composé de plusieurs couches successive de matériaux non-traités et traités mis en oeuvre sur un sol support souvent hétérogène. La partie supérieure du sol support est généralement soumit aux effets du gel. Le soulèvement différentiel dû au gonflement des sols support gélifs peut provoquer la rupture de la partie superficielle de la chaussée. La mise hors gel du sol support est rarement viable économiquement. Les matériaux traités à l'émulsion s'adaptent aux déformations lentes du sol support sans fissurations. Les observations en laboratoire et en chantier tendent à démontrer que les caractéristiques mécaniques des matériaux traités à l'émulsion s'apparent plus à celles d'une membrane plutôt qu'à celles d'une dalle comme c'est le cas pour les enrobés à chaud. De plus, les matériaux traités à l'émulsion ne sont pas aussi susceptibles à la fissuration thermique que les enrobés à chaud traditionels. Les matériaux traités à l'émulsion peuvent être utilisés comme couche de base ou comme couche de roulement. Ils sont fabriqués soit en centrales d'enrobage à froid soit en place à l'aide de motopavers. La granulométrie de ces matériaux peut être serrée ou continue. L'expérience acquise au cours des 25 dernières années en Ontario a contribué à définir les conditions dans lesquelles ces enrobés à l'émulsion peuvent être fabriqués et mis en oeuvre. La présente communication fait un survol des matériaux traités à froid de même que les résultats de chantier de la route «York/Durham Line 30» dans la région de York.

1. INTRODUCTION

1.1 Emulsion Mixes

Emulsion mixes are obtained by dispersing a bitumen emulsion in an aggregate. They are produced in cold mix plants as well as with mix-pavers. The aggregate gradation of these mixes may be open or dense. The coating of aggregate by the bitumen emulsion may be selective or complete. Emulsion mixes are used as a base layer in a pavement structure as well as a surfacing course. They are applied in thickness ranging from 40 mm to 200 mm.

1.1.1 Open Graded Emulsion Mix

The U.S. Federal Highway Administration, in co-operation with the U.S. Forest Service Bureau, initiated the development of Open Graded Emulsion Mixes (OGEM) in the mid-sixties. The development work was to result in a product that would favour the construction of low cost pavement structures and low maintenance roads. The product was to provide a high degree of flexibility to minimize cracking due to low temperature and subgrade movement. The first paving work using an OGEM was performed in the State of Oregon in 1966 [1] and it was introduced in Ontario in 1975 in the District of Muskoka [2].

1.1.2 Emulsion Stabilized Granular Material

The idea of dispersing a binder in a granular material is not recent. The grader mix "mulch" [2] system and the in-place "retreat process" [3] were the first form of stabilization of granular material. The processes consisted of scarifying the in-place material, reprofiling the roadway, adding new granular material, incorporating a bitumen emulsion or a cut-back and performing the mixing with motograder by moving the stabilized granular material back and forth from one side of the road to the other. As the process evolved, cut-backs were abandoned and the mixing was performed in a cold mix plant specifically design to mix large volumes of granular material with bitumen emulsion. The application of the Emulsion Stabilized Granular Material (ESGM) on the roadway may still be performed using motograders; however, conventional pavers are usually preferred.

In the mid-seventies, a stabilized granular material called Dense Graded Emulsion Mix (DGEM) was developed. The product was used as an alternative paving mixture to hot mix asphalt (HMA) on low volume roads in remote locations. In order to provide an equivalent performance to HMA, DGEM needed to be sealed with surface treatment. Unfortunately, the necessary combination of DGEM with surface treatment did not provide considerable saving compared to HMA and the production of DGEM was slowly abandoned. During the same period in France and in Spain a similar ESGM called "Grave-Emulsion" was developed for road base applications [3,4]. Contrary to the Ontario experience, the savings associated with the usage of "Grave-Emulsion" as a road base product were substantial and the performance was excellent. Nowadays, it is a widely accepted and used product, precisely defined with respect to the manufacturing process and the conditions under which it must be used.

1.2 The York Region Project

In 1998, the Transportation and Works Department of York Region selected a combination of emulsion mixes to rehabilitate York/Durham Line 30 in York Region. The pavement rehabilitation strategy included a granular correction of the in-place granular material and the placement of an Emulsion Stabilized Granular Material base followed by the placement of an Open Graded Emulsion Mix/Slurry Seal surfacing system.

2. PROJECT DESCRIPTION

2.1 Location and Pavement Condition

The length of the York/Durham Line 30 project is 3.1 km and it is located between Hwy 7 and Steeles Ave in the Town of Markham in York Region. York/Durham Line 30 is a two-lane collector regional road with an estimated average annual daily traffic (AADT) of 1500 to 2000, of which less than 5% is classified as commercial traffic.

In 1998, the pavement condition was in a state of disrepair. The pavement condition rating (PCR) was estimated to be below 20. The PCR is based on a survey of distresses and a measurement of roughness [5]. The gravel surfacing was severely damaged: potholing and frost heaving was nearly continuous throughout the entire 3.1 km section. In February-March 1998, York/Durham Line 30 was considered dangerous to travel and on occasions the southern section had to be closed down (Figure 1).

Figure 1 - Condition of York/Durham Line 30 before Pavement Rehabilitation

2.2 Contract Requirements

The contract requirements were as follows:

- placement of a geogrid and a geotextile in a 300 m section at the south start of the project
- blending of a corrective coarse aggregate in the in-place existing gravel surfacing
- application of 75 mm of an Emulsion Stabilized Granular Material
- application of 50 mm of an Open Graded Emulsion Mix
- placement of a Slurry Seal.

The required width of the roadway surfacing was 7.0 m with a 2% crossfall for each lane. The geogrid/geotextile was placed 150 mm below the surface of the existing granular material surfacing. The corrective coarse aggregate was a 19 mm clear stone. The ESGM mixture was produced using a continuous gradation type granular material and a Cationic Slow Setting emulsion. The OGEM mixture was manufactured using a 16 mm clear stone and a Cationic Medium Setting emulsion. The Slurry Seal was produced using screening and a Cationic Quick Setting emulsion.

3. PAVEMENT DESIGN

3.1 Pavement Components

Roadway pavement is composed of three primary components: surfacing, pavement structure and subgrade (Figure 2). The surfacing component provides an interface with the traffic and the environment in terms of skid resistance, smoothness, noise reduction and waterproofing of the pavement structure. The function of the pavement structure is to transfer loads imparted on the surface by vehicles to the underlying subgrade. The subgrade or roadbed soil supports the pavement structure and it is composed of in-place material in "cut" areas or imported material in the "fill" areas. The strength characteristics of the roadbed soil dictate the type of pavement structure required to spread the applied surface load to a magnitude that can be supported by the subgrade.

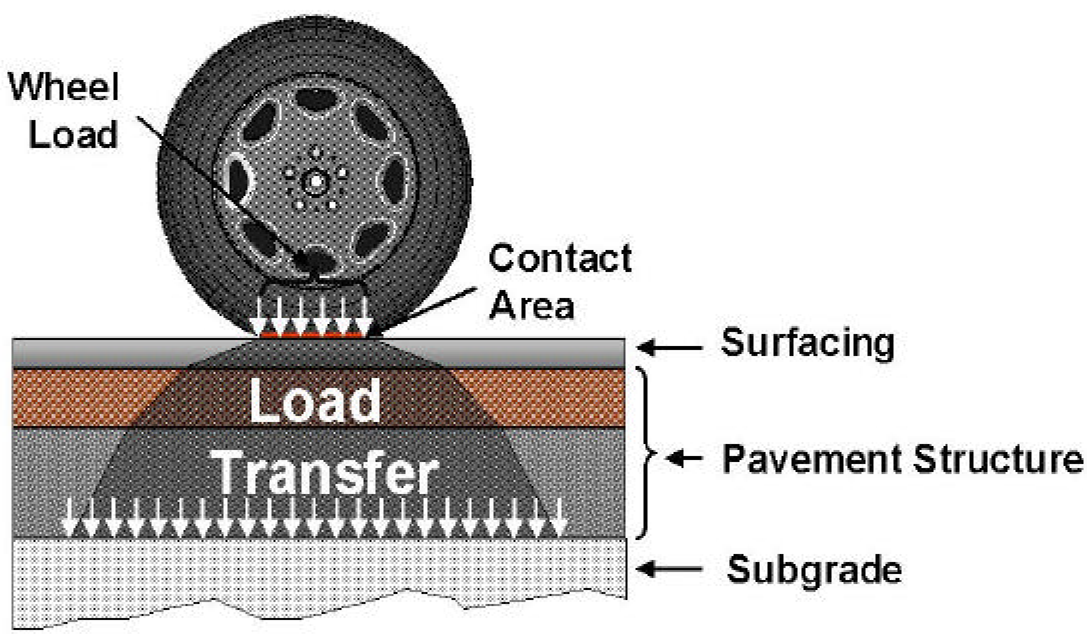

Figure 2 - Pavement Components

3.2 Pavement Structure Materials

Two types of pavement structure materials are available for road construction: unbound materials such as crushed stone and gravel, and bound materials, which include stabilized materials and HMA.

3.2.1 Unbound Materials

Unbound materials transfer loading through the individual particles of the compacted granular material. The ability of a granular material to transfer loading is controlled by both the strength of the individual particles and the friction between the particles. The high friction between the particles is obtained with angular particles, dense graded materials, densely compacted material and a low water content to prevent lubrication between the particles (Figure 3).

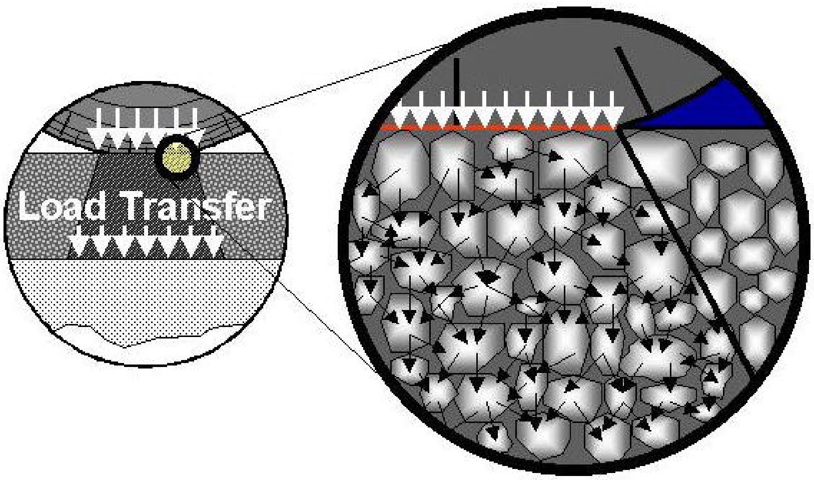

Figure 3 - Load Transfer through Unbound Materials

3.2.2 Bound Materials

Bound materials may have a slab and/or a membrane-like behaviour with respect to load transfer. Vertical loading onto the surface of a slab-like bound material generates horizontal compressive stresses in the upper portion of the layer and tensile stresses in the lower portion of the layer (Figure 4). Vertical loading applied on a membrane like bound material only develops tensile stresses. The size of the subgrade area onto which surface loading is transferred is dictated by the tensile strength at the bottom of layer of bound materials.

The slab/membrane behaviour of bound materials is influenced by the thickness of the layer, the nature of the stabilizing agent and the duration of the applied loading. Thicker and cement stabilized materials have a slab-like behaviour while thinner and bitumen stabilized materials may have more of a membrane-like behaviour. Futhermore, bitumen-stabilized materials have a slab-like behaviour when loading is applied rapidly for a short duration while, but a membrane-like behaviour if the loading is applied slowly for a long period.

3.2.3 Functional Life of Pavement

Under repeated loading the mode of failure of the pavement manifests itself in deformation of roadbed soil and/or fatigue cracking of bound material layers. Thus, the structural capacity of a pavement is determined in terms of the number of times it can be loaded before deformation in the roadbed soil and/or fatigue cracking become unacceptable.

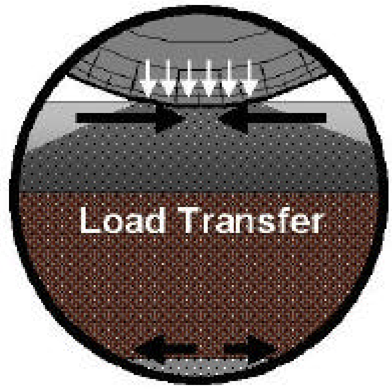

Figure 4 - Load Transfer through Bound Materials

The functional life of pavement may also be determined in terms of its capacity to withstand changing environmental conditions. Temperature changes and wet or dry conditions influence the functional life of pavement. The primary cause of pavement distress and failure in Eastern Canada is not related to repeated loading but to temperature-induced stresses: thermal cracking. Frost heave action and settlement of roadbed soils may cause unacceptable distresses in the pavement and consequently influence the functional life of the pavement.

3.3 York/Durham Line 30

3.3.1 Limiting Factors

The limitations associated with the pavement design for York/Durham Line 30 were considerable. The roadbed soils range in composition from silty clay till to silty sand till. The strength of the subgrade is not uniformed and considered low. Silty soils are considered highly frost susceptible and their drainage characteristics are poor. Furthermore, the road drainage, as a result of the relatively flat relief of the area, is not very good. In addition, the water table is relatively high.

The existing roadway width was also a limiting factor. The roadway of York/Durham Line 30 is relatively narrow and any addition of material on top of the existing roadway would result in an even narrower roadway.

3.3.2 Emulsion Rehabilitation Strategy

The difficulties associated the poor subgrade conditions and the narrow roadway dictated the selection of the rehabilitation strategy. The criteria for the selection of the rehabilitation method were as follows:

- maximum flexibility of the pavement structure materials to mitigate damages related to roadbed soil movements
- maximum resistance to thermal cracking to minimize water infiltration in the pavement structure and subgrade
- minimum increase in elevation of the existing roadway to minimize the width reduction of the existing roadway (travel lanes and shoulders)
- maximum increase in pavement strength to withstand the traffic volume.

Rehabilitation that includes the addition of a thick layer of unbound material to accommodate the HMA surfacing was rejected because of the higher cost and resulting narrowing of the roadway. The emulsion rehabilitation strategy was retained because of the ability of emulsion mixes to withstand thermal cracking and subgrade movements [1,2,3,4] (Figure 5).

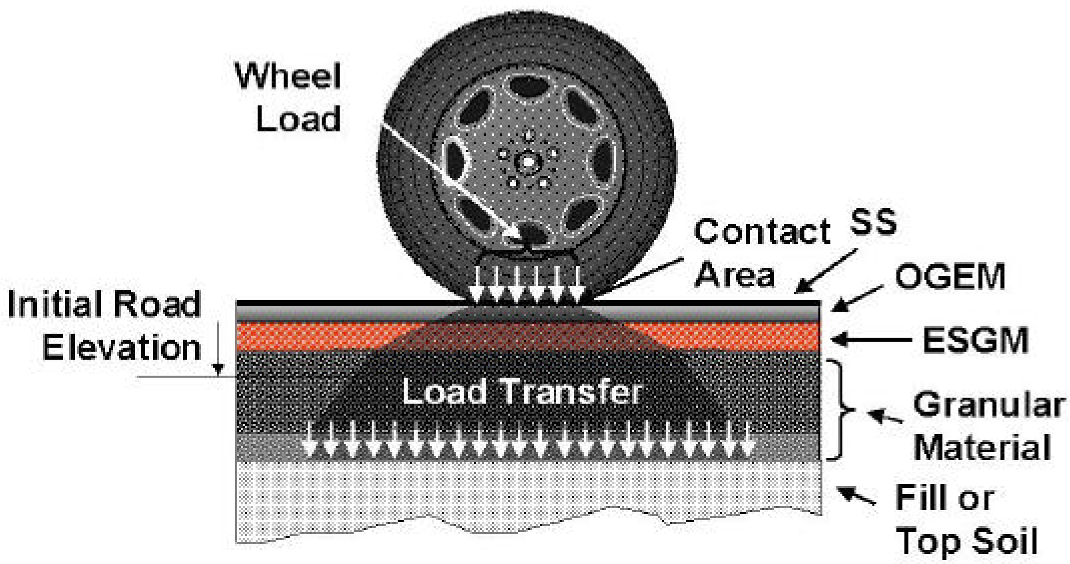

Figure 5 - Durham/York Line 30 Rehabilitation Strategy

The pavement strength in Ontario is expressed in terms of Granular Base Equivalency (GBE) [6]. Durham/York Line 30 may be considered a secondary highway. The volume of traffic on Durham/York Line 30 varies between 1500 to 2000 AADT. The soil condition ranges from silty clay till to silty sand till. The recommended GBE value for Durham/York Region Line 30 is 450 in the areas of silty sand till and 550 in the areas of silty clay till. However, because of the relatively low volume of commercial traffic (probably less than 5.0%) the target GBE value was established at 500 for the complete length of the project.

The resulting GBE value obtained with the retained emulsion rehabilitation strategy was 509 and the increase in elevation was 175 mm. The GBE factor assumed for the in-place granular material was 0.67, the GBE value for the granular corrected layer was 1.0 and the GBE value used for the emulsion mix layer was 1.8.

4. MATERIALS AND MIXTURE DESIGN

4.1 Granular Correction

The thickness of the existing gravel surfacing before the granular correction varied between 300 and 500 mm. The gradation of the in-place granular material did not meet the Ontario Provincial Standard Specifications (OPSS) for granular base material (Granular A). However, most of the samples extracted from the roadway meet the OPSS for subbase granular material (Granular B). Figure 6 defines the gradation envelope of the in-place granular material.

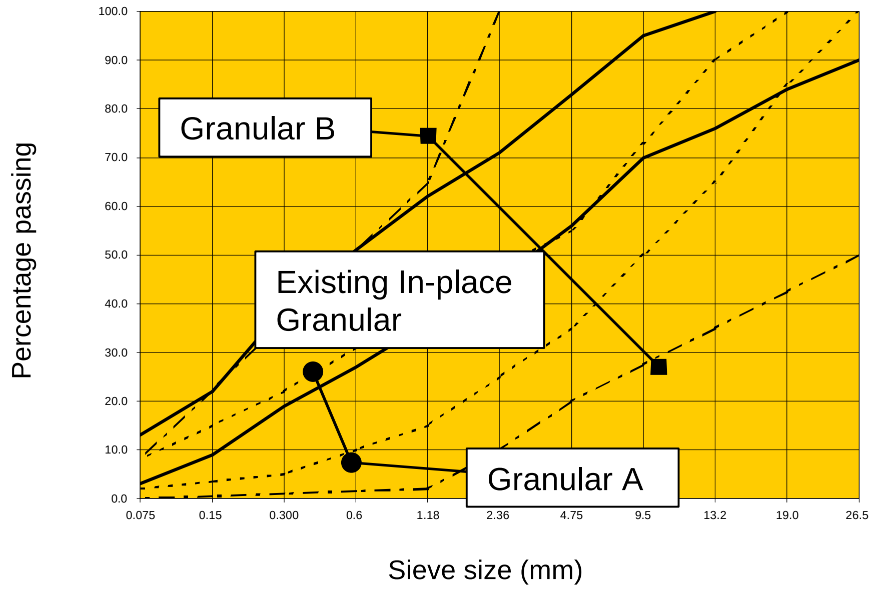

Figure 6 - Gradation Envelop of the Existing In-place Granular Material on Durham/York Line 30

The ability of a granular material layer to transfer load to the underlying material is strongly influenced by its gradation. To maximize the load transfer capacity of the in-place material, a granular correction operation was carried out using 19 mm clear stone. The required corrective aggregate necessary to modify the existing granular material to satisfy the OPSS standard for base material (Granular A) was 33%. The thickness of the new layer of granular material created by blending the existing material with the corrective aggregate was 150 mm.

4.2 Emulsion Stabilized Granular Material Mix Design

The mix design retained for the Emulsion Stabilized Granular Material for York/Durham Line 30 is outlined in Table 1. The aggregate came from a submerged gravel pit and it met the OPSS Granular A requirement.

Table 1 - Emulsion Stabilized Granular Material Mix Design for Durham/York Line 30

	Values	Specifications
Mixture Design		
Granular Material (Gr. A)	94.0 %	
Emulsion (CSS-1)	6.0 %	
Laboratory Results		
Marshall Stab. @ 22ºC (Unsoaked)	21586 Newtons	4500 Newtons (min.)
Flow Index @ 22ºC (0.25 mm)	28.0	10.0 (min.)
Marshall Stab. @ 22ºC (Soaked)	19937 Newtons	
Flow Index @ 22ºC (0.25 mm)	28.5	
% Retained Stability	92.3	
Bulk Relative Density	2.366	
Maximum Relative Density	2.546	
% Air Voids	7.07	between 4.0 and 12.0 %

4.3 Mix Design for Open Graded Emulsion Mix & Slurry Seal

The standard Ontario mix design procedure for OGEM was used to select the optimum emulsion content. The mix design procedure consist of mixing measured quantities of aggregates and emulsion for a predetermined length of time to determined the capacity of the emulsion to properly coat the aggregate. The mix design procedure indicated that 6.0 % of Cationic Medium Setting (CMS-2) was required to properly coat the selected aggregate. The aggregate came from a limestone quarry. The gradation envelope of the 16 mm aggregate is provided in Figure 7. A standard Type II Slurry Seal was used to seal the surface of the OGEM.

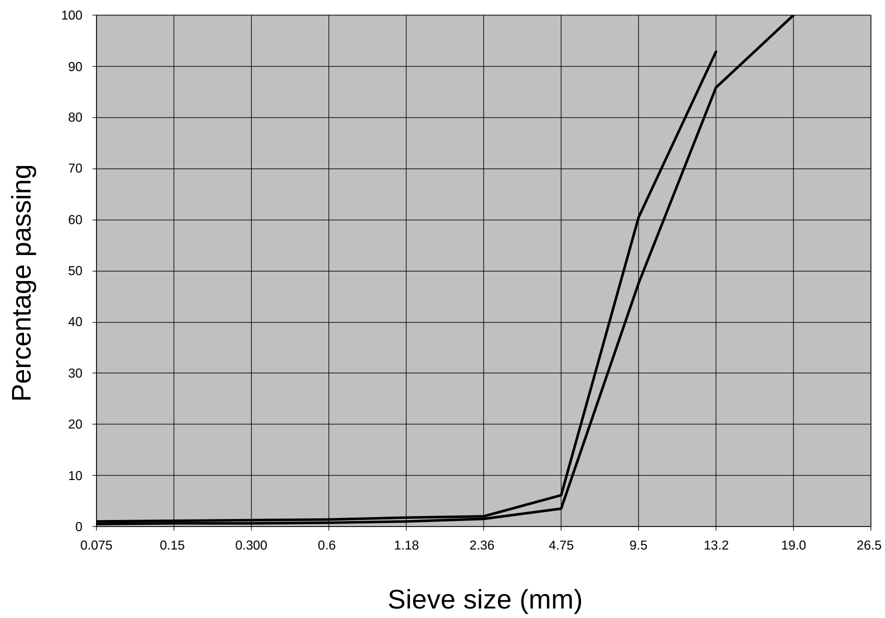

Figure 7 - Gradation Envelop of OGEM Aggregate used at Durham/York Line 30

5. CONSTRUCTION

The tendering procedure was initiated in June 1998 with a closing date of July 7, 1998. Miller Paving Limited was successful in obtaining the contract and the work was performed during the months of August and September 1998.

5.1 Granular Correction

The granular correction operation consisted of restoring the existing roadway grade and profile, spreading 50 mm of a 19 mm clear stone onto the surface and blending the existing material with the corrective aggregate using a reclaimer (Figure 8). The results of the blending are provided in Figure 9.

5.2 Emulsion Stabilized Granular Material

The ESGM was produced using a mobile cold mix plant set up at the source of aggregate (Figure 10). The placement operation was carried out with a standard paver and the ESGM was compacted using both a vibratory double drum steel roller and a pneumatic roller (Figure 11).

Figure 8 - Blending Operation of Corrective Aggregate with Existing Granular Material

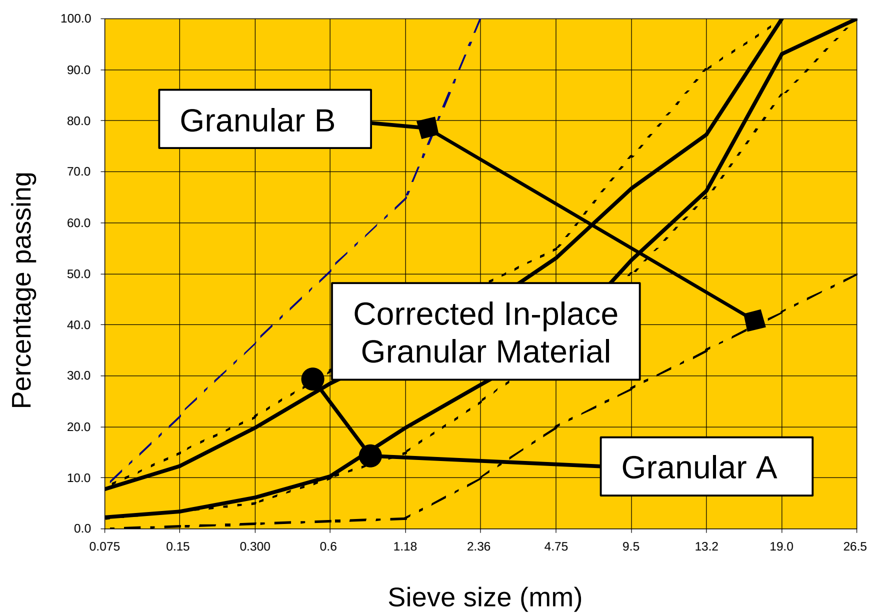

Figure 9 - Gradation of In-place Material after Granular Correction

Figure 10 - Cold Mix Plant

Figure 11 - Paving of Emulsion Stabilized Granular Material

When working with ESGM, the optimum fluid content for compaction is defined by using the combined content of the total emulsion fluids (water and bitumen) and the inherent moisture of the granular material. Before breaking, the emulsion has a viscosity comparable to that of water and it works in a similar manner by providing lubrication between the aggregate particles during compaction. Should the total fluid content be lower or greater than approximately 8.0 ± 0.5 %, proper compaction may become difficult. Furthermore, if the field fluid content greatly exceeds the optimum fluid content, hydraulic pressures will develop making it impossible to compact the material.

The combined field fluid content, had the initial mix-design for the ESGM been maintained, would have been in the neighbourhood of 9.5 %, which was much greater than anticipated and in excess of the optimum fluid content. The inherent water content was approximately 3.5 % in the core of the aggregate pile while the initial mix design was carried out assuming a moisture content of 1.75 %.

Field adjustments in the production of the ESGM were required and a simple reduction in the amount of added emulsion to reduce the combined field fluid content was not considered an option because of the resulting lower residual bitumen in the ESGM. In order to reduce the combined field fluid content while maintaining the mix design residual bitumen, it was necessary to not only modify the job mix formula but also to modify the emulsion formula. The amount of added emulsion was reduced to 5.0 % from 6.0 % and the residual bitumen content in the emulsion was increased to 69 % from 60 %. The initial mix-design residual bitumen was still not maintained. However, the consequences of the necessary reduction in the amount of added emulsion on the residual bitumen content were reduced.

5.3 Open Graded Emulsion Mix/Slurry Seal

The Open Graded Emulsion Mix was produced and placed with a mix-paver that combines the functions of a cold mix plant and a laydown machine (Figure 12). The compaction was performed using a standard vibratory double drum steel roller in the static mode.

Mix-pavers include the following components:

- a front-loading feed hopper for the supply of aggregates
- a conveyor system to deliver the aggregates from the feed hopper to the twin shaft pug-mill mixer
- a tank for the storage of emulsion
- an auger system to distribute the OGEM in front of the screed
- a variable width screed to achieve a smooth surface of the OGEM.

The mixing and the laydown of OGEM using a mix-paver are nearly simultaneous. Any detrimental effects on the mixture related to weather conditions or transportation of the mixture is greatly reduced. For example, the possible drain-off of emulsion in the haulage trucks during transportation, in the case of a mixing site being away from the paving operation location, is avoided. In fact, when using a mix-paver any excess emulsion drains down within the thickness of the laid down mixture and provides additional tack coating and sealing at the bottom of the OGEM layer.

The moisture content of the aggregate used for the production of OGEM influences the coating of the aggregate by the emulsion. Proper coating without run-off is generally obtained when the moisture content of the aggregate is in the neighbourhood of 2.0 % [2]. The moisture content was not measured on York/Durham Line 30; however proper coating without run-off was obtained.

Figure 12 - Production and Placement of Open Graded Emulsion Mix using a Mix-paver

In order to remove the tackiness of the surface and to allow traffic to circulate, a cover aggregate was spread over the surface after the initial rolling. The cover aggregate also provides surface cohesion and choking of the surface of OGEM. The aggregate used was sand and the rate of application was approximately 5.0 kg/m^2.

The void content in OGEM is typically between 20 and 30 % after compaction. Because of the open nature of the mixture, unsealed OGEM may be prone to binder stripping and binder oxidation. In addition, unsealed OGEM does not provide waterproofing of the pavement structure and the cohesion at the surface of OGEM layer may not be sufficient to withstand surface tangent stresses. By sealing the surface of OGEM with a slurry seal surfacing, waterproofing is achieved. Inherent performance of OGEM is not compromised by premature stripping or oxidation and strong surface cohesion is obtained (Figure 13).

6. PERFORMANCE OF EMULSION MIXES

6.1 Mechanical Properties of Emulsion Mixes

6.1.1 Emulsion Stabilized Granular Material [3,4]

The unique residual bitumen distribution in the mineral skeleton of ESGM provides this bound material several distinctive properties. Even if a hot bituminous mixture were to be made up of the same granular material and the same bitumen, at an equivalent residual binder, the properties of ESGM would still be quit distinctive. The residual bitumen on an ESGM selectively adheres to the smaller particles of the granular material, forming a very rich mastic. This bitumen-rich mastic binds the larger particles of the ESGM mineral skeleton. Emulsion Stablized Granular Material is not a fully coated material like HMA.

The mastic provides unique properties to ESGM layer. On one hand, the binding mastic is very stiff under rapidly applied loading such as traffic, resulting in a slab-like behaviour of the ESGM layer. On the other hand, under slowly applied loading such as subgrade movement, the ESGM layer tends to behave like a membrane. In this latter case, the ESGM does not creep but the layer of stabilized material has the ability to deform in such a manner that the layer follows the underlying material movement without cracking.

Figure 13 - Application of a Type II Slurry Seal Surfacing

The blend of fluid (aggregate moisture and emulsion) also provides unique properties to ESGM. Compaction of ESGM is performed at optimum fluid content just like any other granular material. Consequently, the granular matrix of an ESGM has comparable internal friction properties when compared to the same granular material compacted at optimum moisture content without the emulsion treatment. The residual binder selectively coats the smaller particles without altering the friction between the larger aggregate particles. Because of the binder distribution within the mineral matrix, Emulsion Stabilized Granular Material may be more accurately described as Granular Material with tensile strength.

The surface of ESGM is relatively fragile when compared to the surface of HMA. Emulsion Stabilized Granular Material is not a fully coated material like HMA and the surface is prone to ravelling. Emulsion Stabilized Granular Material is best used as pavement structure material.

6.1.2 Open Graded Emulsion Mix [1]

Performance data collected during three studies indicates that the service life of OGEM is in the order of 15 years. Structural layer coefficient (AASHTO coefficient) values of 0.25 to 0.30 have been used. A performance survey of projects in the Pacific Northwest State (Oregon, Washington and Idaho) indicates that value as high as 0.40 were found. The GBE for OGEM is 1.8 [6]. Hot Mix Asphalt AASHTO layer coefficients range between 0.35 and 0.44 and the GBE value of HMA is 2. Even though layer coefficients may, in certain cases, be equivalent for OGEM and HMA, the two materials have different mechanical characteristics and different properties with respect to long-term durability. Comparing the two materials' structural properties solely on layer coefficient may not be appropriate.

Like ESGM, the surface of OGEM is also relatively fragile when compared to the surface of HMA. Even though OGEM is generally a fully coated material, the surface of OGEM is not as rich in fines as HMA, resulting in less cohesion at the surface which makes unsealed OGEM also prone to ravelling. The best performance of OGEM is obtained when the surface is sealed.

6.1.3 Resistance to Thermal and Fatigue Cracking [7]

Materials with more voids and lower stiffness characteristics perform very well with respect to resistance to thermal and fatigue cracking. Both materials, ESGM and OGEM, have high void content: in-place voids for ESGM range between 10 and 15% and in the case of OGEM the void contents may reach as much as 25%. Typical HMA in-place void contents are below 8.0%. The stiffness of both materials, ESGM and OGEM, is also relatively low when compared to HMA. Moduli (ratio of stress to strain) of 3000 MPa measured at 15 °C, 10 Hz have been reported for ESGM and a modulus of 1500 MPa may be assumed for OGEM. Hot Mix Asphalt moduli measured at 15 °C, 10 Hz are typically in the neighbourhood of 5000 MPa.

6.3 Oxidation

Oxidation of the binder also influences the performance of bitumen stabilized materials by reducing the ductility of binder. As it oxidizes, a bituminous binder becomes harder and more brittle, which leads to thermal cracking and accelerates fatigue cracking. Oxidation of hot or cold treated bituminous materials occurs differently. For HMA, the process of oxidation occurs in two distinctive periods: during manufacture of HMA and during service life. In the case of emulsion mixes, only service life oxidation is of concern. Unlike HMA, emulsion mix manufacture does not require heat. Consequently, premature oxidation of bitumen associated with the hot mixing of aggregates and bitumen does not occur. The ductility of bitumen used in the cold mix process is preserved and the long- term negative effects associated with oxidation are reduced.

7.0 CONCLUSIONS

The limiting factors associated with the selection of a pavement rehabilitation strategy for York/Durham Line 30 were considerable. The emulsion rehabilitation strategy was mainly retained because of the ability of emulsion mixes to withstand potential difficulties associated with the poor subgrade conditions. The York/Durham Line 30 project indicates that emulsion mixes may offer considerable cost savings for rehabilitation of low to medium volume roads because there is no need for the costly road base improvement with unbound materials that would be needed to accommodate the application of traditional hot mix surfacing.

Figure 14 - York/Durham Line 30 after one year of service

Emulsion Mixes are precisely defined with respect to the manufacturing process and the conditions under which they may be must be used. Emulsions Mixes have distinctive properties when compared with hot mix technology. The binder within an Emulsion Stabilized Granular Material selectively coats smaller particles. The stiffness of emulsion mixtures is lower than hot mix asphalt. The voids content ranges between 12 and 15 % for the Emulsion Stabilized Granular Material and between 20 and 30 % for Open Grade Emulsion Mixes. Finally, unlike hot mix asphalt, the manufacturing of emulsion mixes does not require heat. Emulsion mixes perform well whenever

- resistance to transverse cracking is required
- capacity to accommodate frost heaving is needed
- ability to follow sub-grade settlement is required.

The surface of emulsion mixes is relatively fragile when compared to the surface of hot mix asphalt. Unsealed emulsion mixes do not provide waterproofing and the cohesion at the surface may not be sufficient to withstand surface tangent stresses. By sealing the surface emulsion mixes, waterproofing is achieved and the inherent performance of emulsion mixes is not compromised by premature stripping, oxidation and ravelling.

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