Ontario Hot Mix Producers Association
365 Brunel Road, Unit 4, Mississauga Ontario L4Z 1Z5
Phone: 905-507-3707 Fax: 905-507-3709 web: www.ohmpa.org

SPECIAL BULLETIN 4-A

QUALITY OF ASPHALT PAVEMENT TASK FORCE

November 2016

Re: The Responsible Use of Recycled Materials in Asphalt Mixtures – Critical Look

This is a follow-up bulletin to Bulletin 4 and addresses the critical elements to be considered with the responsible use of recycled materials in asphalt mixtures. This bulletin is organized to address the following elements:

1. Review of the common best practices with recycling RAP;
2. Recycled Binder Ratio (RBR);
3. Critical look at available RAP PGAC for Asphalt Mix Designs;
4. RAP Management and Best Practices; and
5. Commitment from Asphalt Producers on Responsible Use of RAP in asphalt mixtures.

Review of the State of the Art of RAP in Asphalt Mixtures

Recycling or reuse of pavement material is a very simple but powerful concept. Recycling of existing pavement materials to produce new pavement materials results in considerable savings of material, money, and energy [1, 2, 3]. The specific benefits of recycling can be summarized as follows [3]:

- Reduced costs of construction;
- Conservation of aggregate and binders;
- Preservation of the environment; and,
- Conservation of energy.

The recycling process uses reclaimed asphalt pavement (RAP) materials combined with new materials, sometimes along with a recycling agent (not common practice in Ontario), to produce asphalt mixtures that are of equal or better quality to virgin aggregate mixtures. Both batch and drum type hot mix plants are capable of producing recycled mix. The RAP material can be obtained by milling or ripping and crushing operation. The mix placement and compaction equipment and procedures are the same as for conventional asphalt mixtures [3, 4].

The most important characteristic of RAP material that would greatly influence the properties and performance of the resulting recycled mix is the stiffness (hardness) of the existing asphalt cement or binder contained in the RAP. The recovered RAP binder is stiffer than virgin or new binders due to ageing. The physical effects of ageing are caused by chemical changes within the binder. Asphalt bituminous binder exhibits two stages of ageing namely, short term and long term and the main factors causing asphalt binder ageing during these stages are [1]:

1. The short term ageing is mainly due to volatilization through evaporation of the lighter oil fractions caused by exposure to hot air temperatures during mixing, storage and construction resulting in a significant increase in viscosity (hardening) and changes in the associated rheological and physiochemical properties; and
2. The in-service long term ageing occurs through various mechanisms with the predominant cause being oxidation which occurs through diffusive reaction between the binder and oxygen and results in the change in composition of the binder over time.

In the production of recycled asphalt mixtures with RAP, superheated virgin aggregate is needed to provide indirect heat transfer to the RAP while maintaining the proper mix temperature. This imposes limitations on the amount of RAP that can be added to HMA in different hot mix plants as highlighted below [1].

1. In conventional hot mix asphalt batch plants, the max limit for RAP content in recycled hot mix asphalt is 50 per cent; the practical limit in Ontario is 25-30 per cent. This is limited by both the heat capacity (required to superheat the aggregate) of the plant and the emissions.
2. In drum mix plants, 60-70 per cent RAP may be processed with a practical limit of 40-50 per cent. For drum mixing plant, there is a need to shield or separate RAP from direct exposure to the burner flame.

When using RAP in recycled asphalt mixtures, the effects of ageing on its binder properties need to be considered in the mix design together with the further ageing expected during the production of recycled mix as a result of the elevated temperatures.

Recycling asphalt pavements became popular in the 1970s due to the high cost of crude oil during the oil embargo. The Federal Highway Administration FHWA provided partial funding to State transportation departments through Demonstration Project 39 to construct paving projects using recycled asphalt and to document the effective use of resources in light of increased material costs. As a result, construction practices and technologies quickly evolved to handle RAP. The National Cooperative Highway Research Program (NCHRP) published *Recycling Materials for Highways* in 1978 and *Guidelines for Recycling Pavement Materials* in 1980. In the 1990s, FHWA issued further guidance and provided information on the state of the practice regarding pavement recycling by publishing *Pavement Recycling Executive Summary and Report and Pavement Recycling Guidelines for State and Local Governments: Participant's Reference Book.*

There are economic benefits to the use of RAP for both users and producers of asphalt mixtures. In general, a mix produced with 20 per cent RAP will have a cost savings in materials of about 15 per cent.

These costs saving are typically passed over to the owner agencies based upon the financial setup of the project. Since the cost of PGAC fluctuates, the potential cost savings will increase or decrease accordingly.

The use of RAP in asphalt mixtures has a long and proven track record in Ontario and around North America producing quality pavements while at the same time promoting sustainability and creating

environmental benefits. In Ontario, the current Provincial and Municipal specifications governing mix designs allow the use of RAP in asphalt mixtures. The use of OPSS specifications is encouraged.

The Ontario Ministry of Transportation (MTO) and Municipal clients depend upon OPSS 1150, OPSS 1151-PROV and OPSS 1151-MUNI, which allow the use of RAP in base course and most surface course mixes.

Recycled Binder Ratio (RBR)

Many owner agencies in the United States are changing their recycling requirements from an Allowable Percentage of RAP to Recycle Binder Ratio (RBR) to better reflect the actual percent of binder contribution from the RAP to the total binder in the mix. This becomes even more critical when RAP is fractionated into Fine RAP and Coarse RAP and Fine RAP is incorporated into the mix. From a mix design and production perspective, the availability of contributing asphalt binder from Coarse and Fine RAP can differ by 1 per cent or more in the final total binder content of the mix, which in turn will affect the effective asphalt binder content in the asphalt matrix.

Based on current practice in Ontario, there is a concern in the industry that the amount of recycled materials allowed in the mix may be high and this may result in poor performance. This is especially important because higher RAP contents may make the mix more brittle and inhibit the ability of the mix to accommodate to changing environmental conditions if not properly designed.

The mathematical formulation for the determination of RBR is defined by National Center for Asphalt Technology (NCAT) as follows [7]:

$$RAP_{BR} = \frac{Pb_{RAP} \; x \; P_{RAP}}{100 \; x \; Pb_{Total}} \qquad (1)$$

Where:

RAP_{BR} = RAP Binder Ratio;
Pb_{RAP} = Binder Content of the RAP;
P_{RAP} = Percentage of RAP; and
Pb_{Total} = Total Binder Content of the Mix (RAP Binder plus Virgin Binder).

This limits the allowable amount of RAP in a mix. Typically, once the properties of the RAP are determined and the desired total asphalt binder content is chosen, the amount of a particular RAP that can be used is determined.

Based on the recommendations of the Federal Highway Authority (FHWA) Mix Expert Task Group (ETG), when RBR values exceed 0.25 the grade needs to be changed and blending charts should be used. The ETG is recommending the use of RBR by owners and producers as a guideline for the limiting conditions for hot mix asphalt designs. MTO historically uses 20 per cent RAP for surface course mixes which is equivalent to a RAP_{BR} of 0.20 when one considers when the research was done (it was assumed that the RAP was not fractionated and the asphalt cement content of the RAP was similar to

new mixes at about 5 per cent). Given the historical development of RAP guidelines in Ontario, 0.2 may be the appropriate value. Based on this value, the following examples are provided to explain the concept and to determine maximum RAP content from a mix design perspective.

Example 1 – Fine RAP

Let's say the specification allows a maximum RAP binder ratio of 0.20, the RAP has an asphalt content of 6.6 per cent, and we would like to design a mix with 5.0 per cent total asphalt cement. Rearranging equation 1, we can calculate the maximum amount of this particular fine RAP that will yield a RAP_{BR} of 0.20.

$$P_{RAP} = \frac{Pb_{Total}\ x\ RAP_{BRRAP}\ x\ 100}{Pb_{RAP}} = \frac{5.0\ x\ 0.20\ x\ 100}{6.6} = 15.2\% \qquad (2)$$

Example 2 – Unfractionated RAP

For an example using unfractionated RAP, let's say the specification allows a maximum RAP binder ratio of 0.20, the RAP has an asphalt content of 4.6 per cent, and we would like to design a mix with 5.0 per cent total asphalt cement. Rearranging equation 1, we can calculate the maximum amount of this particular unfractionated RAP to get a RAP_{BR} of 0.20.

$$P_{RAP} = \frac{Pb_{Total}\ x\ RAP_{BRRAP} x\ 100}{Pb_{RAP}} = \frac{5.0\ x\ 0.20\ x\ 100}{4.6} = 21.7\% \qquad (1)$$

In the above mentioned examples, if the trial mix designs have air voids below 4.0 per cent (or the mix design target air void content), then another aggregate blend or a lower RAP content will have to be tried but the RAP_{BR} at the design asphalt cement content remains fixed at 0.20

Available Asphalt Content

There is ongoing research concerning the contribution of RAP to the available asphalt cement in the mix. This is the so called the "black rock" debate. Current research carried out by Imperial Oil [8] suggests that full blending may not occur before final compaction but diffusion will result in full blending within 12 to 24 months.

Currently, the Ontario mix design procedure allows for a 100 per cent contribution to the mix. AASHTO M323-13 *Standard Specification for Superpave Volumetric Mix Design* recommends 100 per cent as the availability and in the latest FHWA Mix ETG communications for the update to AASHTO M323 continue with this recommendation. However, the 100 per cent availability is not necessarily applicable to all types of RAP.

RAP Management and Best Practices

The use of quality control and best management practices are strongly encouraged. A disciplined approach to RAP management which is based on management of RAP processing, uniformity, and

quality will maximize the return on investment in materials, equipment and result in a compliant and well performing asphalt mixture [9].

Good management of RAP begins with collecting or accepting the materials in ways that ensure the materials are not contaminated. Most RAP material is obtained through roadway milling operations.

Premium millings from a single project are typically very consistent in properties such as asphalt content, gradation, specific gravity, and binder characteristics. When a significant quantity of premium RAP is obtained from a single project, best practice is to stockpile this material separately to minimize further variability.

RAP from multiple sources can be made into a very consistent material with good stockpiling and processing techniques. An inventory analysis is very helpful to make the best decisions on when and how to process. Good stockpiling practices include building in layers to help average out variations and avoiding pushing material over the edge of the stockpile to minimize segregation.

The goal of processing RAP is to make a uniform material that meets the needs of mix designs that will use RAP as a component. Setting the crusher top size is a balance between the need to utilize the material in a range of mix types versus the generation of additional fines. Fractionating RAP can give more control or options for use in mixes but should be a contractor's choice, not a specification requirement.

Sampling, testing, and analysis of the RAP are vital to good management of this valuable material. The testing data is not only necessary for use in mix designs, it is also essential for assessing uniformity of the RAP. Sampling at 1000 tonne intervals during processing from raw RAP into a working stockpile is recommended. As with all materials, consistent RAP is important to producing consistent mixes, especially as RAP contents increase.

Commitment from Asphalt Producers

A total commitment from asphalt produces to adhere to the governing industry guidelines is necessary for any of the above mentioned processes and steps to be successful. This commitment can come in the form of owner certifications similar to a self-regulation scenario, to ensure compliance and due diligence during production of the mix. It has been recommended in the past that until a self-regulation/certification program is formalized in the industry, active review and inspection of the processed RAP stockpile by owner agencies should be considered. The objective of this step is eventual self-regulation to ensure compliance (i.e. what is being stated is being produced).

Total commitment from the asphalt producers is required to ensure maximum allowable percentages of RAP are not exceeded during production of the mix and that mix designs are being adhered to. Proactive measures by owners and industry in monitoring and enforcing the addition of RAP are a necessity. It is highly recommended by the Task Force that owner agencies should consider additional plant inspections during production to ensure both the quality of the RAP stockpiles and that submitted mix designs and actual production correlate (i.e. allowing full time inspection access to the asphalt

plant control room). These types of contract requirements are simple and cost effective and various municipalities in Ontario have started to use such measures to control the quantity of RAP and the quality of the asphalt mixtures on their projects.

Industry is more than willing to work with road owner agencies with an 'open door' policy to further develop appropriate controls that ensure that the proper amount and quality of RAP is being utilized by the producer at all times.

References

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5. How Should We Express RAP and RAS Contents, National Centre of Asphalt Technology (NCAT) - Asphalt Technology News, Fall 2014.

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The Quality of Asphalt Pavement Task Force

In response to the concerns about the quality of asphalt pavement in Ontario, OHMPA formed the Quality of Asphalt Pavement Task Force. The purpose of this group comprised of industry experts, consultants and academics and representatives' municipalities and MTO is to assess these concerns and propose workable solutions that are scientifically sound and also practical. In response to this challenge, the task force has road owners' concerns in mind and has drawn on the expert options of the members of the group.

These and other findings and recommendations of the Quality of Asphalt Pavement Task Force will be published on OHMPA's website (www.ohmpa.org). For more information, please contact the OHMPA office at 905-507-3707 or by email at info@ohmpa.org.

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