Expected Service Life of Michigan Department of Transportation Reinforced Concrete Bridge Decks

Prepared for
Michigan Department of Transportation
Bureau of Development, Design Division,
Bridge Development Section

By
Stacey Valentine, Undergraduate Student
University of Michigan

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Introduction

1.1 History

This report provides an update to the “Epoxy Coated Rebar Bridge Decks: Expected Service Life” report by Brandon Boatman from 2010[1].

The Michigan Department of Transportation (MDOT) has been designing and constructing bridges dating back to the early 1900s. Around 1975, the first use of epoxy coated rebar (ECR) was implemented into concrete bridge deck design. Variations of the epoxy coating and design details were experimented with, and in 1982, the Engineering Operations committee approved the use of epoxy coated rebar for all bridge decks in the top and bottom mat. To this date, ECR is the most common rebar used to reinforce MDOT bridge decks, but there are two other types of rebar that have been used in recent years. In 1982, the first use of stainless steel rebar was implemented into a concrete bridge deck design and in the 2000s, stainless rebar was implemented into multiple designs and included as a standardized option in the bridge design manual. In the 2000s, fiber reinforced polymer (FRP) also started to be implemented into MDOT bridge deck design. MDOT owns one aramid fiber reinforced polymer (AFRP) bridge deck, built in 2000; and three carbon fiber reinforced polymer (CFRP), with the first being built in 2010. Michigan also has a local agency bridge, the Bridge Street Bridge owned by the City of Southfield, built with CFRP reinforcement and prestressing. This structure, built in 2001, was the first vehicular bridge built in the United States using CFRP reinforcement and prestressing.

1.2 Objective

The objectives of this study are as follows:

- Update the estimate for service life of ECR bridge decks.
- Review the early age performance of stainless rebar bridge decks.
- Review the early age performance of FRP rebar bridge decks.

1.3 Methodology

The study uses the National Bridge Inventory (NBI) condition rating scale to show the performance of ECR, stainless rebar, and FRP rebar bridge decks. The condition ratings range from 0 (failed) to 9 (excellent). A bridge deck surface rated 7 through 9 is considered to be in good condition. A deck surface rated 5 or 6 is rated in fair condition, and a bridge rated 4 or below is in poor condition in need of rehabilitation. The time it takes for a new deck to reach a condition state of 4 (poor) is called “time to poor” or “service life” of the deck surface. ECR used transition probabilities to estimate the time to poor, while stainless rebar and FRP rebar decks were plotted based off each bridge’s NBI condition rating to review the early age performance of the bridge decks.

1.3.1 Data Set

A data set of 805 bridge decks was selected for use within this study. Out of this sample, 788 were ECR bridge decks, thirteen were stainless rebar bridge decks, and four were FRP rebar bridge decks. ECR bridge decks were filtered to remove bridges with prestressed box beams built prior to 1989 (Item 43A = 5 or 6, Item 43B = 05) because this structure type uses a 1 ½ inch unreinforced concrete overlay instead of a reinforced concrete deck. All thirteen stainless rebar bridge decks were used in the study. There are five FRP bridge decks in Michigan. Four are owned by MDOT and one by a local agency. Only the four MDOT FRP decks were used in the study. The local agency structure carries Bridge Street Bridge over Rouge River (Structure Number: 8305, Bridge Key: 635634800672B01). In several instances, surface ratings prior to the current build date were discarded for ECR, stainless, and FRP bridges, because the bridges had been rebuilt.

1.3.2 Transition Probabilities and Deterioration Curves

In order to provide an updated service life estimate for ECR, transition probabilities were calculated using bridge deck surface ratings from 2009 to 2015. These ratings were analyzed from year to year intervals, resulting in a transition probability for each year. For instance, in 2009 340 ECR bridge decks held a rating of a 7 (good). In 2010, 325 remained with a rating of 7 (good), while the other 15 decks worsened to a rating of a 6 (satisfactory). The transition probability is 95% that the deck will remain at a 7 (good), and a 5% chance that the deck will lower to a 6 (satisfactory). This was repeated for all condition ratings in the years 2010-2011, 11-12, 12-13, 13-14, and 14-15, resulting in six different matrices shown in the appendix. The probabilities were then averaged based on the six different matrices, resulting in an average transition probability matrix. The transition probabilities were then converted to a deterioration rate using the following equation:

$$n = \frac{\log(0.5)}{\log(T)}$$

T = Transition probability
n = Average number of years to reach next condition statement

Deterioration rates help predict the time for a bridge deck to reach a specific condition state. The deterioration curves are plotted with the x-axis showing time in years (from build date) and y-axis showing NBI condition rating. Stainless rebar and FRP rebar do not have enough data to be able to calculate the transition probabilities. As an alternative, each bridge’s NBI rating was plotted from date built or reconstructed. A trend line was added to the stainless and FRP graphs to show how both types of rebar are performing, at least in their early life.

Results

2.1 Epoxy Coated Rebar

Table 2-1 displays the average transition probability from 2009-2015 for ECR bridge decks. The numbers located along the left side and highlighted in bright green represent the previous year deck surface rating. The numbers located along the top and highlighted in bright green represent the following year deck surface ratings and highlighted in blue are the average transition probabilities, with the value furthest to the right being the transition probability of the deck surface rating remaining the same and the values to the left are the probability that the rating will fall into the denoted condition. For instance, in Table 2-1, there is an 80.42% chance that a deck surface rated 8 (very good) will remain an 8 (very good) the following year, and a 17.52% chance the deck surface rating will fall to a 7 (good) rating. The light purple values are the calculated average number of years to reach the next condition state. The yellow values are the cumulative time to reach the next condition state from the built date.

Table 2-1: Average Transition Probability Matrix for Epoxy Coated Rebar

				Epoxy Rebar						
				107=1 108a=1 108b=0 108c=0						
Average from 2009-2015				**Item 58A Deck Surface Ratings**						
	Transition Probability Matrix							Percent		
	0	1	2	3	4	5	6	7	8	9
9	0	0	0	0	0	0	0.006448	0.1115772	0.2853956	0.000001
8	0	0	0	0	0	0.0010753	0.0195757	0.175192	0.804157	0.0501717
7	0	0	0	0	0	0.002228	0.0370264	0.9603534	3.1801471	
6	0	0	0	0	0.0015291	0.0192918	0.9791791	17.134252	3.2303188	
5	0	0	0	0	0.0098039	0.9901961	32.943216	20.364571		
4	0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	70.35387	53.307788			
3	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	123.66166				
2	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!					
1	#DIV/0!	#DIV/0!								

Figure 2-1 displays the deck surface ratings plotted against deterioration rates calculated in Table 2-1. This graph shows that given today's deterioration rates, on average, it takes 53 years to attain a deck surface rating of 5 (fair). Because there is a lack of MDOT bridge decks having reached a deck surface condition of 4 (poor) or less, the deterioration curve can only be estimated beyond a condition rating of 5 (fair), represented by a dotted line.

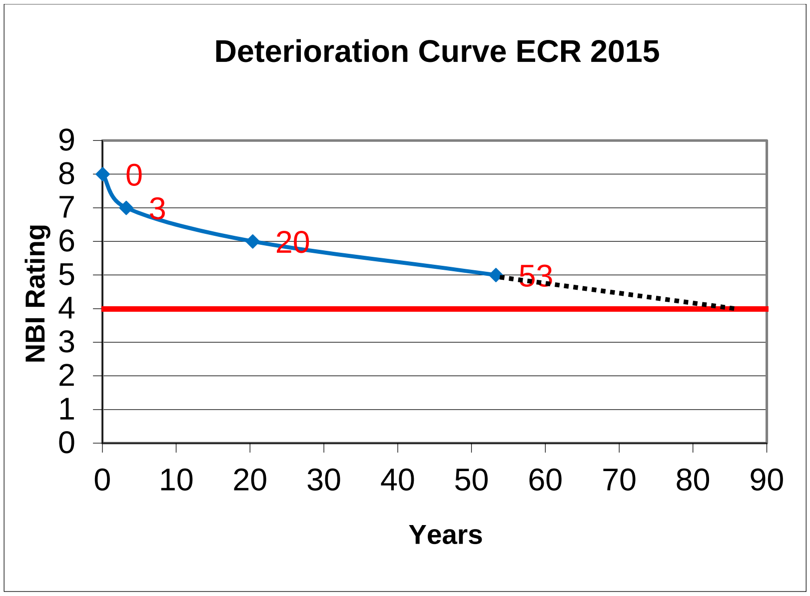

Figure 2-1: ECR Bridge Deck Deterioration Curve 2015

2.2 Stainless Rebar

There are thirteen bridge decks that have stainless rebar in Michigan. The MDOT bridges that have stainless rebar decks are as follows, showing the most recent NBI condition rating for the deck surface, deck bottom surface, and overall deck:

Structure Number	*Facility*	*Feature*	*Year Built*	*Deck Surface (Item 58A)*	*Deck Bottom Surface (Item 58B)*	*Deck (Item 58)*
3770	I-496 WB	CSX RR & Holmes St.	2000	6	6	6
12532	M-37	Pine River	2011	8	7	8
783	I-94 WB	Galien River	2008	7	6	6
782	I-94 EB	Galien River	2008	7	6	6
11729	Cicotte Ave	I-75	2002	7	8	7
11665	Champaign Rd	I-75	2002	8	9	8
11662	London Moore Rd	I-75	2002	7	8	7
1253	I-94 WB	Riverside Drive	2009	7	7	7
1252	I-94 EB	Riverside Drive	2009	7	7	7
11381	NB Oakland Ave	M-8	2000	7	8	8
11133	I-94	Greenfield Rd	2004	8	7	7
8470	M-64	Duck Creek	2013	8	8	8
7964	I-696 to I-75 Ramp	N-S Service Rd	1982	7	7	7

Due to the limited number of bridges and years in service, a transition probability from 2009-2015 for stainless rebar was not created. Instead of using the transition probability matrix, all the stainless steel bridges were plotted together as shown in Figure 2-2, to find the overall linear regression of stainless rebar bridge decks. As shown in Figure 2-2, stainless rebar decks take an average of 19 years to attain a deck surface rating of 7 (good). When comparing this limited data to that of ECR decks, it appears stainless steel--at least in early life--is performing better.

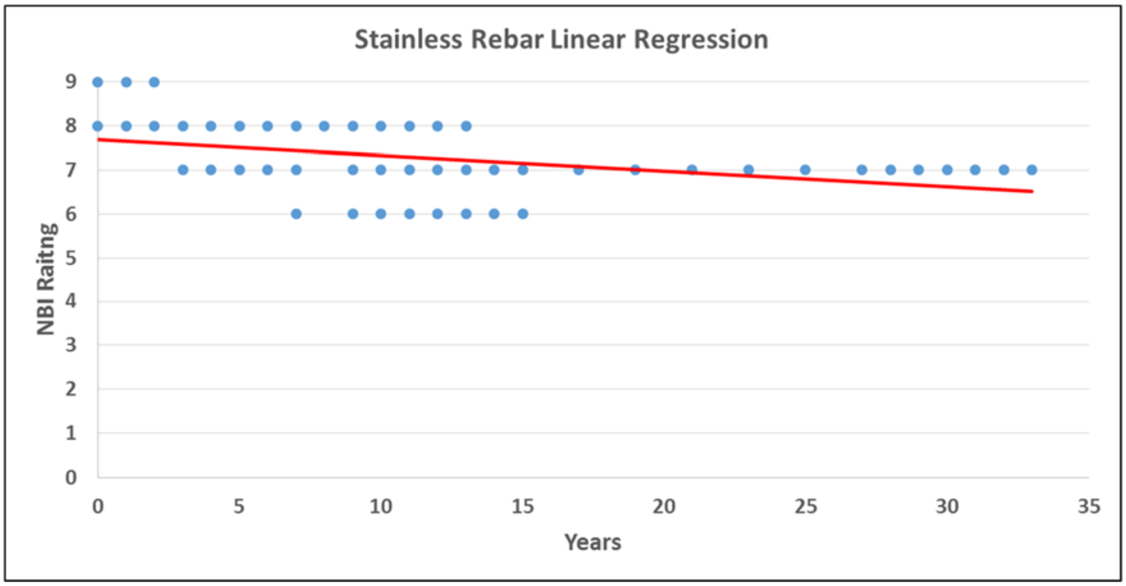

Figure 2-2: Stainless Rebar Bridge Deck Linear Regression

2.3 Fiber Reinforced Polymer

There are four MDOT owned bridge decks that have used FRP rebar, and all of these bridges have been built in the past 15 years. The bridges are as follows, showing the most recent NBI condition rating for the deck surface, deck bottom surface, and overall deck:

Structure Number	*Facility*	*Feature*	*Year Built*	*FRP Type*	*Deck Surface (Item 58A)*	*Deck Bottom Surface (Item 58B)*	*Deck (Item 58)*
11621	M-102 EB	Plum Creek	2013	Carbon	7	8	7
13482	M-102 WB	Plum Creek	2013	Carbon	9	9	9
10408	M-15	Goodings Creek	2000	Aramid	6	6	6
11712	Pembroke Ave	M-39	2010	Carbon	9	N	9

Just like stainless rebar there is a limited amount of data, so the transition probability matrix could not be used. The four MDOT bridges were plotted together in Figure 2-3 to find the overall linear regression of the FRP rebar bridge decks. Based on Figure 2-3, FRP rebar decks take on average 12 years to attain a surface rating of 6 (satisfactory). Comparing this very limited data to ECR (20 years to reach NBI Deck Surface condition rating of 6) shows early life of FRP decks do not appear to be performing as well as ECR decks. Bridge inspector comments show that the predominant deficiency being reported in these decks is cracking. MDOT engineers note that FRP has a lower modulus of elasticity than steel, which may explain the deck cracking that is occurring in the FRP decks. Examples of inspector comments are as follows:

- Goodings Creek (Structure: 0408):
  - Two longitudinal cracks visible in the wheel patches of the southbound lane and two longitudinal cracks visible in the center of the northbound lane. (08/14)
- Plum Creek (Structure: 11621):
  - New concrete. Deck with combination of CFCC and conventional reinforcement. 1/16” cracks at 5’ at both ends. (09/14)

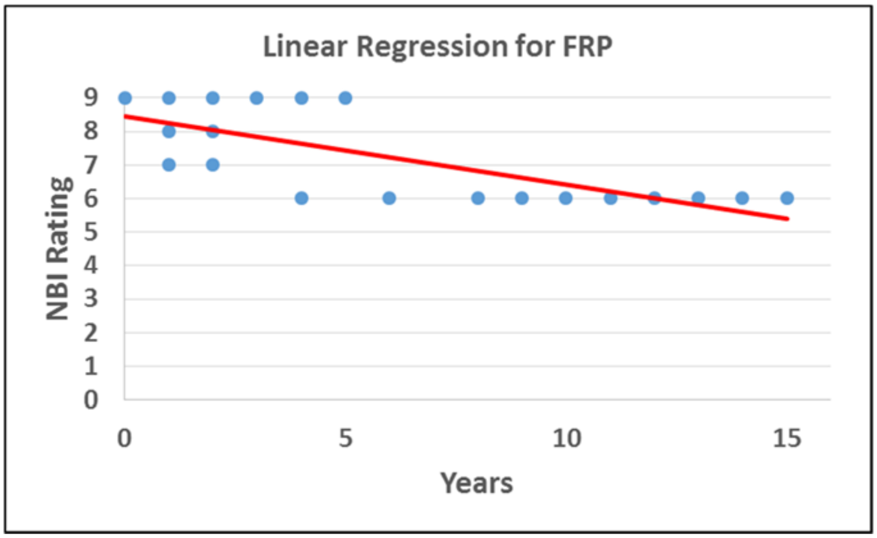

Figure 2-3: FRP Rebar Bridge Deck Linear Regression

Extensive deck cracking was also observed in the local agency owned CFRP bridge deck carrying Bridge Street, as shown in Figure 2-4. The bridge deck has a 1½ inch concrete overlay, so it believed that the cracking is mostly influenced by delamination of the concrete overlay from the structural deck.

Figure 2-4: Cracking on north span of Bridge Street Bridge

Discussion

3.1 Expected Service Life of Bridge Decks

3.1.1 Epoxy Coated Rebar

With five additional years of data, it still is not possible to conclusively estimate the time it takes for ECR bridge decks to attain a deck surface rating of 4 (poor), because after 33 years so few of these decks have reached a poor condition rating. There is only one bridge that the deck surface has reached poor condition, and this deck built with a 7 ½ inch deck, two mats of ECR, and 1 ½ inch concrete overlay, is not indicative of the current design which is a solid nine inch deck with two mats of ECR rebar. Figure 2-5 shows the ECR deterioration curve from 2010 and 2015. Based on Figure 2-5, the deterioration rate of ECR has remained relatively consistent in the last five years. With the additional five years of data, the early life of ECR bridge decks are shown to deteriorate at a slightly faster rate than predicted in 2010. A rating of 6 was achieved in 26 years in 2010, compared to 20 years in 2015. Between 2010 and 2015, ECR bridge deck surfaces lingered longer between a rating of 6 (satisfactory) and 5 (fair). A rating of 5 is achieved in 47 years in 2010, compared to 53 in 2015. The amount of time ECR bridge deck surfaces linger between a rating of 6 (satisfactory) and 5 (fair) increased by 12 years from 2010 to 2015. This increase shows that ECR decks are performing better than the data predicted five years ago. This may be the result of MDOT's deck preservation program. In both years, the deterioration curve can only be estimated beyond a condition of 5 (fair). The 2010 study estimated the time to poor for ECR decks was 70 years, the new estimation from 2015 is 86 years.

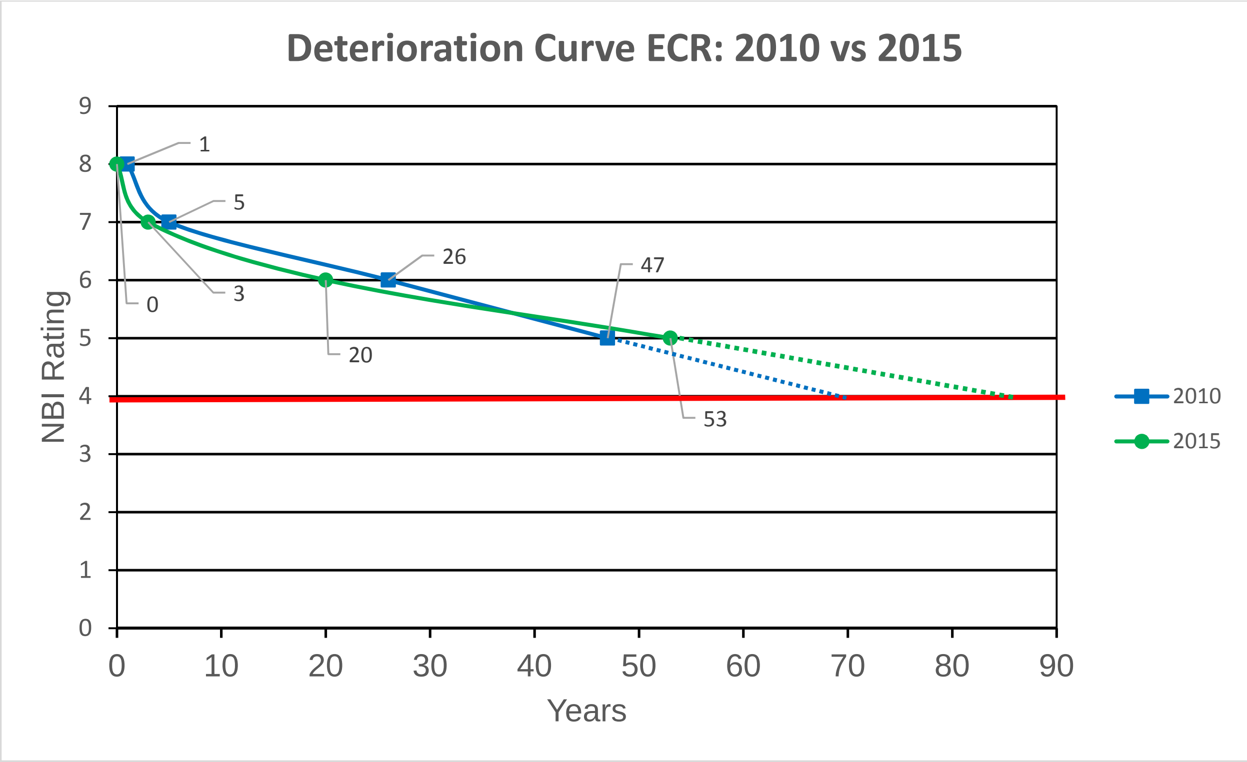

Figure 2-5: ECR Bridge Deck Deterioration Curve 2010 and 2015

3.1.2 Stainless Rebar

A sample size of thirteen stainless rebar bridge deck surface ratings range from 9 (excellent) to 6 (satisfactory). The maximum time since built date is 33 years. The limited ratings and years did not allow for transition probabilities to be calculated. Instead, all thirteen bridges were plotted and a linear trend line is shown for the deck surface ratings. Figure 2-2 shows it is estimated to take 19 years to reach a rating of 7 (good).

3.1.3 Fiber Reinforced Polymer

The four MDOT owned FRP rebar bridge deck surface ratings range from 9 (excellent) to 6 (satisfactory) and the maximum time since built date is 15 years. The limited ratings and years, did not allow for transition probabilities to be calculated. Just like stainless rebar decks, the FRP rebar decks were plotted and a linear trend line is shown for the deck surface rating. Figure 2-3 shows 7 years to reach a rating of 7 (good) and 12 years to reach a rating of 6 (satisfactory). Beyond a rating of 6 (satisfactory), it is not yet possible to estimate the time to a specific NBI rating.

The Goodings Creek Bridge was built in 2000 and used AFRP rebar. The superstructure is spread box beams and the deck is nine inch with two mats of AFRP rebar. As of 2015, the deck surface has a rating of 6 (satisfactory). This deck has been rated a 6 (satisfactory) since four years after it was constructed. The southbound lane has two longitudinal cracks visible in the wheel patches and the northbound lane has two longitudinal cracks visible in the center of the lane. The width of the four longitudinal cracks range from 1/32 inch to 1/16 inch, which are defined as moderate and wide cracks respectively in the Michigan Bridge Element Inspection Manual[2].

Figure 2-6: Longitudinal crack on southbound lane

Figure 2-7: Longitudinal crack with a width of 1/16 in at the top

The first MDOT owned CFRP rebar bridge is the Pembroke Avenue Bridge, built in 2012. The bridge has a six inch deck with a single row of CFRP rebar, supported by side-by-side prestressed box beams. The prestressed box beams use more extensive transverse post tensioning which likely contributes to the good performance. As of 2015 it is still rated a 9 (excellent). There are no cracks observed on this deck.

Figure 2-8: Pembroke Ave in excellent condition (Rated 9)

Caution needs to be taken when evaluating the performance of MDOT’s FRP bridge decks as all are demonstration projects using differing materials and design.

3.1.4 Comparison

Figure 2-9 shows the ECR deterioration curve, the stainless rebar deck surface ratings, the stainless trend line, the FRP rebar deck ratings, and the CFRP trend line. The methodologies for calculating the deterioration line or curves are different so one must be careful in over interpretation of the trends. However, given the best information MDOT has at this time, a rough comparison of early age performance is shown.

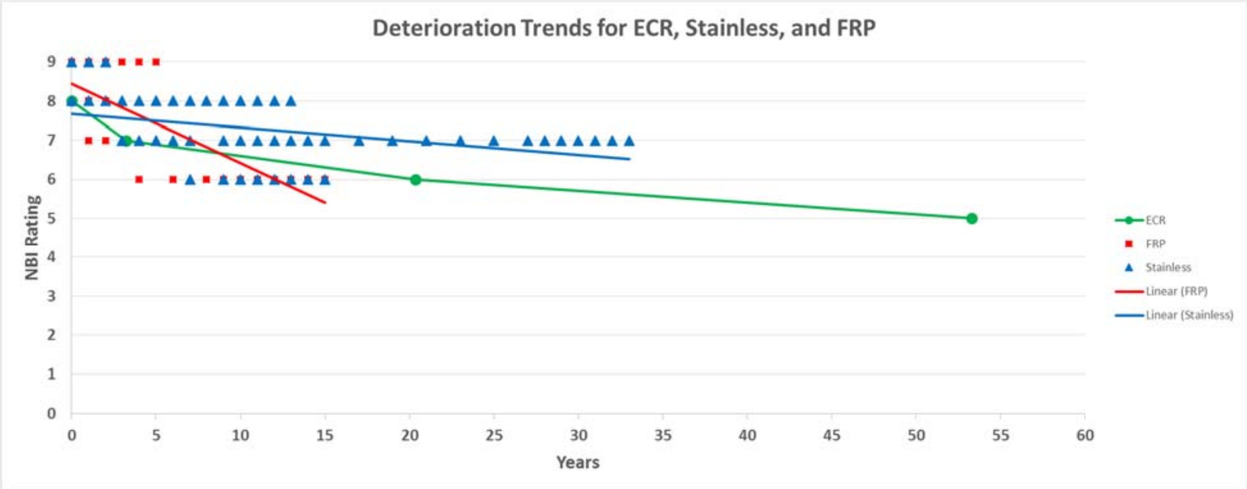

Figure 2-9: Deterioration trends of ECR, Stainless and CFRP

Conclusion

The study has yielded the following conclusions:

- The service life of an ECR bridge deck is estimated to be approximately 86 years. Comparing the resulting deterioration curves from 2010 to 2015, it shows good correlation and consistently good performance of MDOT's ECR reinforced bridge decks.
- The stainless rebar bridge deck trend in the early stages is performing well. It appears to be performing slightly better than ECR.
- The FRP rebar bridge deck trend is not performing as well as ECR in the early age years. This is attributed to the lower modulus of elasticity of the FRP rebar that may be resulting in increased cracking of the bridge deck surface. It needs to be pointed out that the few FRP decks included in this study use different materials and design. The Pembroke Avenue Bridge which uses a single mat of CFRP rebar in the deck supported on side-by-side prestressed box beams with MDOT's latest advancement in transverse post tensioning is performing very well.

Time is still the largest constraint when evaluating bridge deck service life. ECR bridge decks date to around 35 years ago. There is only one deck containing ECR that has reached a poor surface rating, which is a very positive demonstration of the performance of ECR bridge decks. Having one ECR bridge deck reach poor condition completed the transition probability matrix, but more decks need to reach poor condition before the matrix becomes accurate at condition states below 5 (fair). Stainless and FRP bridge decks only date back to around 15 years. There is one stainless bridge deck that dates back 33 years. To date it is not possible to accurately estimate the service life for both stainless and FRP bridge decks beyond good condition at an early age.

Appendix

5.1 Epoxy Coated Rebar Transition Probabilities and Deterioration Curves

Table 5-1: 2009-2010 ECR Transition Probability Matrix

Bridge Condition Change Matrix — 2009-2010 — Number

Went up	Sample Size		0	1	2	3	4	5	6	7	8	9
0	29	9								1	12	16
1	184	8							3	38	143	
1	340	7							15	325		
17	109	6					1	2	106			
8	17	5					1	16				
11	6	4					6					
2	4	3				4						
2		2			0							
		1		0								
5		0										
47	689											

Transition Probability Matrix — Percent

Unrated

	0	1	2	3	4	5	6	7	8	9
9	0	0	0	0	0	0	0	0.0344828	0.4137931	0.0000001
8	0	0	0	0	0	0	0.0163043	0.2065217	0.7771739	0.0430043
7	0	0	0	0	0	0	0.0441176	0.9558824	2.7495898	
6	0	0	0	0	0.0091743	0.0183486	0.9724771	15.362156	2.792594	
5	0	0	0	0	0.0588235	0.9411765	24.836162	18.15475		
4	0	0	0	0	1	11.433427	42.990912			
3	0	0	0	1	#DIV/0!	54.424339				
2	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!					
1	#DIV/0!	#DIV/0!								

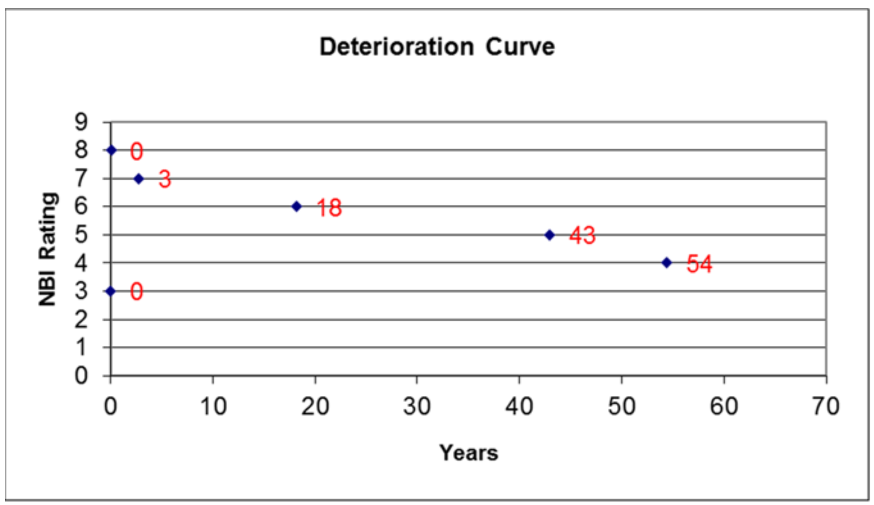

Figure 5-1: 2009-2010 ECR Deterioration Curve

Table 5-2: 2010-2011 ECR Transition Probability Matrix

Bridge Condition Change Matrix 2010-2011 Number

Went up	Sample Size		0	1	2	3	4	5	6	7	8	9
0	33	9								7	5	21
	164	8							9	25	130	
19	360	7						2	15	343		
21	105	6						3	102			
6	14	5						14				
5	3	4					3					
6		3				0						
		2			0							
		1		0								
4		0										
61	679											

Transition Probability Matrix Percent

Unrated		0	1	2	3	4	5	6	7	8	9
	9	0	0	0	0	0	0	0	0.2121212	0.1515152	0.00000001
	8	0	0	0	0	0	0	0.054878	0.152439	0.7926829	0.03762875
	7	0	0	0	0	0	0.0055556	0.0416667	0.9527778	2.9834343	
	6	0	0	0	0	0	0.0285714	0.9714286	14.329043	3.021063	
	5	0	0	0	0	0	1	23.911903	17.350106		
	4	0	0	0	0	1	#DIV/0!	41.26201			
	3	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!				
	2	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!					
	1	#DIV/0!	#DIV/0!								

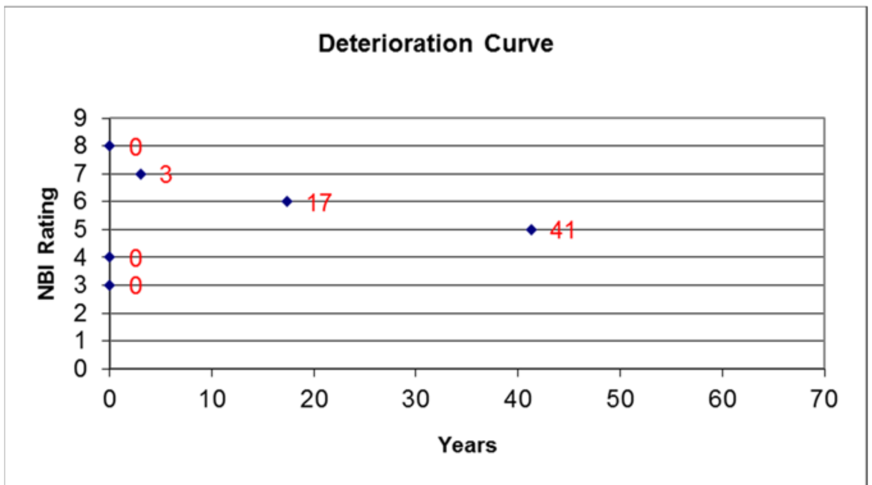

Figure 5-2: 2010-2011 ECR Deterioration Curve

Table 5-3: 2011-2012 ECR Transition Probability Matrix

Went up	Sample Size	**Bridge Condition Change Matrix**				2011-2012			Number		
			0	1	2	3	4	5	6	7	8	9
0	41	9								2	6	33
6	149	8							2	27	120	
10	385	7							11	374		
15	112	6						3	109			
11	8	5						8				
2	1	4					1					
		3				0						
		2			0							
		1		0								
8		0										
52	696											

Unrated		**Transition Probability Matrix**							Percent		
			0	1	2	3	4	5	6	7	8	9
		9	0	0	0	0	0	0	0	0.0487805	0.1463415	0.0000001
		8	0	0	0	0	0	0	0.0134228	0.1812081	0.8053691	0.0430043
		7	0	0	0	0	0	0	0.0285714	0.9714286	3.2022757	
		6	0	0	0	0	0	0.0267857	0.9732143	23.911903	3.24528	
		5	0	0	0	0	0	1	25.529353	27.157183		
		4	0	0	0	0	1	#DIV/0!	52.686536			
		3	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!				
		2	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!					
		1	#DIV/0!	#DIV/0!								

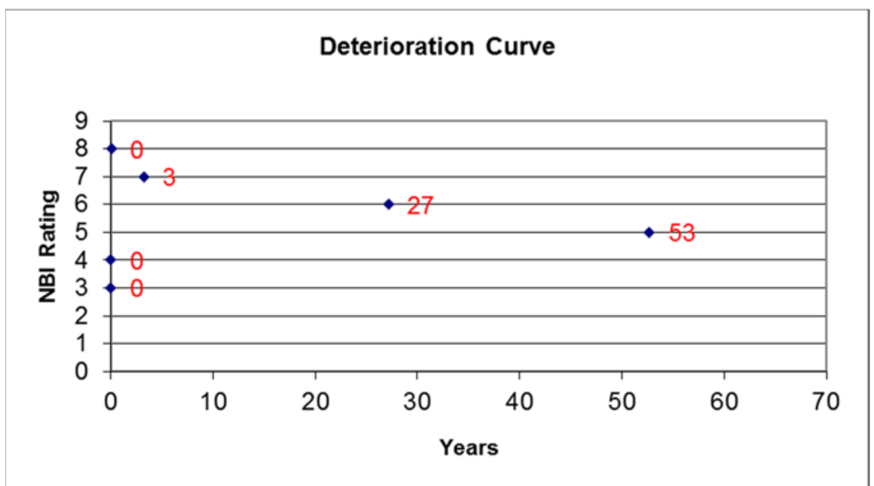

Figure 5-3: 2011-2012 ECR Deterioration Curve

Table 5-4: 2012-2013 ECR Transition Probability Matrix

Bridge Condition Change Matrix — 2012-2013 — Number

Went up	Sample Size		0	1	2	3	4	5	6	7	8	9
0	59	9							1	7	24	27
1	138	8							2	23	113	
26	384	7						3	16	365		
13	111	6						2	109			
4	9	5						9				
	1	4					1					
		3				0						
		2			0							
		1		0								
20		0										
64	702											

Transition Probability Matrix — Percent

Unrated			0	1	2	3	4	5	6	7	8	9
		9	0	0	0	0	0	0	0.0169492	0.1186441	0.4067797	0.00000001
		8	0	0	0	0	0	0	0.0144928	0.1666667	0.8188406	0.03762875
		7	0	0	0	0	0	0.0078125	0.0416667	0.9505208	3.4680618	
		6	0	0	0	0	0	0.018018	0.981982	13.659365	3.5056906	
		5	0	0	0	0	0	1	38.122045	17.165055		
		4	0	0	0	0	1	#DIV/0!	55.2871			
		3	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!				
		2	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!					
		1	#DIV/0!	#DIV/0!								

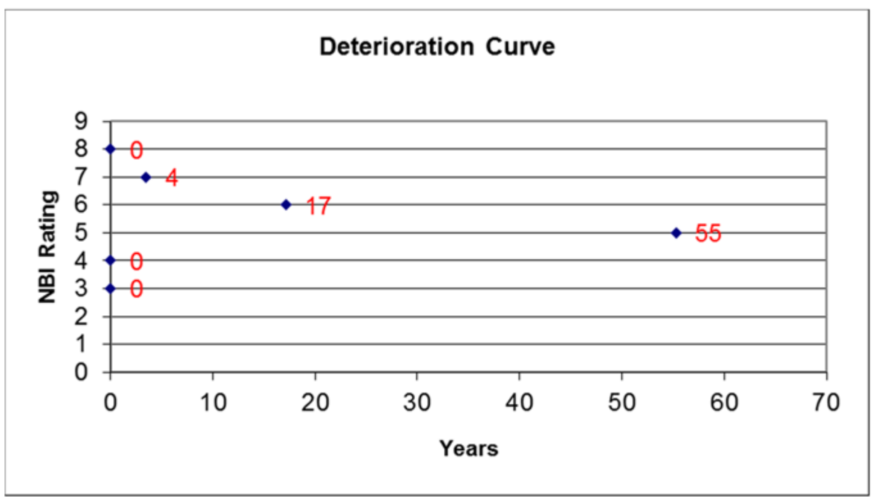

Figure 5-4: 2012-2013 ECR Deterioration Curve

Table 5-5: 2013-2014 ECR Transition Probability Matrix

Bridge Condition Change Matrix 2013-2014 Number

Went up	Sample Size		0	1	2	3	4	5	6	7	8	9
0	56	9								7	15	34
	168	8							2	34	132	
5	399	7							17	382		
6	122	6						2	120			
4	10	5						10				
1		4					0					
		3				0						
		2			0							
		1		0								
8		0										
24	755											

Transition Probability Matrix Percent

Unrated		0	1	2	3	4	5	6	7	8	9
	9	0	0	0	0	0	0	0	0.125	0.2678571	0.0000001
	8	0	0	0	0	0	0	0.0119048	0.202381	0.7857143	0.0430043
	7	0	0	0	0	0	0	0.0426065	0.9573935	2.8741967	
	6	0	0	0	0	0	0.0163934	0.9836066	15.919484	2.917201	
	5	0	0	0	0	0	1	41.93445	18.836684		
	4	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	1	#DIV/0!	60.771134			
	3	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!				
	2	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!					
	1	#DIV/0!	#DIV/0!								

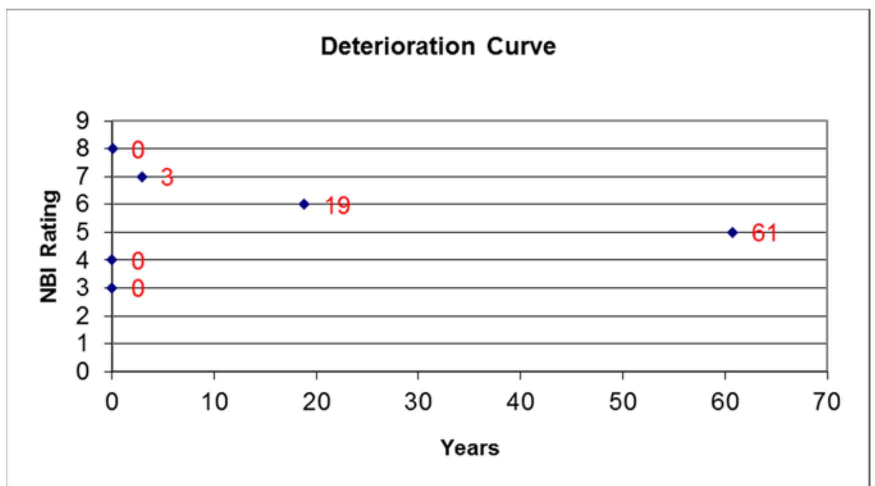

Figure 5-5: 2013-2014 ECR Deterioration Curve

Table 5-6: 2014-2015 ECR Transition Probability Matrix

Bridge Condition Change Matrix — 2014-2015 — Number

Went up	Sample Size		0	1	2	3	4	5	6	7	8	9
0	46	9							1	6	15	24
1	155	8						1	1	22	131	
1	425	7	1						10	414		
8	131	6						1	130			
2	11	5						11				
		4					0					
		3				0						
		2			0							
		1		0								
4		0										
16	768											

Transition Probability Matrix — Percent

Unrated

	0	1	2	3	4	5	6	7	8	9
9	0	0	0	0	0	0	0.0217391	0.1304348	0.326087	0.0000001
8	0	0	0	0	0	0.0064516	0.0064516	0.1419355	0.8451613	0.0430043
7	0.0023529	0	0	0	0	0	0.0235294	0.9741176	4.1202893	
6	0	0	0	0	0	0.0076336	0.9923664	26.432598	4.1632936	
5	0	0	0	0	0	1	90.455264	30.595892		
4	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	121.05116			
3	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!				
2	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!					
1	#DIV/0!	#DIV/0!								

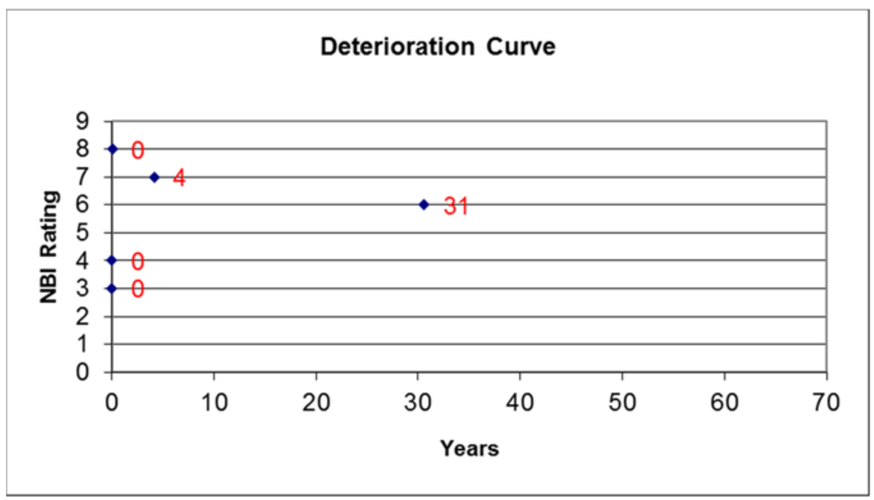

Figure 5-6: 2014-2015 ECR Deterioration Curve

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2. *Michigan Bridge Element Inspection Manual*. Lansing, MI: Michigan Department of Transportation, 2015. Web. http://www.michigan.gov/documents/mdot/MiBEIM_2015-03-05_Final_486188_7.pdf