Green Asphalt Pavement Technologies Are Sustainable Only if They Deliver Acceptable Performance

Ludomir Uzarowski, Ph.D., P.Eng., Golder Associates Ltd., Ontario
Michael Maher, Ph.D., P.Eng., Golder Associates Ltd., Ontario

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ABSTRACT

Green pavement technologies include innovative pavement materials as well as pavement rehabilitation methodologies. Some of materials such as the use of RAP and RAS and crumb rubber in HMA are included in this paper. On the pavement rehabilitation side green technologies have included pavement recycling such as hot in-place recycling, cold in-place recycling, full depth reclamation, stabilization of soils, concrete pavement rubblization, and concrete pavement restoration.

The purpose of this paper is to bring attention to the importance of the technical quality of green asphalt technologies. Although there are a large number of cases where they are used correctly, there is also a growing number of applications that have sometimes serious negative impact on pavement performance. It is critical that when green technologies are applied it is certain that they do not compromise the pavement performance and that proper quality procedures for material production, pavement and mix design and construction are known and followed. This paper describes some recycling failures and examples of poorly performing new pavements. Green asphalt pavement technologies are sustainable only if they deliver acceptable performance.

1.0 INTRODUCTION

Green pavement technologies have a long history. Some of them have been used in Ontario for more than 30 years while others may be very new to the pavement industry. They include innovative pavement materials as well as pavement rehabilitation methodologies. On the materials side these technologies have included the use of Reclaimed Asphalt Pavements (RAP) and asphalt shingles (RAS) in hot mix asphalt (HMA) and granular materials, crumb rubber in HMA, various additives to asphalt cements, recycled concrete as aggregates, steel slag, crushed glass and ceramic as HMA aggregates, and warm mix asphalt. On the pavement rehabilitation side green technologies have included pavement recycling such as hot in-place recycling (HIR), cold in-place recycling (CIR), full depth reclamation with foamed asphalt stabilization, cold in-place recycling with expanded asphalt material (CIREAM), full depth reclamation with asphalt overlay, stabilization of soils with lime and Portland cement, concrete pavement rubblization, and concrete pavement restoration (CPR). This list of green technologies can be further expanded.

The authors of this paper have been involved in the above listed aspects of green technologies for almost 30 years and have written numerous papers on the subject. It is generally agreed that the main purpose for the use of green technologies is to make pavements more sustainable in terms of: economics (improving cost effectiveness); environment (reducing use of scarce resources and green house gas emissions); and social (bringing social benefits to the public). There are pavement rating systems that give credits for alternatives that use green technologies.

The purpose of this paper is to bring attention to the importance of the technical quality of green asphalt technologies. Although there are a large number of cases where they are used correctly, there is also a growing number of applications that have sometimes drastic negative impact on pavement performance. Poorly designed asphalt mixes with excessive or unknown RAP sources or RAS addition ravel and crack early. Some asphalt cement additives cause mixes to become brittle and crack, particularly in winter. Poorly stabilized pulverized pavements significantly underperform. It is critical that when green asphalt technologies are applied that they do not compromise the pavement performance and that proper quality procedures for material production, pavement and mix design and construction are known and followed. In many recycling technologies there is a maximum recycling ratio and this must be identified and adhered to. This paper describes some recycling failures and examples of poorly performing new pavements and focus on what are the criteria for selected technologies that must be followed to achieve success. The examples of good and poor performance of green asphalt pavement technologies presented in this paper are mainly in Ontario, although references from other provinces are also included. Green asphalt pavement technologies are sustainable only if they deliver acceptable performance.

2.0 PAVEMENT SUSTAINABILITY

The effectively designed sustainable pavements should aim at:

- Minimize the use of natural resources;
- Reduce energy and fuel consumption during construction and operation;
- Minimize greenhouse gas emission;
- Limit pollution;
- Improve health, safety and risk prevention;
- Ensure high level of user comfort and safety, and
- Provide long term value for money.

Sustainability comparison of pavement alternatives is typically considered from three main aspects: economical; environmental, and social. Figure 1 show a typical comparison of two pavement design alternatives.

This typical approach to pavement sustainability misses one major aspect, technical quality. In environmental and cost benefits analysis the focus is often on the reduction of initial capital cost and initial gas emission and use of resources. Long term costs and environmental impacts including maintenance and the necessity of repairs are frequently ignored. This may lead to the selection or approval of ‘green’ asphalt technologies that are focused only on short term benefits and may compromise pavement performance.

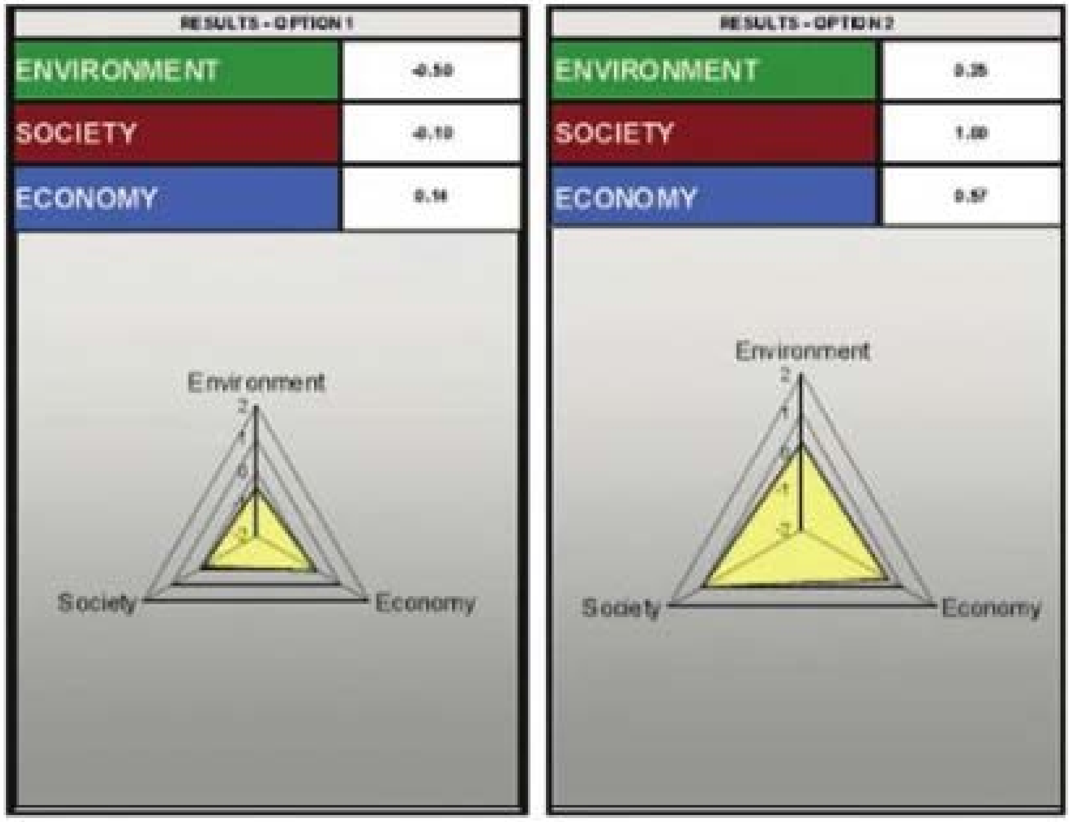


Figure 1 Sustainability comparison of pavement alternative strategies.

This paper provides selected examples of asphalt pavement green technologies that provide benefits in all four aspects, i.e. environmental, social, and economical and provide good technical quality. It will also show examples of solutions that may be of concern from the technical quality point of view. This paper is focused on municipal experience.

3.0 PAVEMENT RECYCLING

The best example of successful asphalt pavement sustainable, green technology is pavement recycling. It has been used by municipalities in Ontario on urban and rural roads for almost 30 years and has been described in numerous technical papers [1-6]. The pavement recycling technologies used by the municipalities in Ontario are as follows:

a. Cold in Place Recycling (CIR) – the pavement is typically milled to a depth of 75 to 100 mm and asphalt emulsion is applied to coat the millings; after spreading and compaction and after minimum two weeks of curing the CIR layer is typically covered with HMA overlay;
b. Full Depth Reclamation with Expanded (foamed) Asphalt Stabilization – the asphalt layers are pulverized, the materials is typically mixed 50/50 with the underlying granular material and stabilized with expanded (foamed) asphalt, spread and compacted. After about two days the foamed asphalt layer is typically covered with HMA overlay;
c. Full Depth Reclamation with Hot-Mix Asphalt Overlay – the existing asphalt is pulverized, the material is mixed with underlying granular material, compacted and covered with HMA overlay; and

d. Cold In-Place Reclamation with Expanded Asphalt Material (CIREAM) – the existing asphalt is partially milled, stabilized with expanded (foamed) asphalt, spread and compacted. After two days the CIREAM layer is typically covered with HMA overlay.

The following aspects are typically considered when the pavement rehabilitation alternative is selected:

a. Pavement type and structure;
b. Pavement condition including the type, extent and severity of distresses;
c. Geotechnical conditions (soil type, water conditions, frost susceptibility);
d. Available budget;
e. Roadway classification;
f. Traffic volume and composition;
g. Geometric constrains (curbs and gutters, elevation restrictions, and others);
h. Drainage conditions;
i. Local experience with proposed technology;
j. Availability of experienced contractors; and
k. Sustainability aspects (economical, environmental and social).

The overall performance of CIR treated pavements is considered to be good to very good. By the early to mid 2000's some municipalities started to migrate from CIR to FDR using foamed asphalt which is currently the most commonly used pavement rehabilitation technique. One of the main reasons for this switch in pavement recycling technique was the long curing period required for the CIR treatment. The required period of two weeks of good weather significantly shortened the construction season. It was observed that if due to adverse weather condition the CIR was not properly cured a significant amount of layer repair was required.

The sustainability benefits of using green technologies in Ontario have been tremendous; in particular financial (reduced cost of construction), environmental (significantly lower green house gas emissions, reusing of limited resources, mainly aggregates and reduced materials hauling) and social (mainly public acceptance). In addition the municipalities that are open to innovations have drawn a number of contractors to the area which has significantly increased the competition resulting in reduced costs and improved quality.

Photographs 1 to 5 show the current condition of a few selected municipal (regional) road (RR) sections where pavement recycling was carried out. Generally, the condition of recycled pavements is considered to be good to very good.

Photograph 1 Low severity joint and transverse cracking on 18 years old cold in-place recycled pavement. The overall condition is good.

Photograph 2 Good current condition of 10 years old cold in-place recycled pavement.

Photograph 3 Centerline, edge and localized alligator cracking in 19 years old cold in-place recycled pavement.

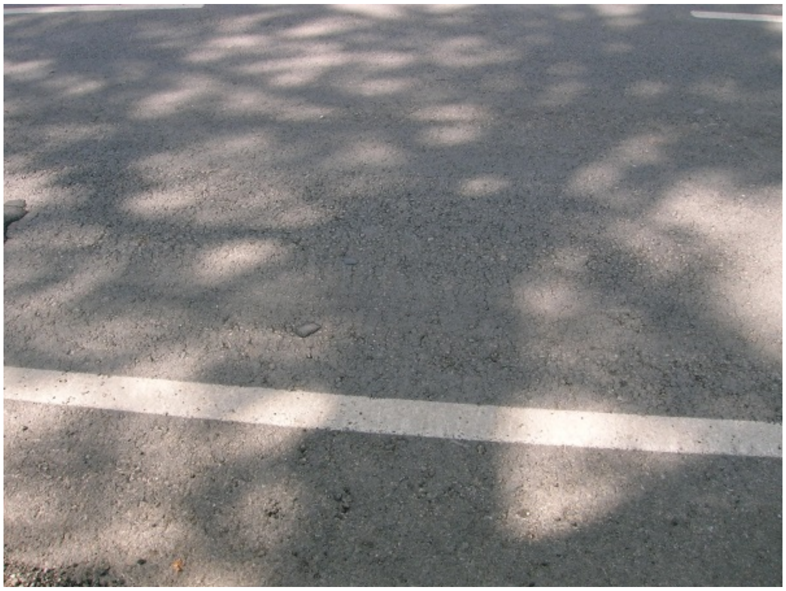
Photograph 4 Excellent current condition of 5 years old re-recycled with foamed asphalt stabilization pavement.

Photograph 5 Excellent current condition of 4 years old foamed asphalt stabilized pavement.

4.0 RECYCLING MATERIALS IN ASPHALT TECHNOLOGY

RAP has been used in asphalt mixes in Canada for a long time. Typically up to 15 or even 20 percent RAP may be allowed in the surface course mixes and up to 40 percent in the binder course mixes [7-9]. Some agencies allow up to 50 percent RAP in binder course mixes. While the addition of small percentage of RAP, up to 15 or maximum 20 percent, may not require changing of the asphalt cement grade in the mix design if more RAP is added the asphalt cement in the mix design should be changed [7]. If between 20 and 40 percent is added a one PG softer grade should be used. However, if more than 40 percent of RAP is added the asphalt cement should be two grades softer or special grades should be used. However, in practice these rules are almost never followed and asphalt paving specifications do not clarify how the mix design should be changed for high content RAP.

Numerous papers have been written on the impact on RAP on the mix behaviour and pavement performance. Its sustainable benefits are obvious. Not surprisingly some of rating systems prepared by road agencies offer credits for the addition of RAP. However, if excessive amount of RAP is added to asphalt mixes it will likely significantly harden the asphalt cement in the mix. Also, not all asphalt cement in the RAP may blend with the virgin asphalt cement and part of the RAP may act as ‘black rock’. This will reduce the effective asphalt cement content and cause the mix to be brittle and prone to cracking. Photographs 6 to 8 show the new binder course that incorporated very high RAP content (about 40 percent instead of designed 15 percent) and exhibited raveling and cracking very shortly after paving.



Photograph 6 Microcracking and raveling of new binder course mix that incorporated very high content of RAP.

Photograph 7 Raveling of new binder course mix that incorporated very high content of RAP.

Photograph 8 Raveling and cracking of new binder course that incorporated very high content of RAP.

The use of Recycled Asphalt Shingles (RAS) or Manufactured Shingle Modifiers (MSM) is getting more popular in Canada. There have been numerous technical papers written on the RAS application in Hot Mix Asphalt (HMA) mixes and its sustainable benefits [10-17]. However, the safe percentage of RAS that can be added is still not clear. It is also not clear how the asphalt cement grade should be modified if RAS is added. The addition of up to 7.0 percent of RAS is considered by some agencies. Emery [15] considered the addition of up to 3.0 percent of MSM to asphalt mix without asphalt cement modification is safe and does not have negative impact on pavement performance. The authors of this paper carried out a research that showed that if 5.0 percent of RAS or more is added the mix becomes stiff and has lower resistance to low temperature cracking unless the asphalt cement is softened [12]. Photographs 9 and 10 show a new binder course that incorporated 5.0 percent RAS and 15 percent RAP in the mix. The binder course developed extensive cracking shortly after paving and required extensive and costly repairs.

Photograph 9 Cracking of new binder course that contained high percentage of RAS.

Photograph 10 Repairs of new binder course that incorporated high percentage of RAS.

5.0 PAVEMENT DESIGNS

In the pavement design aspects the authors would like to express their concern with the current common trend of reducing the thickness of the pavement structures, particularly granular layers, without proper consideration of the impact it may have on performance, mainly on frost heaving and drainage capacities. Although there are also other methods of frost heaving protection, such as insulation and subsurface drainage, sufficient thickness of granular layers is considered to be the most effective. The two last cold winters (2013/2014 and 2014/2015) in Ontario had detrimental impact on pavements and severe frost heaving and associated cracking was observed on number of roads and streets. Photographs 11 and 12 show the effect of pavement frost heaving on a street and rural road, respectively. The damaged pavements require costly repairs and have negative impact of riding comfort.

Some pavement designers believe that reducing the thickness of granular layers in the pavement structures is sustainable by reducing the amount of depleting aggregates. Some designers also believe that by using pavement reinforcement systems such as geogrids or by stabilizing the soils the thickness of granular layers can be significantly reduced. However, in the Canadian cold and wet climate, the main functions of the granular layers is providing good subsurface drainage and frost protection. Unjustified reduction in the thickness of the granular layers may result in pavement heaving in winter and deformation and cracking during the spring thaw period. Poor performance will increase life cycle cost of the pavement and will have a negative impact on pavement sustainability.

Photograph 11 Frost heaving deformation at an intersection in a vicinity of a manhole.

Photograph 12 Severe cracking on a rural pavement due to frost heaving.

6.0 ASPHALT CEMENT MODIFICATION

The pavement industry has migrated significantly from conventional asphalt cements, including performance graded, that were used 10 to 20 years ago. The asphalt cements now are typically modified with different additives. Some of those modifiers are known to improve asphalt cement characteristics. The additives that enjoy the most trust with the road agencies are polymers. They have been commonly used in asphalt cements in Ontario for more than 20 years.

However, there are methods of asphalt cement modification that raise concern with the owners. Severe, premature pavement cracking was observed mainly is Southern and Central Ontario after the last two winters. Number of owners blame the premature, catastrophic pavement failures on the way the asphalt cements are modified. Most of the observed failures were with PG 64-28 asphalt cements. The base grade of asphalt cement in this part of Ontario is 58-28. For heavy and slow traffic the asphalt cement grade is typically bumped to 64-28 in order to prevent rutting. It is a common opinion that the best way of modifying the asphalt cement to bump it to 64-28 is by polymer modification. However, it is known that some suppliers modify it by oxidizing it and then adding recycled engine oil to meet the low temperature requirement. Although there are number of published technical paper that state that the responsible addition of recycled engine oil does no harm to asphalt cement and may not have negative impact on pavement performance [18-22], there are also opinions that the addition of recycled engine oil causes physical hardening of asphalt cement which causes the asphalt mixes to become brittle and crack, particularly in winter [23-24]. While the discussion is still going on, the fact is that the catastrophic failures are common and of serious concerns to the owners and the industry.

Photographs 13 to 15 show examples of asphalt pavement premature cracking. The laboratory testing indicated that recycled engine oil was likely used to modify the asphalt cement. These pavements were only 6 months to 2 years old and exhibited microcracking, longitudinal and irregular cracking of low to medium severity. The causes of the failures are still under investigation. Also asphalt cement specifications are still discussed as well as the method of asphalt cement testing.

Photograph 13 Premature asphalt cracking on 2 years old pavement.

Photograph 14 Premature asphalt cracking on 2 years old pavement.

Photograph 15 Premature asphalt cracking on 6 months old pavement.

Whatever the causes of the failures are and the final content of the specification is, it is the authors opinion that before any methods of asphalt cement modification are used, they should be investigated, trial sections should be constructed and monitored and it should be well proven that they do not compromise pavement performance. The testing and acceptance criteria should be clearly stated in the specifications.

7.0 SPECIFICATIONS AND ACCEPTANCE CRITERIA

The intention of this paper is not to present the numerical values for the acceptance criteria for the presented green technologies but to emphasize the importance of having good clear specifications and acceptance criteria for pavement performance. The technologies should only be implemented if they are well proven, the mix design testing methodologies are clear and accepted and the numerical values for the criteria are accepted. This should be covered in the paving specifications that should then be enforced during construction. Without clear specifications and acceptance criteria based on field and laboratory trials further pavement failures should be anticipated.

8.0 CONCLUSIONS

This paper showed some green asphalt pavement recycling technologies that can be considered to be sustainable. These technologies are well proven, covered in specifications and have well establish acceptance criteria.

The paper also expresses concerns about the so called ‘green’ technologies that can compromise pavement performance. The examples of these technologies include excessive or uncontrolled addition of RAP in HMA, excessive addition of RAS to HMA, unjustified reduction the thickness of pavement structure, particularly granular layers, and uncontrolled methods of asphalt cement modifications. By contrast, these technologies do not have clear specifications or the specifications are not enforced and do not have clear acceptance criteria. It should be recognized that green asphalt technologies are sustainable only if they deliver acceptable performance.

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