THE ECONOMIC VALUE OF PAVEMENT OVERLAY ALTERNATIVES

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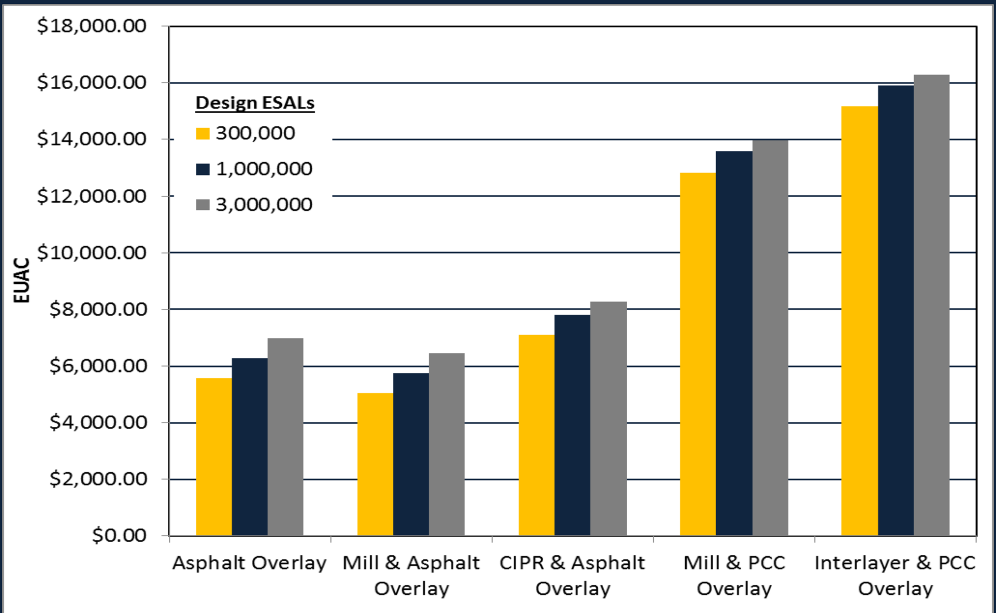
The majority of the US highway roadway system has been completed for many years, thus requiring agency resources to be focused on maintaining and rehabilitating existing pavements. Economic analysis of pavements must consider initial costs, design life, maintenance costs over the life of the pavement and salvage value at the end of its life-cycle. This case study examines five pavement rehabilitation methods for asphalt roadways using equivalent 20-year pavement overlay designs in contrast to the 40-year life cycle designs traditionally used for new construction and full-depth reconstruction. These designs will be judged under the scrutiny of the economic value of the pavement from the beginning to the end of the 20-year pavement life-cycle.



Background

The most common rehabilitation strategy for existing asphalt pavements is using an asphalt pavement overlay, both with and without milling the existing asphalt pavement roadway. The Long Term Pavement Performance Program (LTPP) established the Specific Pavement Studies 5 (SPS-5) experiment consisting of 210 pavement test sections to examine rehabilitation strategies of asphalt concrete pavements (Von Quintus et al., 2006). The SPS-5 experiment considers different rehabilitation techniques and site conditions that were primarily constructed in 1989 and 1990. The study found less transverse cracking on sections with intensive surface preparation than on sections with minimal surface preparation prior to the overlay and that the International Roughness Index (IRI) values were lower (i.e. smoother) for overlays placed on fair condition and milled pavements.

Recent research conducted by Thompson et al. (2009) found both cold-in-place recycling (CIPR) and full depth reclamation of pavements to be successful in Illinois. CIPR has also been used in Iowa successfully for many decades on lower volume roads and generally consists of CIPR all but 2-inches of the existing asphalt pavement and placing a 2 to 5-inch asphalt pavement overlay (Chen et al., 2009).

Recent full-scale testing done in Kansas (Romanoschi et al, 2009) and Minnesota (Burnham, 2005) on concrete overlays have found the use of 6-inch concrete overlays to be superior to those of 4 and 5-inch in thickness. Regardless of the concrete overlay thickness, both researchers found that the bond between the concrete and asphalt pavement surfaces is critical to the performance of the overlays (Burnham, 2005 and Romanoschi et al, 2009). Successful bonding strategies included milling the existing asphalt surface or the use of an asphalt pavement interlayer. Further, the use of fibers and a reduced panel size (3ft by 3ft as compared to 4ft by 4ft) improved performance and placing the joints further from the trafficked wheel paths (Snyder, 2009.)

Socio-Economic Value of Recycled Pavements

The American public has determined that preservation of natural resources is both environmentally and fiscally responsible. Asphalt pavements are commonly recycled through the use of milling machines with the recycled asphalt pavement (RAP) being reused in the new asphalt pavement mixes. Additionally, the use of cold-in-place recycling may be used by first injecting the milled asphalt pavement with a rejuvenating emulsion and then laying the recycled material on the grade as an intermediate stress relief layer. In both cases, the existing asphalt cement and aggregates are recycled and the economic value is recouped when the pavement is rehabilitated. PCC pavements may be crushed and reused as an aggregate base but the value of the Portland cement is not recovered through this method and the removal and crushing operation costs are prohibitive.

Design Considerations

Asphalt pavements are the predominate pavement in the United States. These pavements generally consist of an asphalt pavement surface course, an intermediate and/or asphalt base course, a compacted stone base and a compacted foundation. In rehabilitating this typical pavement structure, this study looks at the five most common and economical methods for rehabilitating a typical asphalt pavement structure: 1. asphalt overlay, 2. milling of the existing asphalt with an asphalt overlay, 3. cold in-place recycling with an asphalt overlay, 4. milling of the existing asphalt with a Portland Cement Concrete (PCC) overlay, and 5. a one-inch asphalt interlayer with a PCC overlay. A baseline pavement structure for this study consisted of six inches of asphalt pavement on six inches of rock base, on a compacted subgrade foundation. The five rehabilitated pavement structures are represented below in Figure 1.

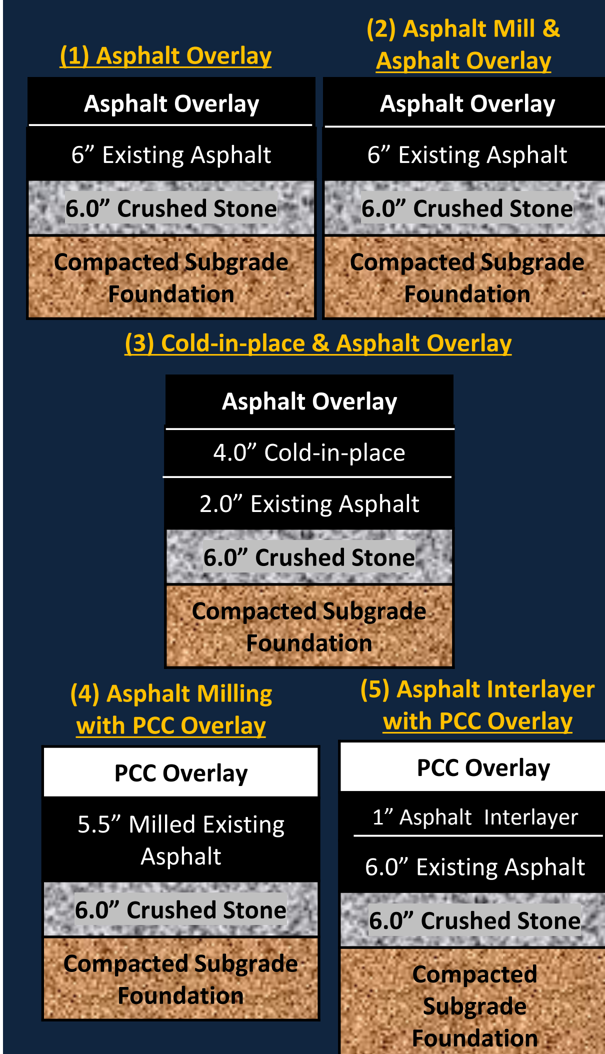


Figure 1. Pavement Design Overlay Options

Pavement Designs

For each of the pavement rehabilitation strategies, three traffic levels were examined: 300 thousand, 1 million and 3 million equivalent single axle loads (ESALs) over a 20-year design period at an 80% level of reliability, resulting in the determination of fifteen pavement designs using the 1993 AASHTO Pavement Design for New and Rehabilitated Pavements. The 20-year pavement designs are summarized in Table 1.

Table 1. Summary of Pavement Designs using 80% Level of Reliability

Design Strategy	ESAL Level	Milling Depth	Overlay Thickness
Asphalt Overlay	300K	0.0”	2.0” Asphalt Pavement
	1M	0.0”	3.5” Asphalt Pavement
	3M	0.0”	5.0” Asphalt Pavement
Milling with Asphalt Overlay	300K	2.0”	3.5” Asphalt Pavement
	1M	2.0”	5.0” Asphalt Pavement
	3M	2.0”	6.5” Asphalt Pavement
Cold-in-place Recycling with Asphalt Overlay	300K	4.0”	4.0” CIPR + 2.0” Asphalt
	1M	4.0”	4.0” CIPR + 3.5” Asphalt
	3M	4.0”	4.0” CIPR + 4.5” Asphalt
Milling with PCC Overlay (Bonded Overlay)	300K	0.5”	5.0” PCC
	1M	0.5”	6.0” PCC
	3M	0.5”	6.5” PCC
Asphalt Interlayer with PCC Overlay (Bonded Overlay)	300K	0.0”	1.0” Asphalt + 5.0” PCC
	1M	0.0”	1.0” Asphalt + 6.0” PCC
	3M	0.0”	1.0” Asphalt + 6.5” PCC

Material Properties used in the design:

- Existing soil with stabilization resulting in a resilient modulus value of 3500 psi,
- 6-inches of crushed stone with a layer coefficient of 0.14/inch,
- Existing asphalt pavement with a layer coefficient of 0.3/inch,
- Asphalt pavement overlay with a layer coefficient of 0.45/inch,
- Cold-in-place recycled pavement with a layer coefficient of 0.36/inch, and
- PCC overlay with a k-value of 236.

Economic Analysis of Designs

The economic analysis was done following the Federal Highway Administration’s (FHWA) recommendations as reported in Life-Cycle Cost Analysis in Pavement Design (Walls and Smith, 1998). The FHWA recommends using the equivalent uniform annual cost analysis approach which considers the effects of the time/value of investment through the use of a discount rate, initial costs, maintenance costs, salvage value, and design life. This method was utilized in examining the aforementioned pavement rehabilitation methods to determine yearly annual costs for each design at an 80% level of reliability. The economic parameters used in the life cycle cost analysis are Minnesota Department of Transportation letting values from 2014 and are summarized in Table 2. The outcomes of the life cycle cost analysis are summarized in Figure 2 and Table 3 below.

Table 2. Values used in Life Cycle Cost Analysis

Asphalt Mixture Price/Ton	$54.96
Asphalt Milling price, for 2"/SY	$1.10
Asphalt Milling, for 0.5"/SY	$0.56
CIP/SY	$3.50
Asphalt Milling Salvage Value/SY inch	$2.00
Surveying/Staking (est.)	$5,000.00
Asphalt Interlayer/SY	$5.20
PCC 6.5“/SY	$21.11
PCC 6.0“/SY	$20.24
PCC 5“/SY	$18.50
PCC Demolition/SY	$5.64

Table 3. LCCA Analysis Results

ESALs	Asphalt Overlay	Mill & Asphalt Overlay	CIPR & Asphalt Overlay	Mill & PCC Overlay	Interlayer & PCC Overlay
300,000	$5,588	$5,044	$7,099	$12,834	$15,163
1,000,000	$6,293	$5,749	$7,800	$13,583	$15,912
3,000,000	$6,998	$6,454	$8,270	$13,957	$16,287

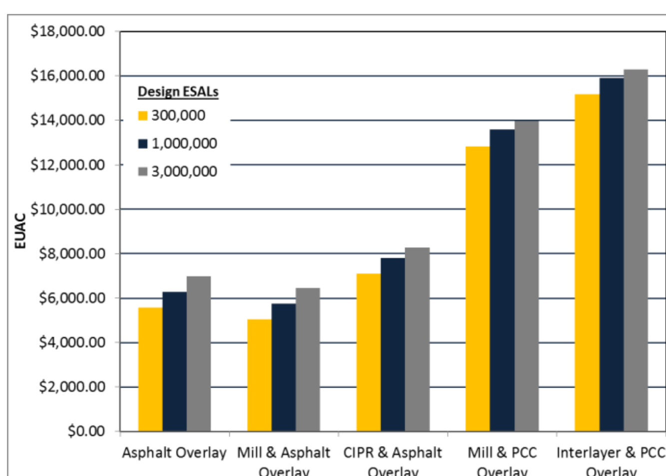


Figure 2. Equivalent Uniform Annual Cost

Findings

Rehabilitation of asphalt pavements is one of the dominant pavement construction practices and will continue as highway facilities mature. The current socio-economic environment is demanding use of public monies to be more efficient with sound environmental practices. The use of life-cycle cost analysis is considered the best method for evaluating competing pavement rehabilitation methods. The ranking of the best economic value for the methods studied were:

1. mill with an asphalt overlay,
2. asphalt pavement overlay,
3. cold in-place recycling with an asphalt overlay,
4. mill with a PCC overlay, and
5. an asphalt interlayer with a PCC overlay.

The current FHWA method of conducting life-cycle cost analysis through end of life value (salvage value) does consider the social and environmental stewardship associated with recycling materials; in addition, this study leads to the conclusion that the best method for rehabilitating asphalt pavements is by using asphalt materials to rehabilitate these roadways.

References

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