Summary Report:
BRIDGE DECKS CONTAINING EPOXY-COATED REINFORCING STEEL

In 2010, a report was prepared for the Michigan Department of Transportation on the expected service life of concrete bridge decks.[1] This report concluded that decks with epoxy-coated reinforcing steel would provide a service life of 70 years and that the use of Markov transition probabilities is acceptable and accurate in analyzing bridge data. This document summarizes that report.

INTRODUCTION

Michigan DOT started using epoxy-coated reinforcing steel in the mid 1970s, and in the late 1980s the Engineering Operations Committee approved the use of epoxy-coated rebar for all bridge decks. In 2010, a study was conducted by B. Boatman and published by the Michigan DOT with the following objectives:

- Estimate the service life of bridge decks containing black (uncoated) reinforcing steel
- Estimate the service life of bridge decks containing epoxy-coated reinforcing steel
- Review the accuracy of Markov's transition probabilities
- Identify different variables influencing the deterioration of the deck surface.

The ultimate objective of the study was to accurately predict the service life of decks with epoxy-coated reinforcing steel. The service life was defined as the time taken for the deck to reach a poor condition. Poor condition of a deck surface is defined as a rating of 4 or less in the *Bridge Safety Inspection Report*, indicating a need for rehabilitation.

MARKOV MODEL

The Markov model uses transition matrices that describe the probability that a bridge element in a known condition at a known time will change to another condition state in the next time period. The process assumes that the probability of changing from one state to another is only a function of the condition state and the time period in which the deck is located. Thus, prior performance of a deck has no impact on the predicted rate of change in the future performance.

Once transition ratings are determined, these are converted to a deterioration rate using the following equation:

$$n = \frac{\log(0.5)}{\log(T)} \qquad \text{...Equation (1)}$$

Where
T = transition probability
n = average number of years to reach next condition state

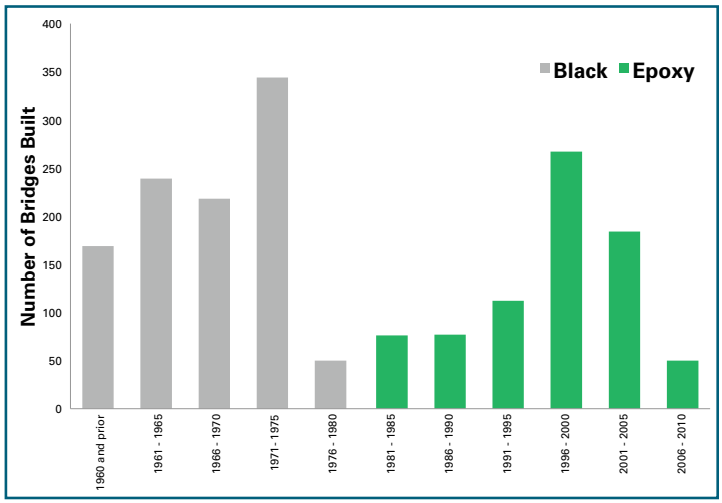

Figure 1:
Number of decks used for Markov analysis.

DATA

Data from 1,790 bridge decks was selected for use. Of this sample, 766 contained epoxy-coated reinforcing steel and 1,024 contained black reinforcing steel. This data was selected from an original sample of 4,350 total bridge decks. Only decks with the following characteristics were selected:

- Monolithic concrete wearing surface
- No membrane
- No bridges requiring reconstruction after 2003
- No bridges built with epoxy prior to 1980
- No bridges built with black bars after 1980

The number of decks used is shown in **Figure 1.**

TRANSITION PROBABILITIES

Transition probabilities were determined using deck surface ratings from 2004 to 2010. These ratings were analyzed from year to year intervals, resulting in a transition probability for each year. In 2004, 234 ECR decks held a rating of 7. In 2005, 227 remained at a rating of 7, while 7 decks worsened to a rating of 6. The transition probability is 97% will remain at 7, while 3 percent will worsen to a rating of 6. This process was conducted for all data from 2004 to 2010, resulting in six different probability matrices. These were then averaged, resulting in an average transition probability matrix.

RESULTS

Table 1 shows the average transition probability from 2004 to 2010 for black bars, while **Table 2** shows the average transition probabilities for epoxy-coated bars. The numbers on the left side represent the previous year's rating. The numbers of the top represent the following year deck rating. The values highlighted represent the average transition probabilities. The values at the bottom of each table are calculated from Equation 1 and added to provide the total time period for a deck to move from one rating to another. These shaded values are also plotted in Figure 2.

Table 1: Deck Surface Rating Transition Probability Matrix for Black Bars (Average from 2004 to 2010)

Current year rating	0	1	2	3	4	5	6	7	8	9
Prior year rating	Percent Probability									
9	0	0	0	0	0	0	0	0.060	0.529	0.411
8	0	0	0	0	0	0.001	0.015	0.183	0.801	
7	0	0	0	0	0.001	0.004	0.095	0.900		
6	0	0	0	0.001	0.009	0.004	0.951			
5	0	0	0	0.008	0.051	0.940				
4	0	0	0	0.044	0.955					
3	0	0	0	1						
2	0	0	0							
1	0	0								
N (years)					15.23	11.23	13.77	6.55	3.13	0.78
ΣN (years)					**50.69**	**35.46**	**24.23**	**10.46**	**3.91**	**0.78**

Table 2: Deck Surface Rating Transition Probability Matrix for Epoxy-coated Bars (Average from 2004 to 2010)

Current year rating	0	1	2	3	4	5	6	7	8	9
Prior year rating	Percent Probability									
9	0	0	0	0	0	0	0.002	0.071	0.481	0.445
8	0	0	0	0	0	0	0.007	0.165	0.828	
7	0	0	0	0	0	0	0.031	0.968		
6	0	0	0	0	0	0.010	0.967			
5	0	0	0	0	0	1				
4	0	0	0	0	0					
3	0	0	0	0						
2	0	0	0							
1	0	0								
N (years)							21.29	21.50	3.66	0.86
ΣN (years)							**47.32**	**26.03**	**4.52**	**0.86**

DISCUSSION

As shown in **Figure 2**, the black bars moved from a rating 5 to 4 at approximately 35 years. Based upon review of other agency data, it was found that overlays were applied on decks with uncoated bars at an average of 38 years, corresponding very well to the Markov analysis.

For decks with epoxy-coated bars, a sample size of 766 decks was used. Due to the fact that only deck ratings between 5 and 9 were obtained, there is no probability that a deck rating of 5 will turn into a rating of 4. Figure 2 shows that for epoxy-coated bars it takes 25 years to achieve a rating of 6 and 47 years to achieve a rating of 5. If a similar straight line to the black bars is used for estimating the time for decks to reach a rating of 4, a time of 70 years is obtained.

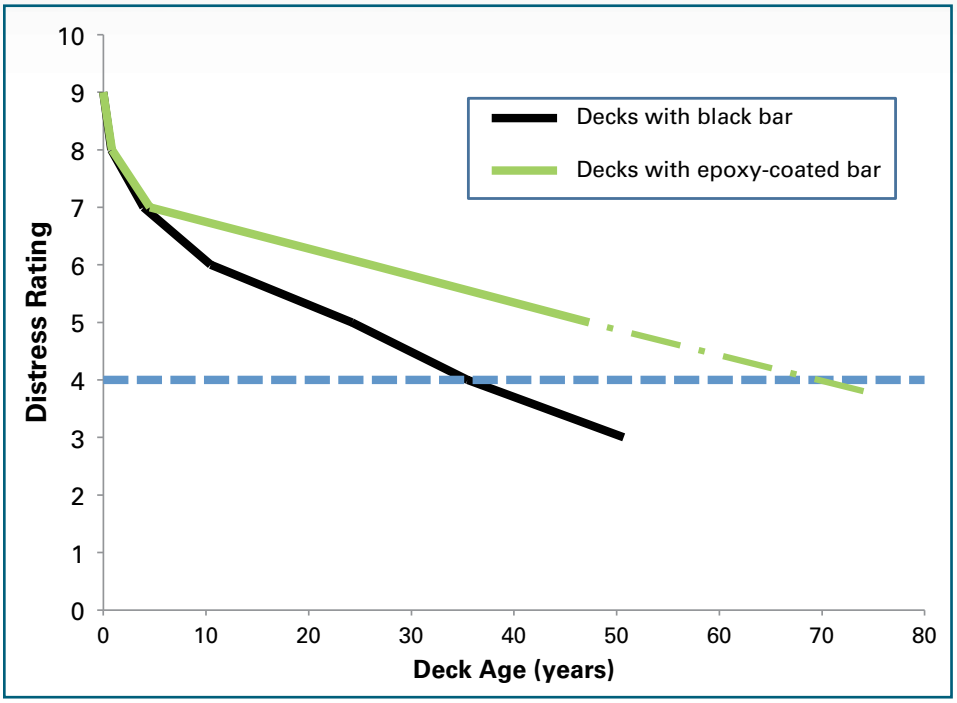

Figure 2: Rating vs Deck age based upon Transition probabilities.

CONCLUSION

Epoxy-coated bars are providing better performance than standard black rebar bridge decks. The decks with black bars reach a grade of 6 approximately 10 years prior to that observed for the epoxy-coated bar decks. A deck with black bars reaches a grade of 5 within 24 years, while the epoxy-coated bar decks reach the same rating after 47 years.

The following conclusions were reached:

- The service life of black bar bridge decks is estimated to be 35 years.
- The service life of an ECR bridge deck is estimated to be approximately 70 years.
- Markov transition probabilities are determined to be acceptable and fairly accurate in analyzing bridge deck data.

REFERENCES

1. Boatman, B. ***Epoxy Coated Rebar Bridge Decks: Expected Service Life***; Michigan Department of Transportation, MI: 2010.

MacArthur Bridge, Detroit, Michigan
Cover photo courtesy of Shutterstock.

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