A Study of the Performance of Asphalt Pavement Rehabilitation Techniques

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Hot mix asphalt pavements comprise approximately ninety six percent of the paved roadway surfaces in the U. S. (Asphalt Institute 2003). Strategies employed to rehabilitate these surfaces vary widely (Hand, et al 1999, Keleman, et al 2003, Labi and Sinha 2003, Morian and Cumberledge 1997, Tighe, et al 2007) at a cost of approximately 150 million dollars annually (Ref ?). The Colorado Department of Transportation utilizes eight of the many available rehabilitation methods for improving the performance of deteriorating asphalt pavements. This report is a summary of a research project intended to determine the performance characteristics of these rehabilitation methods. Projects were selected based on a ten-year design life, one-half mile minimum length, which were constructed between 1997 and 2001. There were 175 projects meeting this criteria included in the study. The eight rehabilitation strategies all included hot mix asphalt overlays with various treatments applied to the existing pavement surface prior to overlay. These treatments included two to four inch overlay with no pre-treatment, stone matrix asphalt with no pre-treatment, cold planing (milling), heater scarification, full-depth reclamation, heater remixing, cold in-place recycling, and heater repaving. Performance was judged based on smoothness, permanent deformation, and transverse, longitudinal and fatigue cracking over a six year period. Results indicate a significant difference in rehabilitation strategy performance depending on factors such as asphalt binder type, traffic loading, aggregate gradation and climate.

Keywords: Asphalt rehabilitation, asphalt overlay, cold planning, heater remixing, full depth reclamation, heater scarification, heater remixing, cold in-place recycling, heater repaving

LITERATURE REVIEW

There have been many different studies done on pavement management, materials testing, and pavement costs (Hand, et al 1999, Keleman, et al 2003, Labi and Sinha 2003, Morian and Cumberledge 1997, Tighe, et al 2007). Some of these studies were done in the laboratory while others were on actual highways. Good pavement management is vital to the longevity of pavements. Evaluating rehabilitation techniques in different environments under varying traffic and with differing materials is part of building a successful pavement management plan.

Morian and Cubermledge (1997) evaluated techniques for selecting correct pavement rehabilitation strategies in Pennsylvania. They identified what information is important to have when analyzing what rehabilitation techniques to use. Understanding project history is the first point, a thorough assessment of traffic history, evaluation of materials used, general understanding of past construction practices, history of climate, and an understanding of the type of subgrade are all important when analyzing what type of rehabilitation technique works best.

Three low-volume test roads were constructed in Canada (Tighe, Falls, & Dore, 2007) in order to measure performance. Test sections were constructed using different techniques and in different locations around the country. They were constructed for the purpose of conducting research to help with technology development, advance planning, design, construction and operation of Canadian roads. (Tighe, Falls, & Dore, 2007). The Canadian road system is constantly being challenged by moving heavy-equipment to remote locations during spring thaw conditions. The access to the sites is regularly done on low-volume pavements. Load equivalency factor (LEF) restrictions are used to limit overloading on roads.

Present serviceability index (PCI) was used in a Nevada study (Hand, Sebaaly, & Epps, 1999) to measure distresses. PCI is a calculation of rut depth, slope variances, cracking and patching. Performance models were developed from the PCI numbers for the overlay and the mill/overlay rehabilitation techniques used by NDOT. Projects were selected around the state to be used in the study. Three restrictions were used when choosing sections there was included a minimum number of replicate sections, a minimum project length of three kilometers, and only projects with enough quality data were chosen. The data that was used to build the performance curves was gathered from NDOT's pavement management system and other historical databases that NDOT has on file. Data from the pavement management system is organized by direction of lane mile. Box plots were then used to plot the data on a graph that shows the percentage of the allowable distress overtime.

BACKGROUND

The objective of this research was to evaluate the performance of eight hot mix asphalt rehabilitation strategies used by the Colorado Department of Transportation (CDOT) between 1997 and 2001. Performance was judged based on the ability of each strategy to maintain ride quality (smoothness), ability to resist permanent deformation (rutting), and ability to resist transverse, longitudinal and fatigue cracking over a six year period. The strategies all included hot mix asphalt overlays or stone matrix asphalt placed on the existing deteriorated pavement but with various techniques employed to prepare the surface for paving unless the overlays were placed directly on the existing surface. These techniques are described briefly below:

Cold Planing

Cold planing is the process of removing the top portion of the existing deteriorated pavement with a milling machine consisting of a rotating drum with carbide cutting teeth. The depth of pavement removed is usually between one and two inches.

Full-Depth Reclamation

Full depth reclamation is an insitu process that grinds up the existing asphalt pavement and aggregate base course and mixes both together and replaces it back on the subgrade soil. This homogeneous mixture is then recompacted and ready for a new asphalt pavement.

Heater Scarification

Heater scarification is a process of heating the surface of the existing pavement with either natural gas fired burners or infrared heaters, scarifying the softened surface with ripper teeth, and sprayed with a rejuvenating agent. This material is all mixed together in an auger chamber and leveled with a screed. Pneumatic rollers compact the loose mixture in preparation for the overlay.

Heater Remixing

The heater remixing process is done by heating the existing pavement with either natural gas fired burners or infrared heaters, milling the pavement between 1 ½ to 2 inches. The milled asphalt usually has a rejuvenating agent added and then a small quantity of virgin hot mix asphalt is added. All of this material is mixed together to form a single mix. The mixture is then spread out and compacted.

Heater Repaving

This process is similar to the heater scarification process. First the pavement is heated, then scarified and a rejuvenating agent is then added and it is mixed. The same time that this process is performed, a layer of hot mix asphalt is placed over the heated recycled surface. A screed is then used to level the pavement. The pavements are then compacted. The scarification is usually between ¾ to 1 ½ inches deep.

Cold In-Place Recycling

Cold in-place recycling is the process of milling the surface of the existing pavement, mixing the milled material with asphalt emulsion and replacing the resulting mixture back onto the surface of the pavement and compacting.

METHOD

The Colorado Department of Transportation measures the condition of all of the pavements in the state network annually. This large database was evaluated in this study for pavements rehabilitated from 1997 to 2001 to determine if enough projects existed which had been rehabilitated using the techniques described above to determine performance behavior. After an initial screening it was determined that 175 projects could be analyzed based on a minimum population of three projects with correlation coefficients for rate of gain in distress with time of no less than 0.50. The distribution of these projects is shown in Table 1.

Table 1. Distribution of Projects Studied

Type of Treatment	Number of Projects
Two to Four Inch Overlay	73
Cold planing and overlay	57
Heater Scarification and Overlay	19
Full depth reclamation and overlay	6
Heater remix and overlay	6
Stone matrix asphalt overlay	5
Cold recycle and overlay	5
Heater repaving and overlay	4
Total	175

Performance of each of the projects shown in Table 1 was evaluated by comparing the rate of change of smoothness and four distress modes over a six year period. These performance criteria and the units of measure for each are shown in Table 2.

Table 2. Performance Criteria

Smoothness	International Ride Index
Transverse Cracking	No. of 12 ft cracks/0.10 mi
Longitudinal Cracking	Linear Feet
Fatigue Cracking	Square Feet
Permanent Deformation	Linear Inches

In addition, the analysis was subdivided since performance of asphalt pavements was presumed to be a function of several variables. Four of the most significant variables considered are shown in Table 3.

Table 3. Variables Presumed to Affect Performance

Asphalt Binder	Unmodified and Polymer Modified
Traffic	Low (less than 0.3M ESAL's) Moderate (0.3-3M ESAL's) High (3-11M ESAL's)
Aggregate Grading	Superpave 'S' (3/4-inch nominal maximum) Superpave 'SX' (1/2-inch nominal maximum)
Environment	Cool (< 81F in summer) Moderate (81 to 88F in summer) Hot (> 88F in summer)

RESULTS

The number of graphs generated to show the results of the entire analysis performed in this study is 8 strategies x 5 performance criteria x 4 variables affecting performance = 160. Therefore, in the interest of space for this paper, five summary graphs are presented as Figures 1 through 5 for each of the performance criteria showing all of the rehabilitation strategies on each. Each graph includes the limit of pavement life represented as 'zero remaining service life' and the threshold established for each performance criteria by CDOT. Based on this information the reader can get a sense for which rehabilitation strategies appear to be most effective during the six year analysis period.

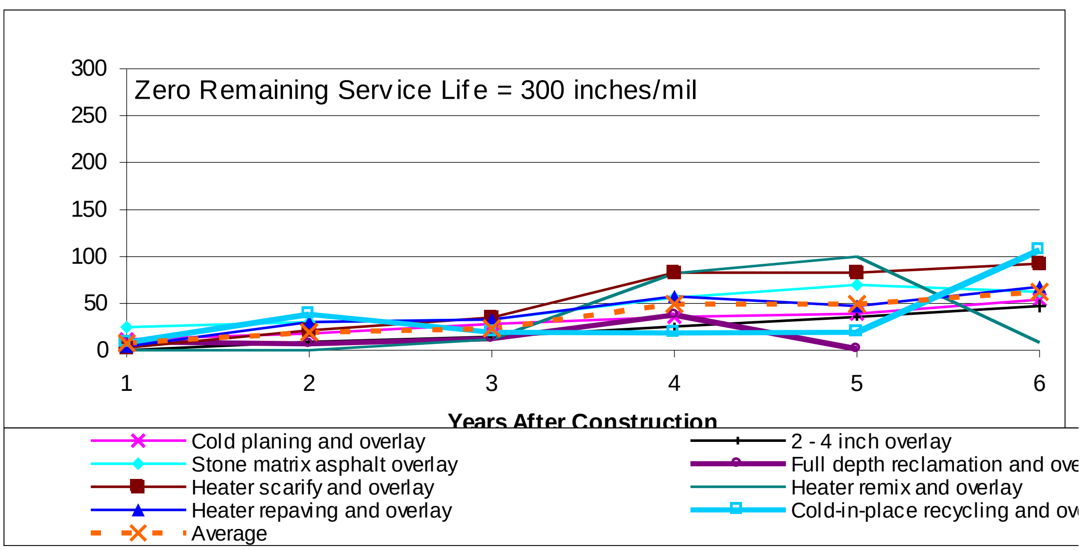

Figure 1. Rate of Change for Smoothness After Six Years

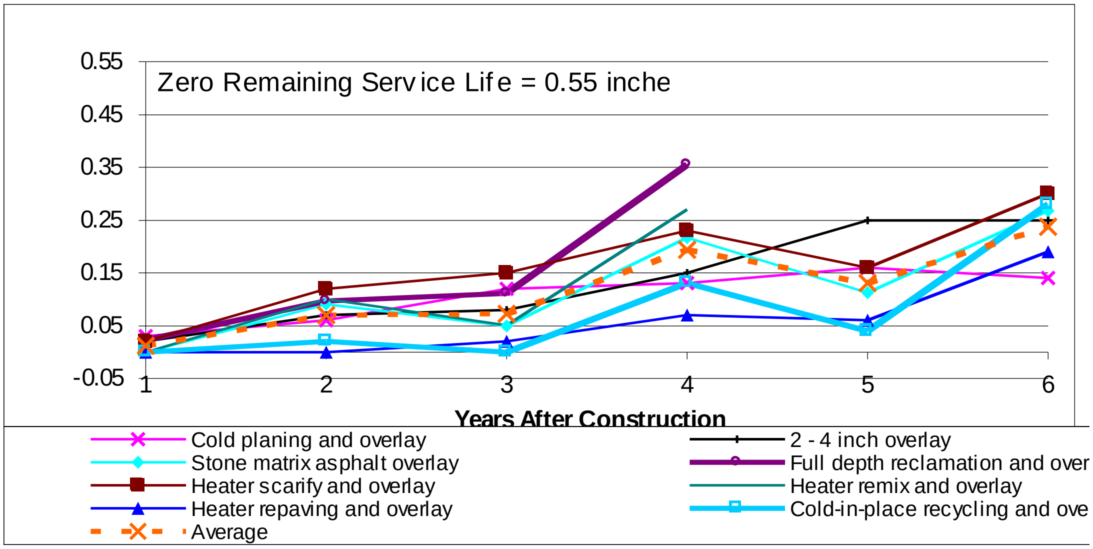

Figure 2. Permanent Deformation Performance After Six Years

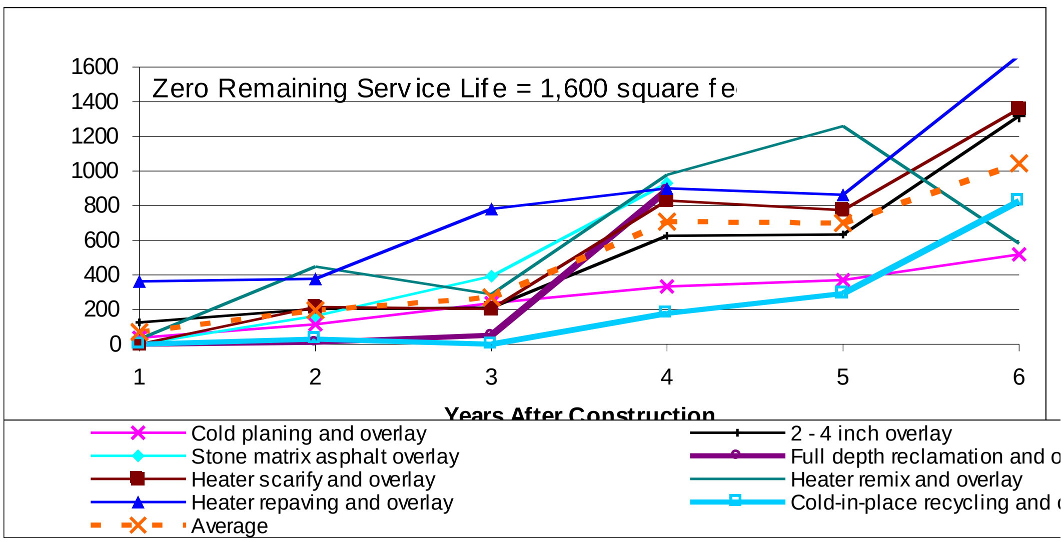

Figure 3. Fatigue Cracking Performance After Six Years

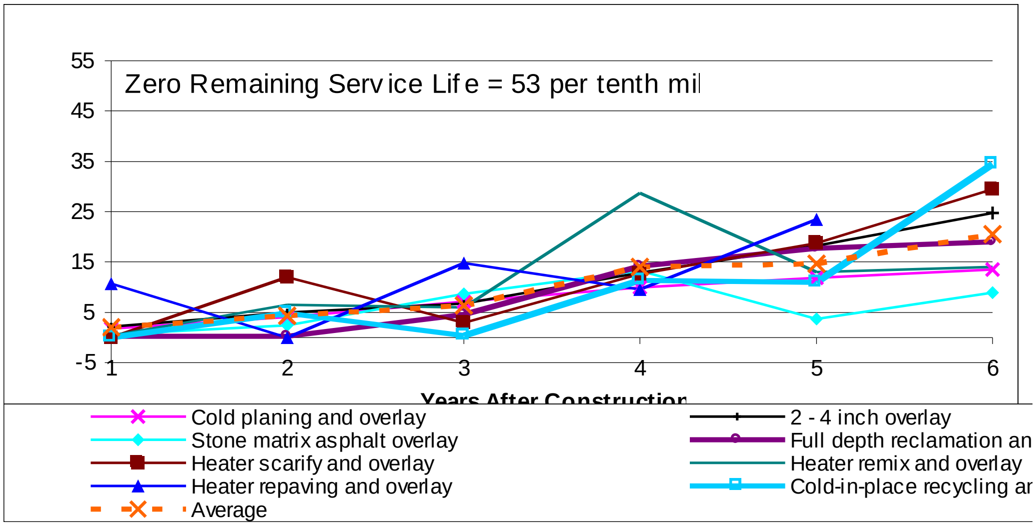

Figure 4. Transverse Cracking Performance After Six Years

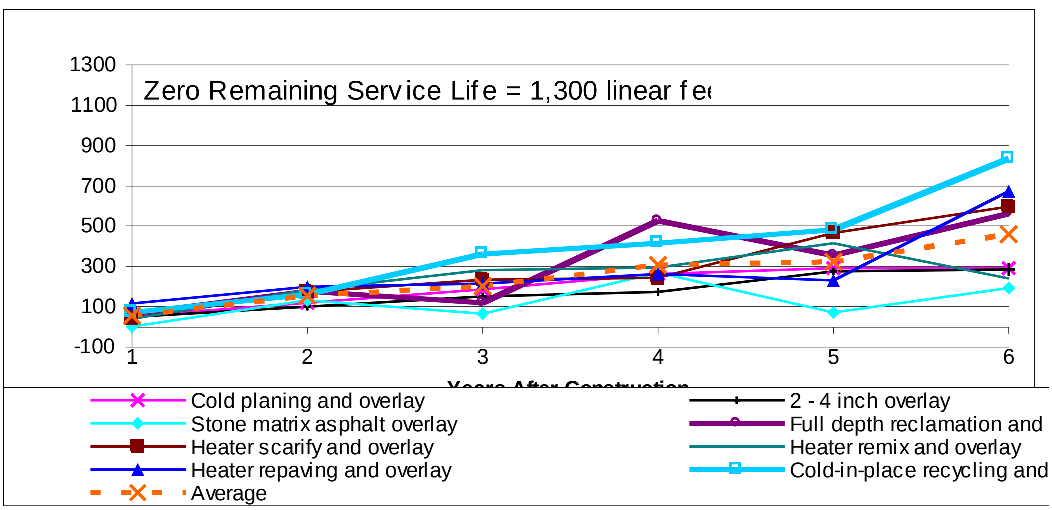

Figure 5. Longitudinal Cracking Performance After Six Years

CONCLUSIONS

Performance is somewhat mixed when looking at all strategies without segregating based on binder type, aggregate grading, traffic and climate results. However, there appears to be a general indication that the cold planing and overlay strategy outperforms the average during the six year evaluation period for each criteria. In addition, the heater scarify and overlay strategy is generally outperformed by the average during the six year evaluation period. Further analysis of this result is warranted, however, as there were 57 cold planing projects compared with 19 heater scarification projects. Also, it appears the cold planing and overlay projects outperformed the straight 2 and 4 inch overlays (75 projects) indicating that the cold planing process may provide some value with respect to rehabilitated pavement performance compared with a simple overlay on the existing pavement surface.

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