Pavement Preservation – A Solution for Sustainability

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ABSTRACT

The Ministry of Transportation Ontario (MTO) is dedicated to maintaining quality roadways in a sustainable manner. MTO has implemented pavement preservation strategies in recent years to maximize cost savings in repair operations and maintain pavement condition. Pavement preservation treatments are considered sustainable as they improve pavement quality and durability, and extend pavement service life, while reducing energy consumption and green house gas (GHG) emissions.

Pavement preservation is a proactive, planned strategy that extends the life of the pavement, providing a cost effective solution for pavement management. This paper outlines the various pavement preservation treatments utilized by MTO to achieve sustainability. These preservation treatments include: crack sealing, slurry seal, micro-surfacing, chip seal, ultra-thin bonded friction course, fiber modified chip seal, hot mix patching and hot in-place recycling (HIR).

Pavement sustainability is quantified by comparing the energy consumption and GHG emissions generated using the PaLate software for various pavement preservation strategies, against typical rehabilitation and reconstruction treatments. This paper presents the benefits of pavement preservation by considering the service life of each treatment and calculating the associated energy consumption and GHG emissions per service year. The results indicate that pavement preservation strategies provide a significant reduction in energy use and GHG emissions when compared to traditional rehabilitation and reconstruction treatments.

Although pavement preservation is proven to be a cost effective solution, there are numerous challenges and barriers to overcome. Some of the challenges and solutions are presented in the paper as well as the strategies to promote pavement preservation for sustainability.

1. INTRODUCTION

The Ministry believes that the protection of air, water, and land resources is necessary to sustain current and future generations. A sustainable pavement can be defined as a safe, efficient, economic, environmentally friendly pavement meeting the needs of present-day users without compromising those of future generations. The main criteria established for a sustainable pavement are reducing the use of natural resources, energy consumption and GHG emissions; and at the same time improving the safety and comfort to the travelling public [1].

Pavement preservation is a planned strategy that extends the life of the pavement while it is still in good condition, and maintains the pavement at a high level of service with reduced overall energy and GHG emissions throughout the pavement life cycle. This satisfies the criteria for sustainability, and pavement preservation is one of the key solutions to pavement sustainability.

2. PAVEMENT PRESERVATION TREATMENTS

A pavement preservation treatment is a proactive, planned strategy applied in a timely manner to extend the life of the pavement without adding structural strength to the pavement. The timeframe to apply pavement preservation is early in the pavement's life and once the pavement was deteriorated to a certain condition, a rehabilitation treatment is required instead of applying the more sustainable pavement preservation treatment. The key to a successful pavement preservation program is to apply the right treatment to the right road at the right time. Figure 1 below shows graphically how pavement preservation can prolong the life of the pavement, maintain a high level of service and delay the application of a costly rehabilitation strategy.

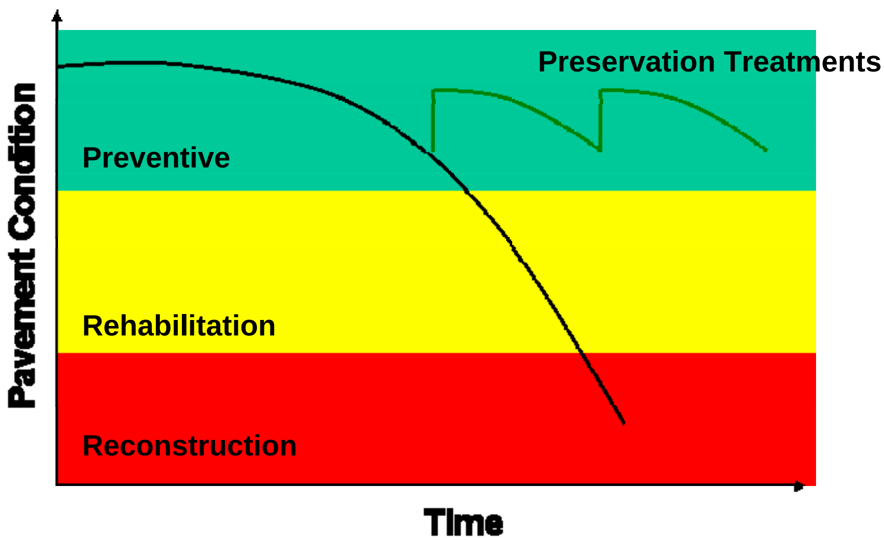

Figure 1. Effect of Pavement Preservation on Pavement Condition over Time

There are a number of different preservation treatments utilized by the Ministry to achieve sustainability. The following is a summary of the various pavement preservation treatments:

2.1 Crack Sealing

Crack sealing treatments are used to prevent water and debris from entering cracks in hot mix asphalt (HMA) pavement. Limiting water infiltration protects the underlying pavement layers and reduces the detrimental effects of freeze thaw cycles. Typically, crack sealing has an expected pavement extension life of 3 years and it is a cost effective treatment to prolong the pavement life.

2.2 Slurry Seal

Slurry Seal is a thin cold slurry treatment applied to the entire HMA surface. Typically it is used to seal the pavement surface, fill minor surface irregularities, address raveling and oxidation, and to improve friction. It consists of a mixture of well-graded aggregate and slow setting emulsion and has an expected pavement extension life of 3-5 years.

2.3 Micro-surfacing

Micro-surfacing is a premium, polymer-modified cold slurry paving system applied to the entire HMA surface. Typically it is used to address raveling and oxidation, fill ruts and minor surface irregularities, and to improve friction and ride. It consists of a mixture of dense-graded aggregate, asphalt emulsion, water and mineral fillers that is typically placed 10-12 mm thick, with an expected pavement life extension of 7-9 years. Micro-surfacing is a good example of preventive maintenance and the Ministry considers this treatment to be one of the most cost effective preservation treatment.

2.4 Chip Seal

Chip seal is a mechanized spray patching application of asphalt and single-sized aggregate chips rolled onto the pavement. Typically it is used to seal the pavement surface, enrich hardened or oxidized asphalt, and to improve surface friction. It can be applied on a small patch area (Dynapatch) or the entire HMA surface, with an expected pavement extension life of 4-6 years.

2.5 Ultra-thin Bonded Friction Course

Ultra-thin bonded friction course, also known as Nova Chip, is a thin HMA treatment that is applied to the entire pavement surface. Typically it is used to address surface distress, seal the surface and increase surface friction. It consists of gap-graded polymer-modified HMA placed about 10 to 20 mm thick on a heavy, polymer-modified emulsified asphalt tack coat. This treatment has a relatively high initial cost and has shown limited use by the ministry.

2.6 Fiber Modified Chip Seal

Fiber modified chip seal, also known as FiberMat, is a mechanized spray patch thin treatment that is applied over the entire HMA surface. It is a similar process to regular chip seal with the addition of fiber to help prevent reflective cracking. It consists of a single chip seal application incorporating chopped fibreglass strands in the polymer-modified emulsion and a covering aggregate layer. Typically it is used to seal the surface to prevent water ingress and control reflective cracking of the new overlay. This is a relatively new treatment utilized by the Ministry, and the results and performance are being monitored.

2.7 Hot In-place Recycling

Hot in-place recycling (HIR) is used by the Ministry for pavements that are generally free of major structural distress. Iit is used to address service distress, and improve surface friction and ride. For the HIR process, the existing surface is heated and scarified in-place to a depth of 40-50 mm, rejuvenated and reprofiled to a new grade. This operation is carried out with an HIR train in a continuous operation. HIR is considered a sustainable preservation treatment since it recycles the existing HMA surface in-place, which minimizes material hauling to and from site. This preservation treatment has an expected pavement life extension of 10-12 years, similar to a typical one lift HMA overlay.

2.8 Warm Mix Asphalt

Warm Asphalt Mix (WMA) is an environmentally friendly alternative to HMA. WMA is produced at temperatures about 50 C lower than conventional HMA. Using less energy at lower temperatures during production results in up to a 50% drop in emissions. WMA claims to have the following benefits: a greater ability to be transported over long hauls, a quick opening to traffic, ability to be placed in thinner lifts; and potential to improve the performance of transverse and longitudinal joints. Other benefits of using WMA include reduced exposure to fumes for workers during placement and compaction of the WMA.

2.9 Quantities of Pavement Preservation Treatments

Over the years, MTO has carried out many pavement preservation treatments to extend the pavement life. Table 1 below is the summary showing the quantities of the pavement preservation treatments that were carried out in the past 10 years (from 1999 to 2009).

Table 1. Summary of Ten Years Preservation Treatment Quantities

Treatments	**Quantities (m^2)**
Slurry Seal	586,834
Micro-surfacing	5,253,256
Chip Seal	1,037,592
Fiber Modified Chip Seal	126,667
Ultra-thin Bonded Friction Course	425,400
Hot In-place Recycling	324,124
Total	**7,754,000**

3. CASE STUDY – SUSTAINABILITY OF PRESERVATION TREATMENTS VERSUS MILL AND OVERLAY

This case study compares the environmental benefits in terms of energy and GHG emission reductions for selected pavement preservation techniques versus traditional mill and overlay techniques.

Recently, MTO has been using the PaLATE software to calculate GHG emissions produced by various road construction activities to assists decision-makers in evaluating the use of recycled materials in highway construction. PaLATE, which stands for Pavement Life-cycle Assessment for Environmental and Economic Effect, was developed at the University of California at Berkley

[2]. Material quantities and haul distances are entered for specific treatments and the model calculates the emissions and energy consumption according to production, transportation and processing.

3.1 Quantifying Environmental Effects using PaLATE

The following are the pavement preservation treatments selected in this case study for comparison with traditional mill 50 mm and overlay 50 mm HMA:

- Mill 50 mm and overlay 50 mm with Warm Mix Asphalt (WMA)
- 50 mm Hot In-place Recycling (HIR)
- 10 mm Micro-surfacing

Based on a typical 7 metre wide 2-lane km highway pavement section, Table 2 below illustrates the energy consumption and GHG emissions of the selected treatments generated by PaLATE and further verified with other references. [3]

Table 2. Energy Consumption and GHG Emissions of various Preservation Treatments

Treatments	**Energy (MJ)**	**CO_2 (tonne)**	**NO_x (kg)**	**SO_x (kg)**
Mill 50mm, Pave 50 mm	674,925	35	307	9,581
Mill 50 mm, Pave 50 mm WMA	477,822	20	161	6,708
50 mm HIR	566,937	27	239	7,473
10 mm Micro-surfacing	56,451	2	45	1,970

According to Table 2, the traditional mill and overlay treatment generated the greatest energy consumption and GHG emissions compared to the other selected preservation treatments. Since the treatments have different expected service lives, the expected service life should be factored into the energy consumption and GHG emissions to normalize the data to allow for an appropriate comparison [3]. Therefore, all the above treatments were further broken down into the energy and emissions generated per year of service (Table 3). The annualized energy and GHG emissions were calculated by dividing the information from Table 2 by the service life of each treatment.

Table 3. Annualized Energy and GHG Emissions Generated

Treatments	Service Life	Energy (MJ)	CO_2 (tonne)	NO_x (kg)	SO_x (kg)
Mill 50mm, Pave 50 mm	10 Yrs	67,493	3.5	30.7	958
Mill 50 mm, Pave 50 mm WMA	10 Yrs	47,782	2.0	16.1	671
50 mm HIR	10 Yrs	56,694	2.7	23.9	747
10 mm Micro-surfacing	7 Yrs	8,064	0.3	6.4	281

According to Table 3, micro-surfacing is the most sustainable pavement preservation techniques among the four treatments. It emits the least GHG and consumes the least amount of energy. It is important to note that the other preservation treatment options are also more sustainable when compared to the traditional mill and overlay techniques.

The following graphs (Figure 2 to 4) illustrate the various GHG emissions of the selected treatments.

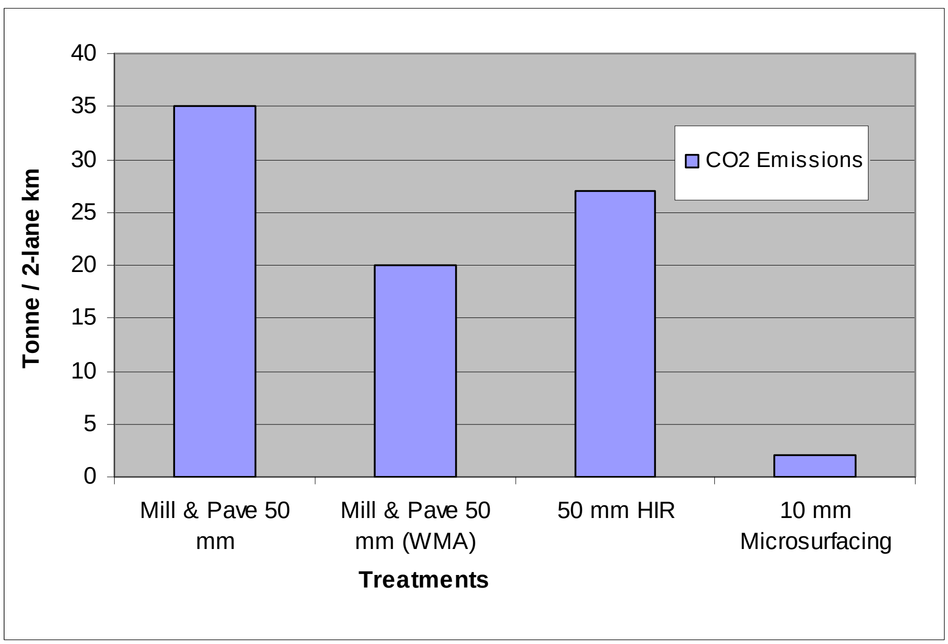

Figure 2. Carbon Dioxide Emissions for Selected Treatments

According to Figure 2, micro-surfacing emits approximately 6% of the Carbon Dioxide (CO_2) compared to traditional mill and overlay 50 mm. With the data presented in Table 1 and 2, if MTO were to perform a traditional mill and overlay instead of micro-surfacing over the past 10 years (from Table 1: 5,253,256 m^2, which is equal to 750 2-lane km), there would have been 24,765 tonnes of additional CO_2 emissions released.

For a more appropriate comparison, the data should be annualized by factoring in the expected service life. Using the information from Table 3, 10 years of CO_2 emissions for mill and overlay would be (3.5 t/year x 10 years) 35 tonnes, whereas 10 years of CO_2 emissions for micro-surfacing would be (0.3 t/year x 10 years) 3 tonnes. Therefore, substituting the microsurfacing quantities in Table 1 with mill and overlay, the 10 years of CO_2 emissions when using mill and overlay would be 24,015 tonnes more than the emissions from micro-surfacing.

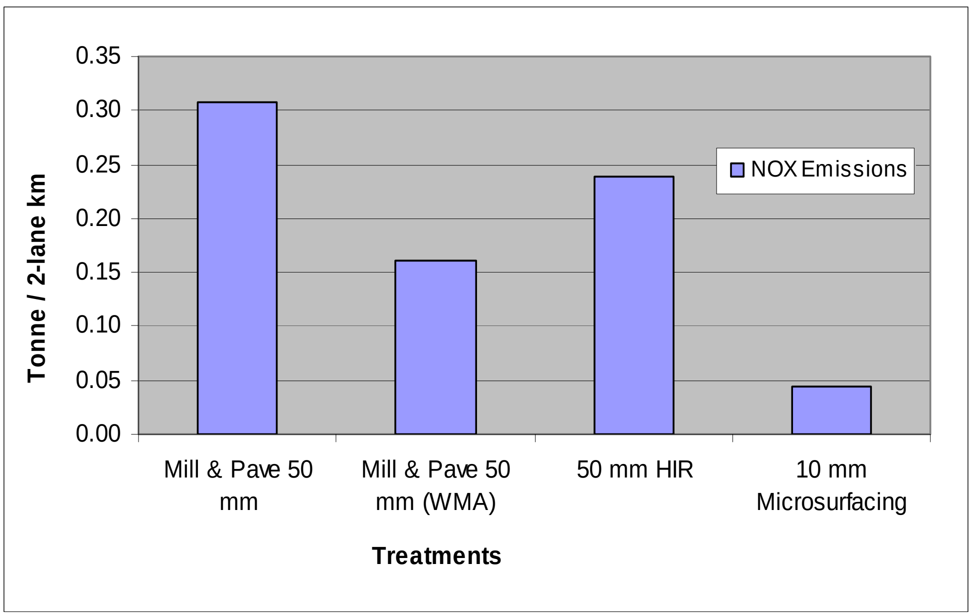

Figure 3. Nitrogen Oxide Emissions for Selected Treatments

According to Figure 3, micro-surfacing emits approximately 15% of the Nitrogen Oxides (NO_x) when compared to traditional mill and overlay 50 mm. Using the quantities from Table 1 and the GHG emissions from Table 2, if MTO were to have performed a traditional mill and overlay instead of micro-surfacing over the past 10 years, there would have been 197 tonnes additional NO_x emissions released.

These results can be annualized by factoring in the expected service life. Using the information from Table 3, 10 years of NO_x emissions for mill and overlay would be (30.7 kg/year x 10 years) 307 kg, whereas 10 years of NO_x emissions for micro-surfacing would be (6.4 kg/year x 10 years) 64 kg. Therefore, substituting the microsurfacing quantities in Table 1 with mill and overlay, the 10 years of NO_x emissions when using mill and overlay would be 182 tonnes more than the emissions from micro-surfacing.

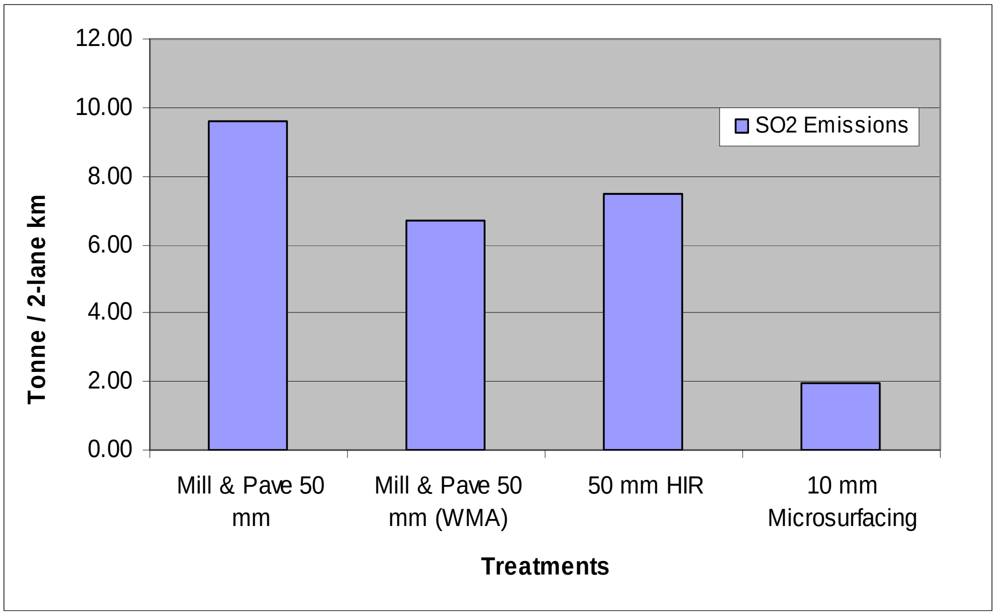

Figure 4. Sulphur Dioxide Emission on Selected Treatments

According to Figure 4, micro-surfacing emits approximately 20% of the Sulphur Dioxide (SO_x) compared to traditional mill and overlay 50 mm. Again using the quantities and GHG emissions information from Table 1 and 2, if MTO were to have performed a traditional mill and overlay instead of micro-surfacing over the past 10 years, there would have been 5,708 tonnes more SO_x emissions released.

Again, we annualized these results by factoring the expected service life into the calculation. Using the information from Table 3, 10 years of SO_x emissions for mill and overlay would be (958 kg/year x 10 years) 9580 kg, whereas 10 years of SO_x emissions for micro-surfacing would be (281 kg/year x 10 years) 2810 kg. Therefore, substituting the microsurfacing quantities in Table 1 with mill and overlay, the 10 years of SO_x emissions when using mill and overlay would be 5,080 tonnes more than the emissions from micro-surfacing.

3.2 Economic Assessment of Preservation Treatment

As part of the definition of sustainability, it is also important to look at the economic side of the preservation treatments. Table 4 below illustrates the approximate cost associated with the preferred preservation technique (micro-surfacing) versus the traditional mill and overlay technique.

Table 4. Annualized Costs Savings For Micro-surfacing vs. Mill and Overlay

Treatments	Unit Cost (m^2)	Expected Service Life	Unit Cost / Service Life /Year
Micro-surfacing	$7.00	7 years	$1.00
Mill and Overlay	$15.09	10 years	$1.51

According to Table 4, micro-surfacing has an initial 53% cost reduction compared to mill and overlay. After factoring in the expected service life of the treatment, the annualized unit cost for micro-surfacing has a 34% cost reduction compared to mill and overlay.

Over the past 10 years, MTO has constructed 5,253,256 m^2 (Table 1) of micro-surfacing. If MTO were to have performed a traditional mill and overlay instead of micro-surfacing over the past 10 years, $42,500,000 more would have been spent on initial construction.

From a life cycle costing perspective, using the information from Table 1 and the annualized unit cost from Table 4, the 10 years construction cost for mill and overlay would be (5,253,256 m^2 x $1.51/ m^2 x 10 years) $79,271,630, whereas the 10 years construction cost for micro-surfacing would be (5,253,256 m^2 x $1.00/$m^2$ x 10 years) $52,532,560. Therefore, the 10 years life cycle cost using mill and overlay would be $26,739,070 more than the cost of micro-surfacing.

<u>3.3 Aggregate Conservation Assessment on Preservation Treatment</u>

As part of the definition of sustainability, it is also important to assess the savings of natural resources in preservation treatments. Table 5 below illustrates the approximate aggregate tonnages associated with the preferred preservation technique (micro-surfacing) versus the traditional mill and overlay technique for a 2-lane-km highway.

Table 5. Annualized Aggregate Consumption For Micro-surfacing vs. Mill and Overlay

Treatments	Weight	Expected Service Life	Weight / Service Life/ Year
Micro-surfacing	140 t	7 years	20 t
Mill and Overlay	831 t	10 years	83 t

According to Table 5, the aggregate savings for using micro-surfacing versus mill and overlay is 691 tonnes per 2-lane km, which is approximately 83% aggregate savings.

Over the past 10 years, MTO has constructed 5,253,256 m^2 (Table 1) of micro-surfacing. If MTO were to have performed a traditional mill and overlay instead of micro-surfacing over the past 10 years, there would have been (691 tonnes x 750 2-lane km) 518,250 tonnes more aggregate consumed.

Life cycle aggregate consumption can be calculated using the information from Table 1 and the aggregate weight from Table 5; 10 years aggregate consumption for mill and overlay would be (83t/year x 10 years) 830 tonnes, whereas 10 years aggregate consumption for micro-surfacing would be (20 t/year x 10 years) 200 tonnes. Therefore, the 10 years aggregate consumption when using mill and overlay would be (630 tonnes x 750 2-lane km) 472,500 tonnes more when compared to micro-surfacing.

4. CHALLENGES AND STRATEGIES

Pavement preservation is a proactive pavement management strategy used to extend the life of the pavement while the pavement is still in good condition. There is a perception that the public will not support a move away from the "worst-first" strategy of fixing the poorest performing pavement first. As such, there are many barriers to promoting pavement preservation to the public and senior management when the funding is limited. Research, innovation, technology transfer, training and education are all important components to promote pavement preservation for sustainability. The following activities are some of the important initiatives to be considered for implementing more sustainable pavements:

- Build on current industry/ministry partnerships in the development of improved specifications and design/construction procedures
- Encourage continued innovation by the province's pavement preservation contractors
- Support dedicated research programs to advance the technology
- Increase technology transfer at the provincial and national levels to accelerate adoption of pavement preservation concepts

The following subsection illustrates some of the strategies used by MTO to overcome the barriers to provide a way of recognizing sustainability in pavement projects.

4.1 Quantifying Pavement Sustainability

MTO uses numerous innovative pavement preservation technologies that conserve aggregates, reduce GHG emissions, and minimize energy consumption. A key MTO sustainability strategy is to implement these technologies on a larger scale and encourage their use province wide. These technologies support a "zero waste" approach and will assist in meeting the GHG reduction commitments while addressing the triple-bottom-line: Social, Economic, and Environmental (SEE).

In order to promote pavement sustainability, it is necessary to quantify the benefits of the treatment by utilizing life cycle cost analysis (LCCA) to evaluate the most cost effective treatment and utilize methodologies such as PaLATE to evaluate the environmental impacts. Currently, MTO is exploring the opportunity to include GHG emission modelling and energy consumption requirements of pavement treatment strategies under an environmental benefits component of LCCA. This will effectively incorporate environmental benefits into the pavement preservation and rehabilitation decision making process.

4.2 MTO Green Pavement Rating System

Currently, MTO is developing an Ontario based Green Pavement Rating System to quantify and encourage pavement sustainability. There are a few existing green rating systems readily available or under development. MTO Green Pavement Rating System is primarily based on the Green Roads (Washington State) and GreenLITES (New York State) rating systems, but customized for Ontario. The LEED® certification program and Alberta's rating system were also assessed during the development. The main difference between MTO's Green Pavement

Rating System and other systems is it focuses specifically on the pavement component rather than the entire road.

Using a simple, points based rating system, MTO Green Pavement Rating System is designed to assess the “greenness” of pavement designs or constructed pavements, both flexible and rigid structures. Assigning a rating to the pavement design will enable the ministry to incorporate more sustainable technologies in pavements and encourage industry to do the same. Assigning a rating to constructed pavements eliminates design assumptions and allows for incorporation of construction components and contractor innovation that cannot be estimated at the time of design [4].

In the proposed rating system, pavements will be assessed within four categories (Table 6).

Table 6. Four Categories in MTO Green Pavement Rating System

Category	**Goal**	**Points**
Pavement Design Technologies	To optimize sustainable designs. These include long life pavements, permeable pavements, noise mitigating pavements, and pavements that minimize the heat island effect.	8
Materials & Resources	To optimize the usage/reusage of recycled materials and to minimize material transportation distances.	13
Energy & Atmosphere	To minimize energy consumption and GHG emissions.	10
Innovation & Design Process	To recognize innovation and exemplary efforts made to foster sustainable pavement designs.	4
	Maximum Total:	**35**

Each category is further broken down to address specific objectives, with corresponding points assigned to each subcategory. Each category is divided into two to four subcategories as illustrated in Figure 5 below.

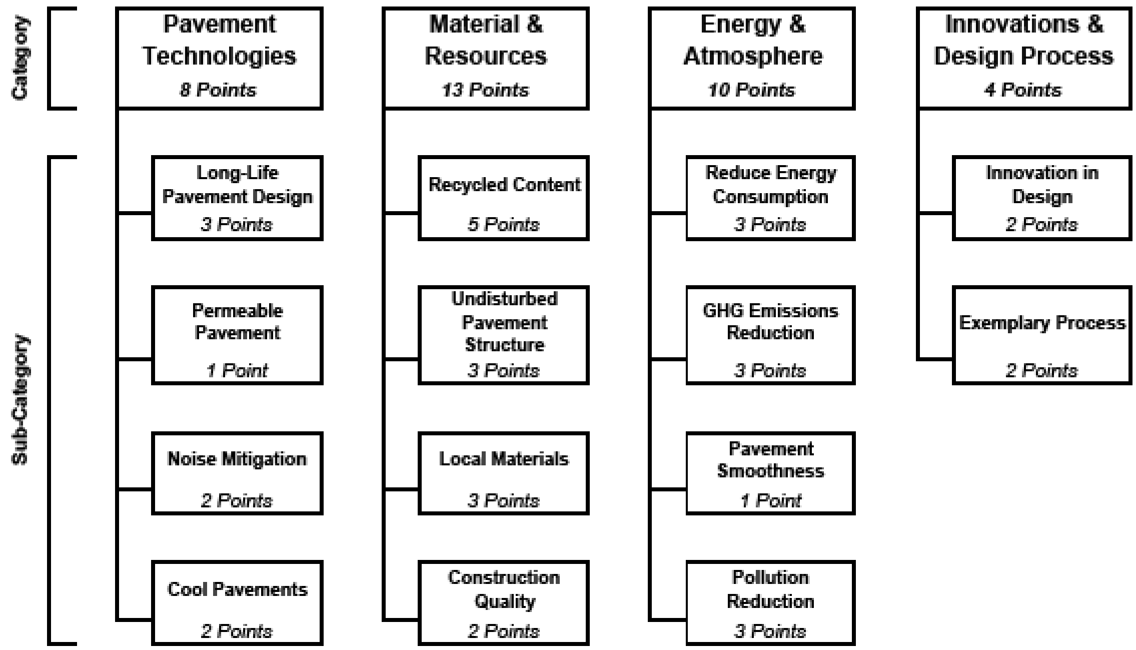

Figure 5. MTO Green Pavement Rating System Overview

Specific objectives within these subcategories must be met in order to achieve the maximum points available. Proposed rating levels for the MTO Green Pavement Rating System projects are bronze (7-10 points), silver (11-14 points), gold (15-19 points), and trillium (20+ points).

The following are some of the recommended options developed for the use of this proposed rating system at the design and construction stages [4]:

- Score pavement designs using MTO Green Pavement Rating System – no change to pavement design selection process
- Calculate a Green Discounted Life Cycle Cost (GDLCC) for projects based on the MTO Green Pavement Rating System.
- Set a target for each ministry Region to obtain a specified number of Gold Level green pavement designs per year.
- Score as-constructed pavements using MTO Green Pavement Rating System.
- Implement a Green Paver of the Year award based on the “greenest” pavement constructed in a year using the MTO Green Pavement Rating System.

Currently the proposed rating system is being fine-tuned, including internal and external consultation. Ultimately, the rating system initiative is to enhance the sustainability of Ontario’s transportation infrastructure through designing and selecting the most economical and environmental-friendly pavement treatment alternatives.

5. CONCLUSIONS

There is an increased focus on sustainable asset preservation, both at the provincial and municipal levels. Pavement preservation and rehabilitation treatments applied at the right time can significantly extend the pavement life and result in improved network performance over time.

Pavement preservation solutions satisfy the definition of sustainable pavements. It begins with the concept that the treatments are cost-effective and they are applied when the pavement is still in a relatively good condition. Pavement preservation treatments are thinner, placed faster, less disruptive, involve less contract administration, produce less GHG emissions and consume less energy. With a coordinated pavement preservation/rehabilitation program, the value of the road network will increase. Implementation of sustainable asset management principles and performance measures are critical to addressing our infrastructure investment requirements and environmental stewardship obligations over the long-term.

6. REFERENCES

[1] Alkins, A., Lane, B., and Kazmierowski, T. "*Sustainable Pavements – Environmental, Economic and Social Benefits of In-situ Pavement Recycling*". Transportation Research Board 87th Annual Conference Proceedings, Washington D.C., January 2008.

[2] Horvath, A. "*A Life-Cycle Analysis Model and Decision-Support Tool for Selecting Recycled Versus Virgin Materials for Highway Applications".* Final report for RMRC Research Project No. 23. University of California at Berkeley, 2004.

[3] Chehovits, J. and Galehouse, L. "*Energy Usage and Greenhouse Gas Emissions of Pavement Preservation Processes for Asphalt Concrete Pavements*". Transportation Research Board 89th Annual Conference Proceedings, Washington D.C., January 2010.

[4] "*GreenPave: Ontario's First Pavement Sustainability Rating System".* Road Talk – Ontario's Transportation Technology Transfer Digest, Winter 2010, Volume 16, Issue 1.