Introduction

Sealing cracks in asphalt concrete pavements is a commonly used maintenance procedure which can reduce pavement deterioration by restricting surface water penetration into underlying base and subbase layers (1). This helps maintain pavement structural capacity and limits future pavement degradation.

Pavement Management Systems (PMS) are designed to manage maintenance and rehabilitation activities to optimize pavement condition with available funds. Use of PMS is becoming increasingly more prevalent due to benefits achieved (2, 3, 4).

Crack sealing is generally considered in PMS as a maintenance activity. Research activities by several organizations have determined that effective crack sealing in asphalt concrete pavements can extend pavement life in a cost effective manner by slowing the rate of condition deterioration (5,6,7). The purpose of this brochure is to discuss life extensions provided by crack sealing and the incorporation of these extensions into Pavement Management Systems.

Pavement Management System Basics

Pavement Management Systems consist of a planned, systematic approach for owner agencies to optimize pavement maintenance and rehabilitation activities to provide the desired level of pavement condition and life span with available funding. Implementation of PMS results in identification of needs of the pavement system and schedules for maintenance and rehabilitation to address identified needs. PMS considers current and future pavement condition, maintenance and rehabilitation alternatives, funding, priorities and other factors to develop maintenance and rehabilitation plans and schedules to achieve desired goals.

Pavement Deterioration and Pavement Condition Index (PCI)

Pavement deterioration is due to environmental and traffic loading factors and results in worsening pavement condition and ride quality. Pavement condition can be quantified by the Pavement Condition Index (PCI) which rates the pavement according to the extent and severity of distress types present (cracking, rutting, shoving, etc.). PCI ranges from 100 to O (Best to worst). Figure 1 shows a typical pavement condition life cycle curve. The plot shows that condition worsens at an increasing rate as the pavement gets older The reason for this is that deterioration begins mostly at the surface and then progresses down into underlying layers as surface cracks develop. Figure 1 shows that a typical pavement without rehabilitation will experience a 40% drop in PCI during the first 75% of its life and an additional 40% drop in the following 12% of its life. To restore pavement condition near the end of its service life will typically cost 4 to 5

CRACK SEALING

COST EFFECTIVE TECHNIQUE FOR USE IN PAVEMENT MANAGEMENT

times as much as it will at 75% of its service life due to the more complete failure experienced. A major goal of PMS is to keep pavement condition in the upper PCI range (60 - 90) by limiting subsurface structural degradation to keep down rehabilitation costs.

PMS Activities for Pavements in Varying Conditions

Pavements in different condition ranges require different types of maintenance and rehabilitation activities. Table 1 shows typical procedures which are applicable for pavements in conditions ranging from very good to very poor Applicable procedures range from minor routine maintenance to total reconstruction depending on pavement condition. Specific procedures selected may vary from agency to agency depending on performance levels in different areas and for different functions. Each procedure used in PMS has an associated cost, PCI improvement level and life cycle.

Steps in Pavement Management

The PMS process consists of several steps which are briefly described as follows:

Inventory

This function consists of identifying, describing and logging the pavement system in discreet similar sections to provide the data base which describes the entire pavement system to be managed.

Condition Survey:

The condition of each inventory section is assessed by various methods. This phase identifies the PCI of each section. Condition surveys are generally performed each year to monitor performance of the pavement system.

Identify Maintenance and Rehabilitative Alternatives:

Specific maintenance and rehabilitation procedures which can be used for each pavement condition category are identified and input into the system. Along with each procedure, associated costs, PCI improvement achieved, life cycle, etc. are input.

Operate the System:

With the pavement inventory, condition survey and maintenance and rehabilitation alternatives input, it is then possible to model pavement condition with various rehabilitation strategies (procedures and timing) to determine future pavement condition and associated costs. Rehabilitation strategies can then be optimized considering goals and funding. Work schedules are then produced and priorities and budgets set. Maintenance and rehabilitation are then performed as scheduled.

Monitoring the System:

During operation of PMS, condition data is collected to monitor and verify if maintenance and rehabilitation procedures used are producing predicted results. Performance predictions are updated as data becomes available. Other changes can be made in the system as data acquisition, rehabilitation and performance prediction technology improves.

Benefits of Crack Sealing

If cracks in asphalt concrete pavements are not sealed, surface water penetration can reduce the strength of base and subbase layers which can result in increased deflections and accelerating deterioration of the surface due to development of greater cracking, depressions and potholes. Crack sealing is performed to reduce water penetration and thereby help maintain pavement structural capacity and to limit future degradation.

The Utah D.O.T. (6] found that effective crack sealing reduced pothole formation and development of additional cracking significantly. Potholes and additional cracking formed at 75 to 80% of unsealed cracks compared to only 1% of the sealed cracks. The study concluded that effective crack sealing reduces future pavement deterioration.

The Ontario Ministry of Transportation as a result of several extensive studies of crack sealing techniques and effectiveness, has substantiated that effective crack sealing can prolong pavement life. One study (4) concluded that sealing retards deterioration and extends pavement serviceability by at least four years. k was also noted that when sealed, transverse crack condition remained static with no spalling or secondary crack development while unsealed cracks developed multiple cracks and spalling. Other studies (8,9) reported that pavement life extensions of between 2 and 5 years can be achieved with effective crack sealing and that crack sealing can be a cost effective preventative maintenance treatment. Figure 2 shows PCI curves which indicate that the sealed (treated) pavement section will have a 2 year greater life than the unsealed control section. Life extensions are shown as indicated by flattening of the PCI curves which indicate a lessened rate of pavement deterioration. Note that in Figure 2, crack sealing resulted in a 10 point increase in PCI after 7 years of service compared to the unsealed central section. The Ministry has developed a knowledge based expert system for se-

lecting crack sealing projects for use in conjunction with PMS (10),

A recent survey by the U.S. Army Corps of Engineers (6) reported that with properly sealed cracks, pavement life is extended by an average of three years with one state reporting as much as eight years extra life. Other references also indicate that pavement life can be increased by crack sealing (12) and that the procedure is cost effective because the added life exceeds the cost of the operation (1 1).

Incorporation of Crack Sealing in Pavement Management Systems

Crack sealing can be used in Pavement Management Systems for pavements in each condition related alternative classification except reconstruction.

Routine Maintenance (75-95 PCI) Very Good Pavement Condition

This is the range of normal PCI in which crack sealing is commonly thought to be most applicable. Pavements in this category are in good to excellent condition and have generally developed only minor amounts of cracking.

Crack Sealing is generally performed by highway maintenance departments along with other types of routine maintenance (minor pothole patching, skin patching, etc.) as needed to keep the road in good condition. Cracks which have developed are generally less than 1/8" wide, may be non-continuous and generally do not experience high degrees of thermal movement. Even though cracking is minor, sealing should be considered early in the pavement life to limit water penetration into the underlying pavement structure.

Suggested sealing consists of using narrow overband treatment with highly adhesive hot applied sealants. Cleaning and preparation can consist of blowing with compressed air or hot air lances.

Preventative Maintenance (60-75 PCI) Good Pavement Condition

Preventative maintenance treatments are performed to extend the service life of the pavement. These procedures can be planned and scheduled in advance. Some agencies have recognized that crack sealing in appropriate manners can be an effective preventative maintenance procedure. As previously discussed, the Ontario Ministry of Transportation has found that performing crack sealing on appropriate roads can extend their life from 2 to 5 years (5, 8, 9, 10). They have determined that crack sealing in effect slows the PCI deterioration rate. This slower deterioration rate can be accounted for in PMS by adjusting the PCI vs. life curves for pavements which have been crack sealed to indicate their increased life expectancy. Specific adjustments for specific PMS systems can be determined by monitoring and evaluating PCI overtime for sealed and unsealed roadways.

Another manner in which crack sealing is incorporated in PMS is how sealed cracks are accounted for during PCI condition surveys. During conditions surveys, cracking type, extent and severity are noted. Sealing does not change crack type or extent but does reduce the amount of future subsurface deterioration associated with the cracks. Crack severity is generally classified as low, medium or high. ASTM D 5340-93, Standard Test Method for Airport Pavement Condition Index Surveys [13), and the Corps of Engineers PAVER System (4) use the following general rating guidelines for defining crack severity. Low severity is described as non or lightly spalled and less than 1/4 inch wide or filled with sealant in good condition. Medium severity cracks consist of cracks which are moderately spalled with a width over 1/4 inch or filled with sealant in unsatisfactory condition. High severity cracks are defined as cracks of any width which are severely spalled with adjacent pieces which are loose or missing and which may be either filled or unfilled. These severity classifications account for functional sealant by reducing the severity rating. The SHRP Distress Identification Manual for the Long-Term Pavement Performance Project (SHRP-P-338) (14) also uses similar classifications for severity and the manner in which functioning sealant is considered. Generally medium severity cracks can be classified as low severity after sealing in either band-aid or rout configurations. High severity cracks will require routing to remove spalling and cutting the pavement back to sound unspalled material and then sealing to reduce the severity rating. Depending on the severity of spalling and parallel cracking, sealing high severity cracks may not be appropriate as a preventative maintenance technique.

From the PCI determination procedures in ASTM D5340, it is possible to determine the effects of crack sealing on the PCI. For block, reflection, longitudinal or transverse cracks with a medium severity rating which are crack sealed to result in a low severity rating, PCI is increased by 5 to 6 for a 1% cracking extent and from 8 to 16 for a 10% cracking extent.

These improvements in PCI due to crack sealing should remain until the sealant no longer is in good functioning condition. Therefore, the better the sealant installation and better performing the sealant is, the longer the PCI improvements will last.

Recommended sealing consists of using routed reservoirs of appropriate sizes with high quality hot applied sealants.

Crack sealing should also be considered as part of other preventative maintenance treatments including chip sealing, slurry seals and micro surfacing. Crack sealing in conjunction with these treatment types can improve their effectiveness.

During preventative maintenance crack sealing, the question arises regarding how long to wait for cracks to develop and widen prior to sealing. Some agencies wait until the crack width reaches 1/4 inch or seal crack only greater than 1/4 inch wide. However, the Corps of Engineers suggests sealing cracks greater than 1/8 inch wide. It is recommended that preventative maintenance sealing should commence when the average crack width reaches 1/4 inch in the Spring or Fall. When performing the job, all cracks greater than 1/8 inch be routed and sealed and cracks less than 1/8 inch should be capped with a band-aid application to provide the greatest benefit from the sealing project.

Deferred Action (50-60PCI) Fair Pavement Condition

Pavements in this condition generally have surfaces which have deteriorated significantly and are beginning to experience subsurface deterioration. These types of pavements are generally not upgraded using surface preventative maintenance strategies, but are just maintained in a usable condition until funds become available for major rehabilitation. Maintenance mainly consists of patching potholes as they occur. However, crack sealing can be used to attempt to hold the pavement together to reduce deterioration until rehabilitation is performed. Alligator cracked areas with intact bases, or high severity reflective, block, longitudinal or transverse cracks can be sealed. Performing sealing in this category can extend the usable life of the pavement until major rehabilitation occurs.

Crack sealing of this type may be relatively extensive and in cracks which may be severely deteriorated. It is doubtful if preparation methods more extensive than air blowing or hot-air lancing are justified. Sealant should be applied in band aid configurations and sealants should be hot applied types which will exhibit high adhesivity in poor application conditions.

Rehabilitation (25-50 PCI) Poor Pavement Condition

Pavements in this category are generally going to receive a major structural overlay. Crack sealing can be performed prior to the overlay to seal existing cracks in the pavement to limit water penetration into the base when future reflective cracks form. Crack sealing of this type under an overlay should be performed in a recessed manner which prevents sealant contact with the overlay to prevent overlay displacement during compaction which can create surface unevenness. For this type of sealing, the widest cracks should be given the highest priority. Routing to create a reservoir would be appropriate for cracks less than 3/8 inch wide. Sealing should be recessed a minimum of 1/4 inch below the surface to minimize contact with the overlay. Sealant types used should be quality hot-applied materials which are typically used in the area for preventative maintenance routing and sealing. Band aid or other surface applications should not be used.

Summary

Pavement Management Systems can be used to aid in keeping roads in better condition for longer times. Effective crack sealing provides documented and quantifiable life extensions in pavements due to restriction of surface water penetration into base and subbase layers. The pavement life extensions provided by effective crack sealing using appropriate preparation methods and quality hot applied sealants can be used as an integral part of Pavement Management Systems in routine maintenance, preventative maintenance, deferred action and rehabilitation condition categories to achieve better performing highways at lesser costs.

TABLE 1

PMS Alternatives and Procedures for Various Conditions

PCI Range	Pavement Condition	PMS Alternative Classification	Objective	Example Procedures
75-95	Very Good	Routine	Correct minor deficiencies	Minor crack sealing, fog sealing, minor patching
60-75	Good	Preventative maintenance	Restore surface, extend life	Slurry seal, chip seal, crack rout & seal, patching
50-60	Fair	Deferred action	No upgrading, maintain current condition	Crack sealing & patching to maintain surface
25-50	Poor	Rehabilitation	Major surface upgrading/ replacement	Structural overlays, grinding
O-25	Very Poor	Reconstruction	Construct new pavement	Surface removal, new base and surface

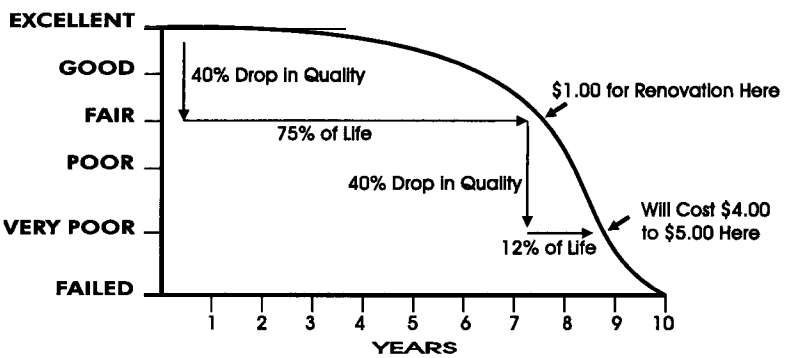

Figure 1
Typical pavement condition life cycle (Reference 4)

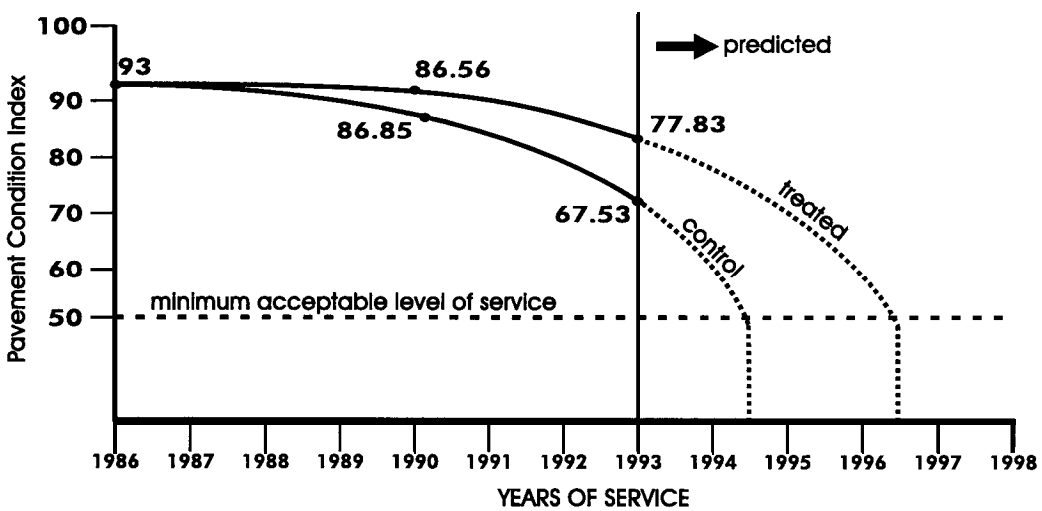

Figure 2
Performance curves for sealed (treated) and unsealed (control) pavement sections (reference 9)

References

1. Eaton, R.A., Joubert, R. H., and Wright, E.A., "Pothole Primer" Spread Report81 -21, U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory Sept. 1981 (Revised Dec. 1989).

2. Haas, R; Hudson, W. R.; and Zaniewski, J.; Modern Pavement Management, Krieger Publishing Company Malaboc Florida, 1994.

3. AASHTO Guidelines for Pavement Management Systems, AASHTO, Washington, D. C., 1990

4. Shahin, M.Y, and Walthec J.A., "Pavement Maintenance Management for Roads and Streets Using the PAVER System", U.S. Army Corps of Engineers Construction Engineering Research Laboratory Report M-90/05, July 1990.

5. Chong, G. J., and Phang, WA. "Improved Preventative Maintenance: Sealing Cracks in Flexible Pavements in Cold Regions", Ontario Ministry of Transportation, Report No. PAV-87-O1, December, 1987.

6. Eaton, R.A., and Ashcraft, J., "State-of-the-Art Survey of Flexible Pavement Crack Sealing Procedures in the United States", U.S. Army Corps of Engineers Cold Regions Research & Engineering Laboratory CRREL Report 92-18, September 1992.

7. Belangie, M. C., and Anderson, D. I., "Crack Sealing Methods and Materials for Flexible Pavements", Utah Department of Transportation, Report No. FHW/AUT-85/l, May 1985.

8. Ponniah, Joseph, "Is Crack Sealing in Flexible Pavements a Worthwhile Maintenance Procedure", Pavement Systems Division 1992 Workshop - Crack and Joint Sealing for Rigid and Flexible Pavements Proceedings, U.S. Army Corps of Engineers, Waterways Experiment Station, May 1992.

9. Ponniah, Joseph, and Kennepahl, Gerhard, "Crack Sealing in Flexible Pavements, a Life Cycle Cost Analysis", Ontario Ministry of Transportation, Presented at 74th Transportation Research Board Meeting, Jan. 22-28, 1995, Washington D.C.

10. Hajeh, J.J.; Chong, G. J.; Haas, R. C. G.; and Phang, WA., "Knowledge-Based Expert System Technology Can Benefit Pavement Maintenance", Ontario Ministry of Transportation, Report No. PAV-86-05, Dec. 1986.

11. Smith, K. L., and Romine, R. "Materials and Procedures in Sealing and Filling Cracks in Asphalt-Surfaced Pavements", Strategic Highway Research Program Manual of Practice, No. SHRP-H-348, August 1993.

12. Rutherford, N.E, "Pavement and Shoulder Maintenance Guidelines", Proceedings Workshop in Pavement Rehabilitation, Technology Sharing Report, FHWA-TS-84-224, Salt Lake City, Utah, September 7-20, 1984

13. ASTM D5340-93, "Standard Test Method for Airport Pavement Condition Index Surveys", American Society for Testing and Materials. Volume 4.03, 1994.

14. "Distress Identification Manual for the Long-Term Pavement Performance Project". Strategic Highway Research Program, SHRP-P-338, Washington DC, 1993.

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