# Pavement Preservation – Effective Way of Dealing with Scarce Maintenance Budget

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**ABSTRACT**

Pavement preservation involves minimizing the destructive impact of climate and traffic by the regular or intermittent timely application of remedial treatments to the pavement. Pavement preservation system should include: pavement management system (PMS); long-term network planning; optimization; cost-effective decision making; and sustainable financing. Objective measurement of pavement performance is required to determine the appropriate treatment.

Preventive treatment of asphalt pavements used in Ontario include: crack sealing; crack filling; fog seals and rejuvenating seals; chip seals; slurry seal; cape seal; microsurfacing; non-structural HMA overlay; surface milling and non-structural overlay; cold in-place surface recycling; and hot in-place HMA recycling. Emerging technologies include Nova Chip and Metro Mat™, for instance.

This paper first discusses the traditional mindset of many road authorities and how it cannot handle the current needs of road users and the growing concerns of scarce maintenance budget. Next, the concept of pavement preservation is introduced, as well as what separates it from common preventive maintenance practices. A short review of the current preventive treatments used in Ontario is then provided. Examples of successful pavement preservation adopted by municipalities and road authorities in Ontario and in the US are also given. The paper concludes by discussing the issue of how road authorities can move forward with this correct approach.

## 1.0 INTRODUCTION

There is an urgent need to change the traditional and inefficient mindset of some of road authorities of "new is better" and "worst first" when it comes to pavement preservation. There is a general feeling that due to the current economic difficulties and budget constraints, as well as escalating costs of pavement maintenance activities, road authorities are likely to be forced to reduce the level of pavement maintenance which will bring obvious negative impact on the pavement serviceability levels. Practical experience shows that pavement preservation can provide an effective solution to this problem.

## 2.0 CONVENTIONAL APPROACH

Two observations can be easily made when we examine the ways many road authorities address deterioration and administer pavement infrastructure. First, due to a lack of preventive maintenance practices, some road authorities wait until road deficiencies become too severe and put themselves into the only position of either carrying out major rehabilitations or complete reconstruction. Second, there is a tendency that road authorities apply maintenance reactively to roads that are in the worst condition in their road networks. This traditional mindset of "New Is Better" and "Worst First" is unfortunately one of the main causes why many road infrastructures are falling apart and not meeting road users' expectations, and the massive amount of money pumped into maintaining the infrastructure is simply not getting the best return on investments.

We easily accept the practice of preventive treatments to preserve the value of our private assets such as homes and automobiles, but when it comes to public infrastructure such as roads and pavements the concept of preservation is still not widely practiced. After years of use without proper preventive treatments, roads and pavements are often left in such bad conditions that they cannot be maintained. Rebuilding them or carrying out major rehabilitations is the only viable option available but they are also very costly in terms of scarce capital and user inconvenience. Facing the growing concerns of limited funding and other budget constraints, road agencies have the tendency to fix the most seriously deteriorated portions of the road network first. However, this reactive approach also puts road authorities into a vicious cycle of cost-ineffective emergency repairs and ever-growing maintenance backlogs.

Clearly, there needs to be a change in the ways road authorities address pavement deterioration and administer their road infrastructure. The traditional approach can no longer meet the current and future needs of the road users and scarce maintenance budget is only exacerbating the situation. Practical experience shows that pavement preservation can provide an effective solution to this problem.

## 3.0 PAVEMENT PRESERVATION

### 3.1 What is it?

The major goal of pavement preservation is to keep good roads good. Pavement preservation is a program employing a network level, long term strategy that enhances functional pavement performance by using an integrated, cost-effective set of practices that extend pavement life, improve safety, and meet motorist expectations [1]. Pavement preservation system includes five key components: pavement management system (PMS), long-term network planning, optimization, cost-effective selection criteria, and sustainable financing. Based on these five components, pavement preservation systematically minimizes the destructive impact of climate and traffic through timely application of remedial/maintenance treatments to the pavement. The key is to apply these treatments when the pavement is still in relatively good condition with no structural damage.

The strategic view of applying pavement preservation to a roadway system involves considering the system or network as a whole rather than a series of independent projects. Basically, a pavement preservation program can be implemented by the following six step process [1]:

1. Develop an inventory of the road network;
2. Conduct a condition assessment of the network of roads. Performance evaluation of the pavement may include roughness, surface distresses, skid resistance and structural evaluation;
3. Determine the needs of the network;
4. Prioritize projects into treatment categories including reconstruction, rehabilitation, preventive maintenance, and routine maintenance;
5. Impose realistic constraints and develop numerous alternative strategies for the network. Compare the impact of the various alternative strategies and funding decisions on the network conditions;
6. Select the most cost-effective strategy within the imposed constraints for future use.

### 3.2 Conventional Approach vs. Pavement Preservation

The separation between pavement preservation and conventional maintenance practices by some of the road authorities lies in the type of treatments applied and at what time actions are initiated. As illustrated in Figures 1 and 2, the conventional approach typically waits until the pavements become too severely deteriorated before actions are taken. By then, the only viable option to restore the functional and structural performance of the pavements is through either major rehabilitation or reconstruction. If a reactive maintenance treatment is applied instead due to budget constraints or other reasons, the after-treatment performance would be substantially jeopardized to a point that the treatment itself basically becomes cost-ineffective, as illustrated in Figure 2 by a drastic drop in the slope of the after-treatment performance curve. In a pavement preservation program, preventive maintenance treatments are proactively applied when the roads are still in good condition. Minor deficiencies are addressed properly and systematically early enough before serious, irreversible underlying structural damage occurs. This way, roadway lives are substantially extended at comparatively low costs.

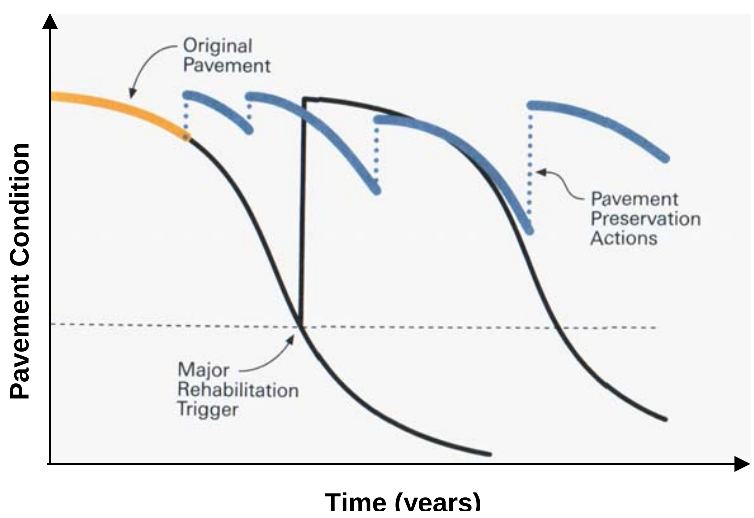



Figure 1 Pavement Preservation Concept [1]

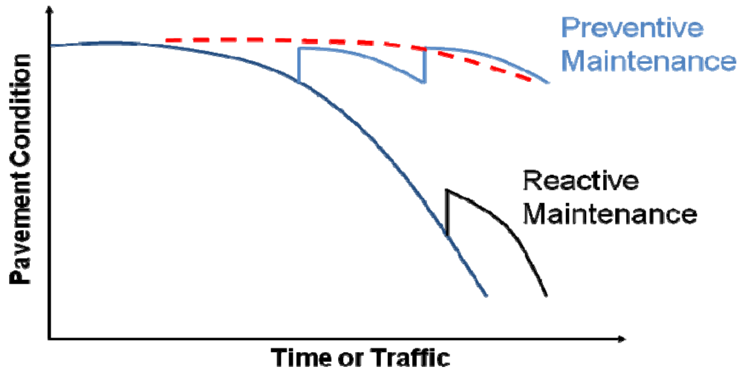



Figure 2 Preventive maintenance vs. Reactive maintenance [1].

Examples of trigger values for pavement treatments are shown in Figure 3. If Pavement Condition Index (PCI) is used, the trigger values for pavement preservation for urban pavements are typically between 75 and 80 and for rural pavements between 70 and 75.

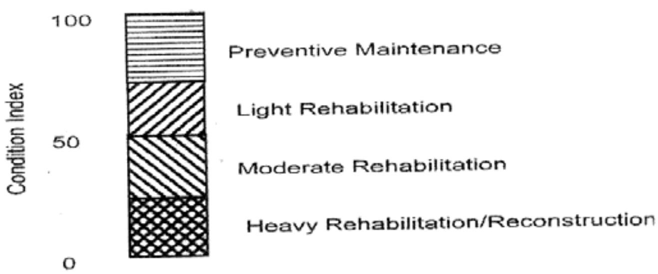



Figure 3 Examples of trigger values [2].

### 3.3 Four Approaches to Pavement Preservation in Ontario

Based on our extensive review of the state of pavement preservation, there are four major approaches observed in Ontario municipalities:

1. Municipalities that do not have any pavement preservation system and do not apply any preservation treatments although they are interested in pavement life extension. Some of these municipalities had bad experience with preventive treatments applications in the past, mainly due to poor treatment selection, and avoid taking risk of new applications. They do not have champion who would be interested in implementing pavement preservation system;

2. Municipalities that apply few preventive treatments but on random, experimental basis. They understand the necessity of using pavement preservation in order to maintain the balance between road needs and the available budget but do not have sustainable financing for pavement preservation;

3. Municipalities that apply preventive treatments on regular basis; typically a fixed percentage of road rehabilitation budget is assigned to preventive treatments. Their PMS's are used to generate shortlists of road needs for field review; and

4. Municipalities that have pavement preservation system that includes PMS, long-term network planning, optimization, cost-effective decision making, sustainable financing and feedback.

Although the majority of municipalities in Ontario use some kind of PMS, the municipalities in Groups 1 to 3 do not fully incorporate pavement preservation into their PMS. The majority of municipalities in Ontario are in Groups 2 and 3.

### 3.4 Pavement Preservation System

An efficient PMS must produce the required information to support the decision to be made at both the network and project levels. There are a number of PMS programs available that can be used for pavement preservation systems. The Regional Municipality of Durham is successfully using the Dighton PMS in their preservation system, for instance. Golder Associates Ltd. used the Micro PAVER program in developing the PMS system for Grand Cayman Island in 2008 that included pavement preservation activities and analysis. Micro PAVER was also used by Kent County in Michigan, US in their pavement preservation system. Recently updated Golder Road Information and Priority Setting System (GRIPSS) program also allows the inclusion of pavement preservation analysis.

The basic elements of network level PMS include inventory, pavement condition assessment, determination of needs, prioritization of projects needing maintenance and rehabilitation, methods of determining the impact of funding decisions and a feedback process. The most common method of prioritization is ranking in order of importance based on established rules. However, care is required in selecting the ranking rules in order to avoid "fixing the worst first". The optimum method of prioritization used in pavement preservation should be based on the greatest benefit-cost ratio or the best cost effectiveness [3].

Optimization is a higher level of decision support using system analysis to allocate funds in the most efficient manner. Typically, it maximizes the benefit in PMS. After the objectives and measures of benefits are established, mathematical models are developed and the optimum solution is determined [2].

The objectives of the project level include:

- Understanding the causes of pavement distresses;
- Selection of the optimum pavement preservation alternative; and
- Improving the existing standards, project selections and designs.

### 3.5 Remaining Service Life

One of the most difficult aspects in pavement preservation system development and implementation is dealing with the paradigm shift from worst- to best-first. Convincing municipality personnel including top management to move from the old practice of fixing worst first to the new practice of fixing good first including a commitment to dedicated funding for preservation is sometimes the major obstacle in the implementation. Pavement condition indices are often not understood and not appealing. The concept of Remaining Service Life (RSL) [2]. is very helpful because of its simplicity and clarity. The authors of this paper have good experience using this concept while dealing with municipalities.

The RSL of a pavement section is an estimated/predicted number of years of service from any given year to the time when the pavement section is expected to reach the threshold value. An example of the concept in linear model is shown in Figure 4. The design life is the estimated number of years after construction of rehabilitation to reach the threshold level. Figures 5a and 5b show the RSL of pavement network in a certain year and the year after if no improvements are done. The zero RSL stuck will increase significantly and the number of years remaining until the end of life will decrease by 1 year for each road segment.

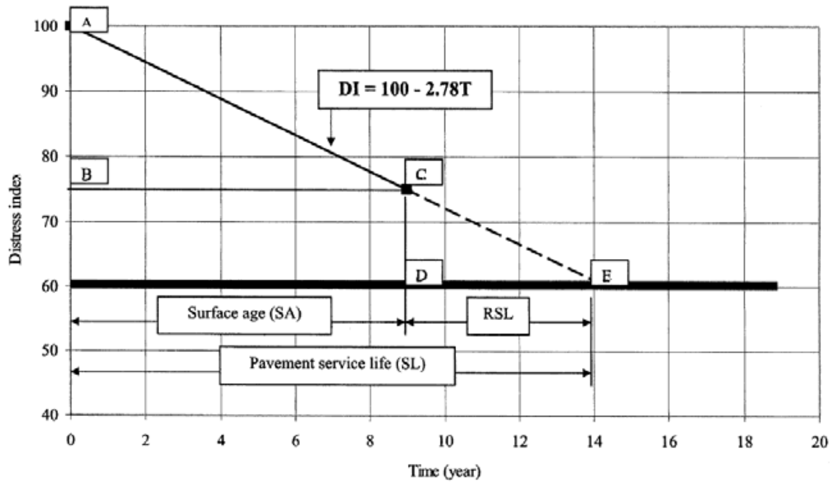



Figure 4 Calculation of RSL based on linear model [2].

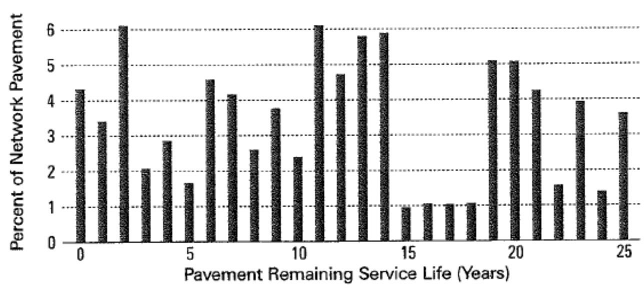



Figure 5a Current RSL condition [3].

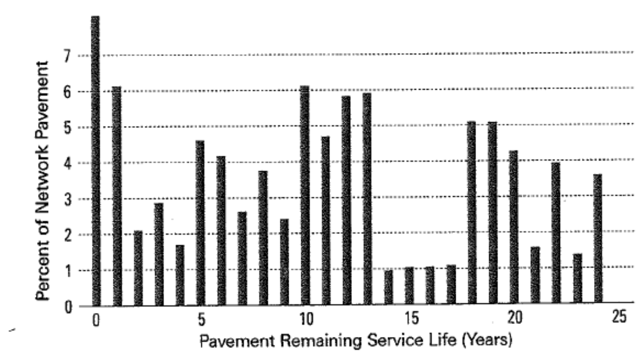



Figure 5b RSL condition 1 year later [3].

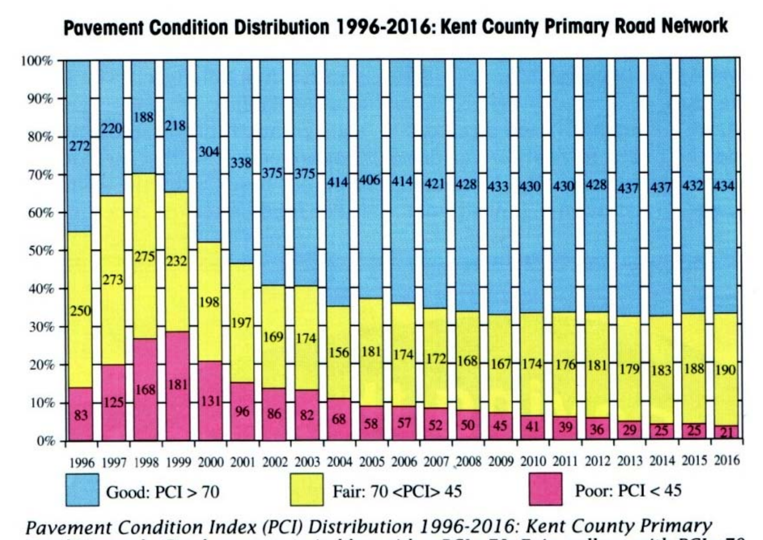
### 3.6 Why is it an effective way to deal with scarce maintenance budget?

With the conventional approach, road authorities can only anticipate what resources may be needed for maintenance because the present reactive operating mode forces them to wait and see what repairs will be needed.

With a pavement preservation program which is a proactive mode of operation, road authorities are able to predict with considerable certainty their planned budget expenditures to prevent the need for random and reactive repairs. This is achieved through an implementation of a pavement management system, incorporating long-term network planning, optimization and cost-effective decision making of preservation treatments.

There are number of municipalities and road authorities in Ontario that successfully use pavement preservation. They include Ministry of Transportation of Ontario, City of Toronto, Regional Municipality of Durham, United Counties of Leeds and Grenville, Town of Markham, to name a few [4 and 5]; however, the majority of municipalities are still at a pavement preservation early consideration or implementation stage.

Kent County in Michigan, US successfully implemented a pavement preservation system [6]. The County implemented a PMS using Micro PAVER. After 3 years of data collection they were aware of obvious alarming trend that the overall condition of the primary road system was rapidly deteriorating despite millions invested to reconstruct and widen many of County's worst roads. After implementing PMS, and dumping "worst first" approach, the County implemented pavement preservation system focusing on long-term perspective and maintaining good roads in good condition. The County established annual improvement targets for preservation updated during annual budget process. The reconstruction and rehabilitation projects are prioritized according to traffic, functional classification and availability of funds. These higher costs projects can be dropped based on availability of funds. The 10-year system condition target was adopted; it included the anticipated level of involvement in preservation, reconstruction, safety and bridge improvement. Figure 6 shows pavement condition from 1996 to 2016. The road network's performance improvement is obvious.



*Pavement Condition Index (PCI) Distribution 1996-2016: Kent County Primary Road Network. Good pavements in blue with a PCI >70; Fair, yellow, with PCI <70 and >45; and Poor, PCI <45*

Figure 6 Pavement Condition Index (PCI) Distribution 1996-2016: Kent County [6].

## 4.0 PRESERVATION TREATEMTNS REVIEW

The types of remedial treatments that are typically employed in a pavement preservation program include routine maintenance, preventive maintenance, and minor rehabilitation. Routine maintenance is the day-to-day maintenance activities; examples include cleaning ditches, filling cracks in the pavement, etc. Preventive maintenance is the most critical treatment type in pavement preservation; it is applied to the existing pavements to retard the rate of future deterioration, and maintain and improve the functional condition of the pavement without increasing structural capacity [7 and 8]. Applying the right preventive treatment at the right time is the key to the success of a pavement preservation program. Minor rehabilitation extends the original pavement service life by increasing the pavement structural capacity; examples include thin overlays and, cold in-place surface recycling, for instance.

With advancements in material technology, such as polymers, emulsions, and additives, remedial treatments employed in a pavement preservation program have become more innovative, cost-effective, and perform better than ever before. In this section, the preventive maintenance treatments of asphalt pavements commonly used in Ontario are reviewed; their limitations, examples of use in Ontario and their user benefits are also discussed.

Asphalt pavement preservation treatments include:

Crack sealing;
Crack filling;
Fog seals;
Rejuvenating seals;
Chip seals;
Slurry seals;
Cape seals;
Sand seals;
Microsurfacing;
Non-structural HMA overlay;
Surface milling and non-structural overlay;
Cold in-place surface recycling; and
Hot in-place HMA recycling.

Emerging technologies include Nova Chip and Metro Mat™. The pavement preservation technologies that are commonly used in Ontario are described below. Nova Chip and Metro Mat were described in [9]. Cold in-place surface recycling and hot in-place recycling were described in [10].

### Asphalt Crack Sealing/ Crack Filling

Asphalt crack sealing generally targets the working cracks. It involves routing or sawing a reservoir, preparing the reservoir through abrasive blasting, and thoroughly cleaning it with compressed air. Hot-poured, rubberized asphalt sealants are most commonly used to seal the reservoir.

Asphalt crack filling is used for treating of non-working cracks. It includes cleaning the cracks with dried, compressed air and filling it with asphaltic material.

### Fog Seal and Rejuvenating Seal

Fog seal is a light application of diluted asphalt emulsion to renew surfaces and seal small cracks and surface voids.

Rejuvenating seal is an application of emulsion of specific petroleum oils to penetrate dry and weathered asphalt pavements to restore its original desirable properties, plasticity and ductility in asphalt cement and restore pavement durability. Reclamite is a rejuvenating agent formulated from petroleum maltenes. It is used by number of municipalities in Ontario (City of Brampton and Regional Municipality of Durham, for instance).

Reclamite is diluted at a ratio of 2 parts Reclamite to 1 part water and applied at rates between 0.30 liters/$m^2$ to 0.65 liters/$m^2$. The pavement is then sanded at an application rate of 0.5 to 1.0 kg/$m^2$ sand with 2 to 12 percent passing 75 µm sieve. Photograph 1 shows the application of Reclamite on asphalt pavement. Normal treatment can provide about 5 years of pavement additional life. The Regional Municipality of Durham typically spends about $100,000 on rejuvenating seals every year.

Photograph 1 Application of Reclamite on asphalt pavement [PTI].

**Chip Seal/ Surface Treatment**

Chip seal consists of an application of asphalt emulsion followed immediately by a thin layer of aggregate. The goal is to have the aggregate particles approximately 70 percent embedded into the asphalt layer [11] and [12].

Chip seal can waterproof the pavement surface, provide sealing of low severity cracks, and restore surface friction. The chip seal membrane also slows down the asphalt cement oxidation process within the original asphalt surface layer. On the other hand, chip seal is not effective on pavements exhibiting medium to severe fatigue, linear or block cracking, rutting, roughness and shoving [2]. The serviceable life of a chip seal treatment is considered to be 3 to 6 years with a typical average of 4 years under low to moderate traffic. Numerous qualified and experienced contractors are available throughout Ontario.

Chip seal is affected greatly by weather conditions; rain can cause problems when chip sealing process is carried out. Also, the asphalt binder needs time to cure. Due to the risk of loose chips and excessive noise, chip seal is used mainly on low volume roads in Ontario.

Photograph 2 shows a chip seal application on Coates Road between Highway 12 and Regional Road 2 (Simcoe Street) in Oshawa, Ontario. The close-up photo shows the surface texture after the treatment application.

Photograph 2 Chip seal applied on Coates Road in Oshawa, Ontario

**Slurry Seal**

Slurry seal is a mixture of slow setting emulsified asphalt, well graded fine aggregate, mineral filler (most often Portland Cement), and water. It is considered a thermal process. The process takes from two to eight hours depending on the heat and humidity. As slurry seal has to set; it should not be placed during rainy weather and the temperature should not be lower than $10^{o}$C.

Slurry seal will not perform well if the underlying pavement exhibits medium to severe fatigue, linear or block cracking, rutting, roughness or shoving [8 and 9]. It should be applied where the existing surface is stable with only low-severity cracking.

Slurry seal is used to seal the existing pavement surface, fill cracks in the pavement, restore a uniform surface texture, seal the surface against water and air intrusion, and to improve skid resistance. They are effective where the primary problem is excessive oxidation and hardening of the asphalt concrete or where there are aggregate “pop-outs” in asphalt wearing courses associated with soft limestone. Slurry seal does not have a strong skeleton and are typically applied as one aggregate layer thick. They are not suitable to correct surface irregularities and rutting.

The life of a slurry seal is from 3 to 5 years. Experienced slurry seal contractors are available throughout Ontario and the product is highly reliable.

**Cape Seal**

Cape seal is basically a type of slurry seal; it has gained some popularity in Ontario over the past several years. In this process, a slurry seal is applied to a newly constructed chip seal surface to improve the retention of the stone chips and seal the open voids. The cape seal treatment has a life expectancy of 9 to 15 years, with the typical life of about 9 years before re-application. Figure 3 shows a cape seal application of Halls Road in Whitby, Ontario in 2003. The close-up photo shows the surface texture after the treatment application.

Figure 3 – Cape seal applied on Halls Road in Whitby, Ontario

**Micro-Surfacing**

Micro-surfacing is a mixture of polymer-modified asphalt emulsion, well graded crushed mineral aggregate (typically 9.5 mm minus), mineral filler (normally Portland Cement), water, and chemical additives, properly proportioned, mixed, and spread on a paved surface [9 and 13]. The aggregates are tough in terms of hardness and resistance to polishing.

Micro-surfacing is a chemically controlled process. The materials are mixed in a truck mounted travelling plant and then deposited into a spreader box. No compaction is needed and traffic may be allowed on the mat within an hour after placement. Micro-surfacing typically involves two coats including a scratch or leveling coat followed by a surface coat. It is applied at ambient temperatures and has low energy requirements. Due to its quick application rate, it causes minimum disruption to traffic.

Micro-surfacing is applied on roads carrying medium to high volume traffic. The pavements should be in good structural condition and not exhibiting any significant structural distresses. A single course micro-surfacing applied to a pavement will retard oxidation and improve skid resistance. A multiple-course micro-surfacing application will correct certain pavement surface deficiencies including rutting, minor surface profile irregularities, polished aggregates or low slid resistance, and light to moderate raveling.

Micro-surfacing can extend the life of pavement by about 7 years. However, there are examples where properly applied microsurfacing can extend the life by more than 10 years. Photograph 4 shows the pavement surface on Thickson Road in Whitby 11 years after microsurfacing application.

Photographs 4 Condition of micro-surfacing on Thickson Road in Whitby 11 years after application

### Non-structural Thin HMA Overlay

Dense graded HMA mixes are typically used in non-structural thin HMA overlays in Ontario to improve the functional condition of a pavement including smoothness, skid resistance and roadway profile correction. Gap graded mixes (such as Stone Mastic Asphalt) can also be used. Thin overlays add little or no structural improvement to the pavement [14]. Prior milling may be required if more severe surface distresses are present or where curb reveal needs to be maintained. Thin overlay thicknesses typically range from 20 to 40 mm. The mixes are sometimes modified with polymers for better field performance. Thin overlays will correct some small surface irregularities and low severity rutting; however, more severe irregularities should be repaired before the thin overlay application.

Thin asphalt overlays should be applied prior to the onset of fatigue-related pavement cracking. Candidate pavements may exhibit surface distresses such as moderate to severe raveling, and moderate longitudinal and transverse cracks with some secondary cracking. Isolated structural distresses, such as alligator cracking must be patched prior to overlay. Thin overlays are particularly suitable for high volume roads in urban areas. The life of a thin overlay ranges from about 5 to 10 years with the average of about 8 years.

A thin asphalt overlay was applied on Taunton Road through Ajax Pickering and Whitby, Ontario in 2001. Taunton Road is one of the major east-west arterials in Durham Region, Ontario. The pavement was in fairly good condition prior to overlay with no severe cracking. Non-structural thin HMA overlay was used as a preventive maintenance treatment to extend the life of the existing pavement, correct some minor rutting, and irregular cross fall.

### Surface Milling/ Non-Structural HMA Overlay

Surface milling is the removal of an existing asphalt surface through cold milling followed by a non-structural thin HMA overlay with a maximum thickness of 20 to 40 mm. This preventive treatment improves the functional condition of a pavement such as smoothness and skid resistance, corrects roadway profile, and matches curb and gutter grades.

## 5.0 CONCLUSIONS

Due to years of tight budgetary situations, many road authorities have become accustomed to the conventional approach applying remedial treatments to their road network too late, which results in sub-optimal return of investment. Pavement preservation offers an effective way of dealing with the scarce maintenance budget situation. It is a proactive sustainable approach that enables road authorities to save substantial resources and provide a consistently high level of service for the traveling public. It can reduce costly, time-consuming major rehabilitation and reconstruction along with associated traffic disruptions.

Proper pavement preservation system should include PMS, long-term network planning, prioritization, optimization, cost-effective selection criteria, and sustainable financing. There are number of municipalities and road authorities in Ontario that successfully use pavement preservation; however, the majority of municipalities are still at a pavement preservation early consideration or implementation stage.

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