Pavement Design Evaluations I-275
Boone and Kenton Counties MP
1.05-7.15

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Pavement Design Evaluations
I-275 Boone and Kenton Counties
MP 1.05 - 7.15

by

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and

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INTRODUCTION

Interstate 275 in Boone and Kenton Counties (MP 1.05 - 7.15) has been in service for more than 20 years. The eastbound lanes from MP 1.05 - 4.07 was rehabilitated by rubblization of the existing continuously reinforced concrete pavement, the addition of an open-graded drainage layer and a 9-inch PCC overlay in 1991. The remaining sections have been broken down into two rehabilitation projects as follows:

Section 1
I-275, Boone/Kenton Counties Kentucky
Eastbound from MP 1.05 - 4.06
3-lanes
Original Construction--1973
11" Jointed Reinforced Concrete Pavement over 6" of Dense-Graded Aggregate Base
MP 1.99 - 4.06
56,000 AADT, 11.5% Trucks
14,603,000 ESALs for 20 years
MP 1.05 - 1.99
76,000 AADT, 11.5% Trucks
21,400,000 ESALs for 20 years

Section 2
I-275, Boone County, Kentucky
East and Westbound MP 4.06 - 7.15
3-lanes
Original Construction--1977
11" Jointed Reinforced Concrete Pavement over 6" of Dense-Graded Aggregate Base
47,000 AADT, 11.5% Trucks
10,700,000 ESALs for 20 years

REHABILITATION ALTERNATIVES

Two rehabilitation alternatives were evaluated for each of the previously mentioned sections. Alternate 1 would break and seat the existing concrete pavement with an application of an asphaltic concrete overlay. Alternate 2 would involve overlaying the existing concrete pavement with a open-graded bond breaker material and then apply a unbonded concrete overlay. The thickness designs were determined based on a design CBR of 3.0 which was used on the previous rehabilitation in the westbound lanes of Section 1.

To allow for the comparison of both the concrete and asphalt alternatives, a 40-year structural design of the pavement was evaluated. Due to the difficulties of forecasting traffic for a 40-year period, the 20-year ESALs were doubled to obtain a 40-year ESAL estimate.
Asphalt Alternative

Thickness designs were developed using the 1993 AASHTO Guide for Design of Pavement Structures and the procedures outlined in Research Report KTRP 87-29 "Pavement Designs Based on Work". The following design parameters were utilized for each design procedure.

Ky Procedure UKTRP Report 87-29

- Broken Concrete Modulus – 25, 100, and 250 ksi
- Subgrade CBR – 3.0

1993 AASHTO Procedure

- Broken Concrete Layer Coefficient – 0.18 and 0.21
- Asphalt Surface Layer Coefficient – 0.44
- Asphalt Base Layer Coefficient – 0.40
- Effective Layer Coefficient of Existing DGA – 0.10
- Initial Serviceability – 4.5
- Terminal Serviceability – 3.0
- Overall Deviation – 0.49
- Reliability – 95%
- Subgrade CBR – 3.0, M_t = 4,500

Using these parameters, thickness designs have been developed for design ESALs from 10,000,000 - 50,000,000. The thickness designs for Section 1 (MP 1.05 - 4.06) are given in Figure 1. The designs for Section 2 (MP 4.06 - 7.15) are given in Figure 2.
I-275 Pavement Design AC Over Broken and Seated Concrete, MP 1.05 - 4.06

- Ky Procedure, 100 ksi Broken PCC Modulus
- AASHTO Procedure, Layer Coefficient 0.21
- KY Procedure, 25 KSI Broken PCC Modulus
- Ky Procedure, 200 KSI Broken PCC Modulus
- AASHTO Procedure, Layer Coefficient 0.18

Figure 1 Asphalt Pavement Design, MP 1.05 - 4.06

I-275 Pavement Design AC Over Broken and Seated Concrete, MP 4.06 - 7.15

- Ky Procedure, 100 ksi Broken PCC Modulus
- AASHTO Procedure, Layer Coefficient 0.21
- KY Procedure, 25 KSI Broken PCC Modulus
- Ky Procedure, 200 KSI Broken PCC Modulus
- AASHTO Procedure, Layer Coefficient 0.18

Figure 2 Asphalt Pavement Design MP 4.06 - 7.15
Based on this analysis, a design thickness of 13 inches of asphaltic concrete over a broken and seated PCC pavement would be recommended for Section 1, and 12 inches of asphaltic concrete would be recommended for Section 2.

**PCC Alternative**

Thickness designs were developed utilizing the Kentucky PCC Pavement Design Catalog and the 1993 AASHTO procedure. To determine the thickness of the required overlay, two parameters must be determined. First, the thickness of new pavement which would be required based on the design traffic and existing subgrade conditions is determined. In addition, the effective thickness of the existing PCC pavement structure must be determined. Once these two parameters are determined the thickness of the required unbonded PCC overlay can be determined using the flowing equation:

\[
D_{\text{overlay}} = \sqrt{D_{\text{future}}^2 - D_{\text{effective}}^2}
\]  

Where:

- \( D_{\text{overlay}} \) = required unbonded overlay thickness,
- \( D_{\text{future}} \) = required PCC thickness of existing conditions,
- \( D_{\text{effective}} \) = effective thickness of the existing PCC pavement based on condition.

To determine the effective thickness of the existing pavement, the actual pavement thickness is reduced based on the estimated remaining life of the pavement structure. A condition factor is determined based on Figure 5.2 in the 1993 AASHTO Guide. The actual pavement thickness, up to 10 inches, is multiplied by the condition factor obtained from the Guide based on an estimated remaining life. For this pavement structure, an estimated remaining life of 50% was chosen, this yields a condition factor of 0.89. Therefore, the effective thickness of the existing pavement structure would be 10 multiplied by 0.89, which yields 8.9 inches. This value was used to determine the required overlay thickness using equation (1) and the future required thickness determined from both the Kentucky and AASHTO methods.

**Kentucky Procedure**

Subgrade CBR = 3, effective k = 100

**1993 AASHTO Procedure**

- PCC Modulus of Rupture – 600 psi
- PCC Modulus of Elasticity – 3,500,000 psi
- Load Transfer Coefficient – 2.7
- Overall Deviation – 0.39
- Reliability – 95%
- Initial Serviceability – 4.5
- Terminal Serviceability – 3.0
- Modulus of Subgrade Reaction – 100 psi
Example:

Existing Pavement Thickness – 11 inches
Estimated Remaining Life – 50%
Condition Factor – 0.89, Figure 5.2, 1993 AASHTO Guide
Required Pavement Thickness for Future Traffic – 12.8”

Effective Pavement Thickness = 0.89 x 10 = 8.9”

\[ D_{overlay} = \sqrt{12.8^2 - 8.9^2} = 9.2'' \]

Using these parameters, thickness designs have been developed for design ESALs from 10,000,000 - 50,000,000. The thickness designs for Section 1 (MP 1.05 - 4.06) are given in Figure 3. The designs for Section 2 (MP 4.06 - 7.15) are given in Figure 4.

**Figure 3** Unbonded PCC Overlay, MP 1.05 - 4.06
Based on this analysis, an unbonded PCC overlay of 10 inches would be recommended for section 1, and a 9-inch overlay would be recommended for section 2.
LIFE CYCLE COST ANALYSIS (LCCA)

Kentucky currently uses a procedure developed in an EXCEL spreadsheet. This procedure is used to compare various design and rehabilitation alternatives. It is a present-worth analysis based on estimates of construction and rehabilitation costs for various discount rates (0, 2, 4, 6, 8, and 10). The procedure outlined in FHWA-SA-98-079 ("Life Cycle Cost Analysis in Pavement Design") was used for the analysis of user costs. Both alternatives were analyzed over a 40-year design period with periodic rehabilitation cycles included.

The rehabilitation schedule for the 40-year analysis period is as follows:

**AC Pavements**
- Year 10 – Mill 1.5" Overlay 1.5"
- Year 20 – Mill 1.5" Overlay 1.5"
- Year 30 – Mill 1.5" Overlay 1.5"

**PCC Pavements**
- Year 15 – Clean and Reseal Joints
- Year 30 – Clean and Reseal Joints

At year 40, a salvage value for each alternative is determined. This salvage value is calculated by taking the total quantity of all paving from the rehabilitation and the original structure and assigning a value equal to that of dense-graded aggregate.

The material unit costs were determined by developing a weighted average cost based on information obtained from three years of unit bid prices. This weighted average was determined based on the quantity of materials in each bid. The unit costs utilized in the LCCA analysis are given in Table 1.
User Cost Analysis

As was previously outlined, the user costs for the project were evaluated based on procedures outlined in Research Report FHWA-SA-98-079. This procedure calculates the user delay cost based on the reduction in capacity of the highway which was based on the parameters of the construction work zone. Separate analyses of user costs were conducted for each design section due to the differences in traffic volumes. User costs were calculated both for the initial construction phase of the project and for rehabilitation at years 10, 15, 20, and 30. These user costs were based on current and projected traffic levels in each of the rehabilitation years. Daily user costs and average length of queue were determined at each of these time intervals. Costs associated with user delay, idling, stopping, and etc. were determined from Research Report FHWA-SA-98-079. During the initial construction and each of the subsequent rehabilitations the work zone parameters, such as number of lanes and working hours must be identified. The following scenarios were utilized for this analysis:

Initial Construction

2 lanes open, 24 hours per day

Rehabilitation Years 10, 15, and 20

2 lanes open, 6 p.m. - 6 a.m.
3 lanes open, 6 a.m. - 6 p.m.

Rehabilitation Year 30

2 lanes open 7 p.m. - 6 a.m.
3 lanes open 6 a.m. - 7 p.m.
Based on this analysis, the expected user costs for both sections of the project are given in Table 2.

### Table 2. User Cost Analysis

<table>
<thead>
<tr>
<th>Activity</th>
<th>Year</th>
<th>Length (days)</th>
<th>Traffic Vol.</th>
<th>1-Direction Daily User Cost ($)</th>
<th>1-Direction Project User Cost ($)</th>
<th>Avg. Queue Length (mi)</th>
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<th>Activity</th>
<th>Year</th>
<th>Length (days)</th>
<th>Traffic Vol.</th>
<th>1-Direction Daily User Cost ($)</th>
<th>1-Direction Project User Cost ($)</th>
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The summary of the LCCA is contained in Table 3 for Section 1 and Table 4 for Section 2 and in Figures 5 and 6.
Table 3. LCCA summary MP 1.05 - 4.06

### Alternate 1A
#### 13" AC Overlay

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### Alternate 1B
#### 10" PCC Overlay

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Table 4 LCCA Summary, MP 4.06 - 7.15
Figure 5. Net Present Value, MP 1.05 - 4.06

Figure 6. Net Present Value, MP 4.06 - 7.15
It may be seen from the results of the LCCA that the net present values for the alternatives in both sections are very close to one another. In Section 1, (Figure 5) it may be seen that for discount rates less than 5 percent, the PCC alternative would have a lower net present value, while above 5 percent, the AC alternative would have a lower net present value. The same scenario holds true for Section 2, Figure 6, in that the PCC overlay would have the lower net present value below approximately 3.5 percent, while the AC alternative would be lower above 3.5 percent.

Typically, LCCA comparisons are conducted at discount rates from 3 to 5 percent. Therefore, it may be seen from the above analysis that for this project, the LCCA did not identify a preferred alternative.

**SUMMARY AND CONCLUSIONS**

Two different pavement rehabilitation alternatives have been identified for each design section, based on the analysis of the current and projected traffic and the existing pavement conditions. The pavement structural design has been evaluated utilizing two methods for each alternative and the following designs would be recommended:

**Section 1 – MP 1.05 - 4.06**  
Break and Seat existing PCC pavement  
Construct a 13-inch AC Overlay  
   or  
Construct a 10-inch Unbonded PCC Overlay

**Section 2 – MP 4.06 - 7.15**  
Break and Seat existing PCC pavement  
Construct a 12-inch AC Overlay  
   or  
Construct a 9-inch Unbonded PCC Overlay

Based on the analysis conducted for this project, the life cycle cost analysis would not identify a preferred alternative.
REFERENCES

