Prestressed vs. Steel Beams: Expected Service Life

Prepared for

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by

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Introduction

1.1 History

Beams designed for a bridge superstructure are typically constructed with either steel or concrete. Concrete beams are typically prestressed, meaning that the steel rebar within the concrete is put into tension before the concrete is poured into the fixture. This strengthens the concrete's ability to resist tension through the rebar. Prestressed concrete is typically known to be more cost effective and has a higher speed of erection as compared to steel beams. Also, concrete doesn't need a paint system for protection, reducing maintenance costs. Steel beams also have advantages over concrete, including less susceptibility to freeze thaw conditions. Steel performs much better than concrete in tension and there is also much less variability in the failure properties of steel. Currently service lives are unknown for either steel or prestressed concrete beams and will be evaluated further within this study using transition probabilities and deterioration curves.

1.2 Objectives

The objectives of this study are as follows:

- Estimate service life of steel beams.

- Estimate service life of prestressed beams.

- Estimate service life of prestressed box beams.

- Estimate service life of prestressed I-beams.

The ultimate objective of this study is to accurately predict and compare the service life of steel and prestressed beams separately. Expected service life is the time until "poor condition". Poor condition is defined as a superstructure rating of 4 or below on the Bridge Safety Inspection Report (BSIR), and indicates the need for rehabilitation. If a known approximate service life was available for different superstructures then future rehabilitations and preventive maintenance can be planned and budgeted accordingly.

1.3 Markov Model

Markov models use transition matrices that describe the probability that a bridge element in a known condition state at a known time will change to some other condition state in the next time period. This process assumes that the probability of changing from one state to another is a function only of the condition state and time period in which the superstructure is currently located. Therefore, the past performance of a superstructure has no impact on the predicted rate of change in future performance [1]. This report reviews Markov transition probabilities for superstructure condition ratings for bridges

containing steel and prestressed beam superstructures. The transition probabilities are then converted to a deterioration rate using the following equation:

$$n = \frac{\log(0.5)}{\log(T)}$$
  [2]

where; T = Transition Probability
n = average # of years to reach next condition state.

Deterioration rates can help predict the time for a superstructure to reach a specific condition state. With multiple year transition probabilities and deterioration rates calculated, averages from each one step transition can be averaged resulting in the most accurate results as possible.

Results

2.1 Data Set

Data was pulled containing the following information: Bridge ID, NBI superstructure rating, and bridge type. Bridge type notes the type of superstructure for the given bridge. Steel, prestressed, box beams, and I-beams are all noted under bridge type allowing for uncomplicated data separation. The bridge types were then separated and resulted in the following:

- Steel Beams: 2,647 bridges.
- Prestressed Beams: 1,198 bridges
- Prestressed Box Beams: 390 bridges
- Prestressed I-Beams: 800 bridges

2.2 Transition Probabilities and Deterioration Curves

Transition probabilities were calculated using NBI superstructure ratings from 2004 to 2010. These ratings were analyzed from year to year intervals, resulting in a transition probability for each year. For instance; in 2004, 941 bridges containing a steel beam superstructure held a rating of a 7, in 2005 856 remained a 7, 67 fell to a 6, and 17 lowered to a 5. The transition probabilities result a 91% probability that a steel beam superstructure will remain at a 7, 7% will lower to a 6, and 2% will lower to a 5. This was done for each superstructure rating, creating a transition probability matrix. This process was then repeated for 2005-2006, 06-07, 07-08, 08-09, and 09-10 resulting in six different probability matrices *(Appendix Tables 5-1 thru 5-24)*. The probabilities were then averaged based on the six different matrices, resulting in an average transition probability matrix. Deterioration rates were calculated using the equation previously mentioned *(Section 1.3)*. The deterioration rates were then plotted along the x-axis with deck surface ratings assigned to the y-axis *(Appendix Fig 5-1 thru 5-24)*.

2.2.1 Steel Beams

Table 2-1 displays the average transition probability from 2004-2010 for bridges containing a steel beam superstructure. 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. For instance; there is a 69% chance that a 9 will remain a 9 the following year, 22% chance to decrease to an 8, and a 8% chance to decrease to a 7. Deterioration rates are in bold and highlighted light green.

Table 2-1: Transition Probability Matrix for Steel Beams

Steel Beams									
Average from 2004-2010						Item 59 Superstructure Ratings			
Transition Probability Matrix						Percent			
	0	1	2	3	4	5	6	7	8	9
9	0	0	0	0	0	0	0.0000	0.0824	0.2253	0.6923
8	0	0	0	0	0	0.0006	0.0054	0.0978	0.8962	**1.88**
7	0	0	0	0.00051	0.00085	0.00871	0.0541	0.9358	6.3247	
6	0	0	0	0.00164	0.0061	0.0442	0.9481	10.4450	**8.21**	
5	0	0	0	0.00899	0.0355	0.9555	12.9950	**18.65**		
4	0	0	0	0.0426	0.9574	15.2133	**31.65**			
3	0	0	0.006	0.9938	15.9399	**46.86**				
2	0	0	0	111.25	**62.80**					
1	0	0								

Figure 2-1 displays the NBI superstructure ratings plotted against deterioration rates calculated in Table 2-1. According to Figure 2-1; on average a steel beam will take 32 years to reach a rating of 5 and 47 years to attain a rating of 4, a 4 being equivalent to poor condition.
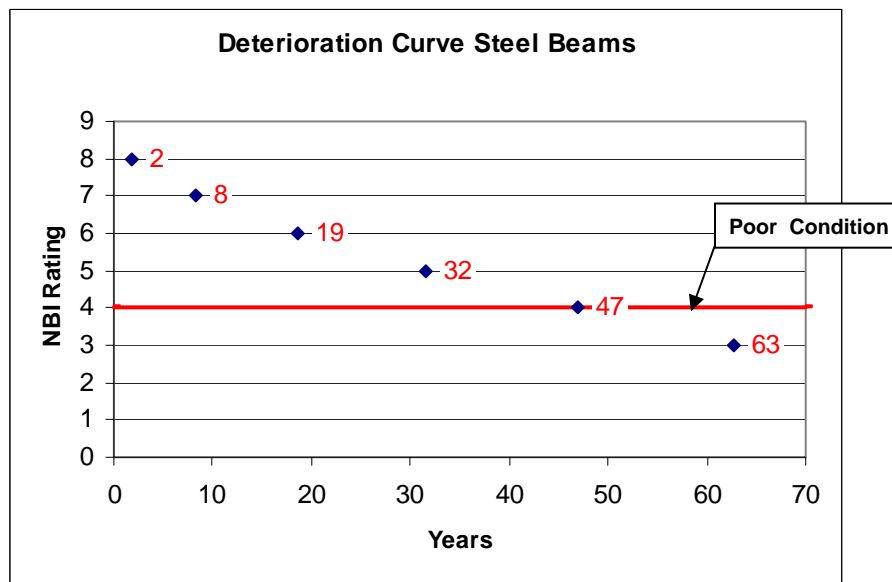

Figure 2-1: Steel Beam Deterioration Curve

2.2.2 Prestressed Beams

Table 2-2 displays the average transition probability from 2004-2010 for prestressed beam superstructures. Again, transition probabilities are highlighted in blue and the deterioration rates are in bold and highlighted light green.

Table 2-2: Transition Probability Matrix for Prestressed Beams

Prestressed Beams									

Average from 2004-2010						Item 59 Superstructure Ratings			
Transition Probability Matrix							Percent		

	0	1	2	3	4	5	6	7	8	9
9	0	0	0	0	0	0	0.0000	0.0275	0.2862	0.6862
8	0	0	0	0	0.00041	0.0012	0.0074	0.0695	0.9215	**1.84**
7	0	0	0	0	0.0022	0.01647	0.0461	0.9352	8.4755	
6	0	0	0	0.00281	0.0038	0.0516	0.9418	10.3522	**10.32**	
5	0	0	0	0.01301	0.0390	0.9480	11.5676	**20.67**		
4	0	0	0	0.1018	0.8982	12.9718	**32.24**			
3	0	0	0.009	0.9913	6.4582	**45.21**				
2	0	0	0	79.3648	**51.67**					
1	0	0								

Figure 2-2 displays the NBI superstructure ratings plotted against deterioration rates calculated in Table 2-2. According to Figure 2-2; on average a prestressed beam will take 32 years to attain a rating of a 5 and 45 years to reach a rating of 4, equivalent to poor condition.
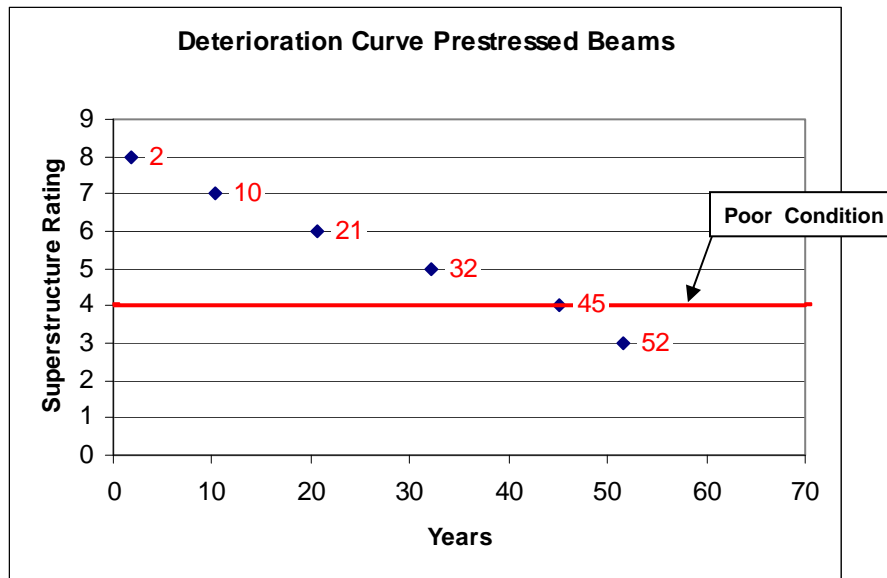

Figure 2-2: Prestressed Beam Deterioration Curve

2.2.3 Prestressed Box Beams

Table 2-3 displays the average transition probability from 2004-2010 for prestressed box beam superstructures. Again, transition probabilities are highlighted in blue and the deterioration rates are in bold and highlighted light green.

Table 2-3: Transition Probability Matrix for Prestressed Box Beams

Prestressed Box Beams									
Average from 2004-2010						Item 59 Superstructure Ratings			
Transition Probability Matrix						Percent			
	0	1	2	3	4	5	6	7	8	9
9	0	0	0	0	0	0	0.0000	0.0179	0.2545	0.7276
8	0	0	0	0	0.00099	0.0030	0.0089	0.0574	0.9297	**2.18**
7	0	0	0	0	0	0.02484	0.0559	0.9193	9.5095	
6	0	0	0	0.00976	0.0146	0.0732	0.9024	8.2329	**11.69**	
5	0	0	0	0.03333	0.0476	0.9190	6.7523	**19.92**		
4	0	0	0	0.1161	0.8839	8.2110	**26.67**			
3	0	0	0.014	0.9855	5.6180	**34.89**				
2	0	0	0	47.4797	**40.50**					
1	0	0								

Figure 2-3 displays the NBI superstructure ratings plotted against deterioration rates calculated in Table 2-3. According to Figure 2-3; on average a prestressed box beam will take 27 years to attain a rating of a 5 and 35 years to reach a rating of 4, equivalent to poor condition.
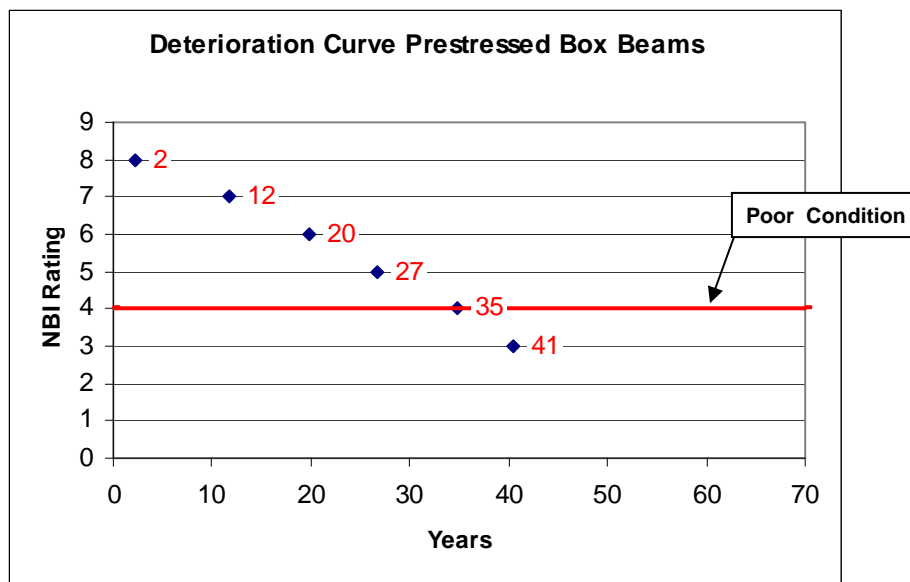

Figure 2-3: Prestressed Box Beam Deterioration Curve

2.2.4 Prestressed I-Beams

Table 2-4 displays the average transition probability from 2004-2010 for prestressed I-beam superstructures. Again, transition probabilities are highlighted in blue and the deterioration rates are in bold and highlighted light green.

Table 2-4: Transition Probability Matrix for Prestressed I-Beams

Prestressed I-Beams									
Average from 2004-2010					Item 59 Superstructure Ratings				
Transition Probability Matrix					Percent				
	0	1	2	3	4	5	6	7	8	9
9	0	0	0	0	0	0	0.0000	0.0376	0.3195	0.6429
8	0	0	0	0	0	0.0000	0.0063	0.0775	0.9163	**1.57**
7	0	0	0	0	0.00272	0.01498	0.0436	0.9387	7.9257	
6	0	0	0	0.00118	0.0012	0.0471	0.9506	10.9635	**9.49**	
5	0	0	0	0.0025	0.0350	0.9625	13.6785	**20.46**		
4	0	0	0	0.0877	0.9123	18.1351	**34.14**			
3	0	0	0	1.0000	7.5500	**52.27**				
2	0	0	0	#DIV/0!	**59.82**					
1	0	0								

Figure 2-4 displays the NBI superstructure ratings plotted against deterioration rates calculated in Table 2-4. According to Figure 2-4; on average a prestressed I-beam will take 34 years to attain a rating of a 5 and 52 years to reach a rating of 4, equivalent to poor condition.
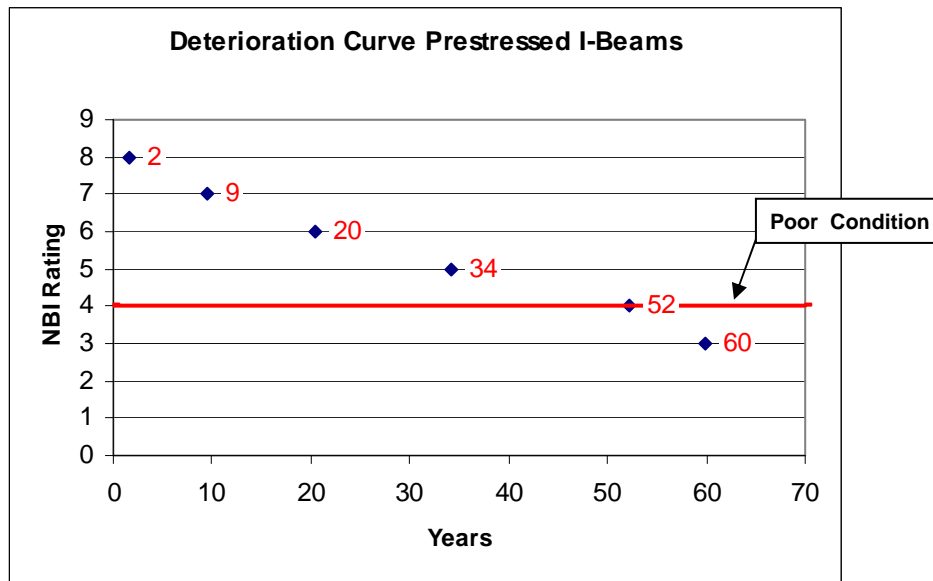

Figure 2-4: Prestressed I-Beam Deterioration Curve

2.3 Comparing Deterioration Curves

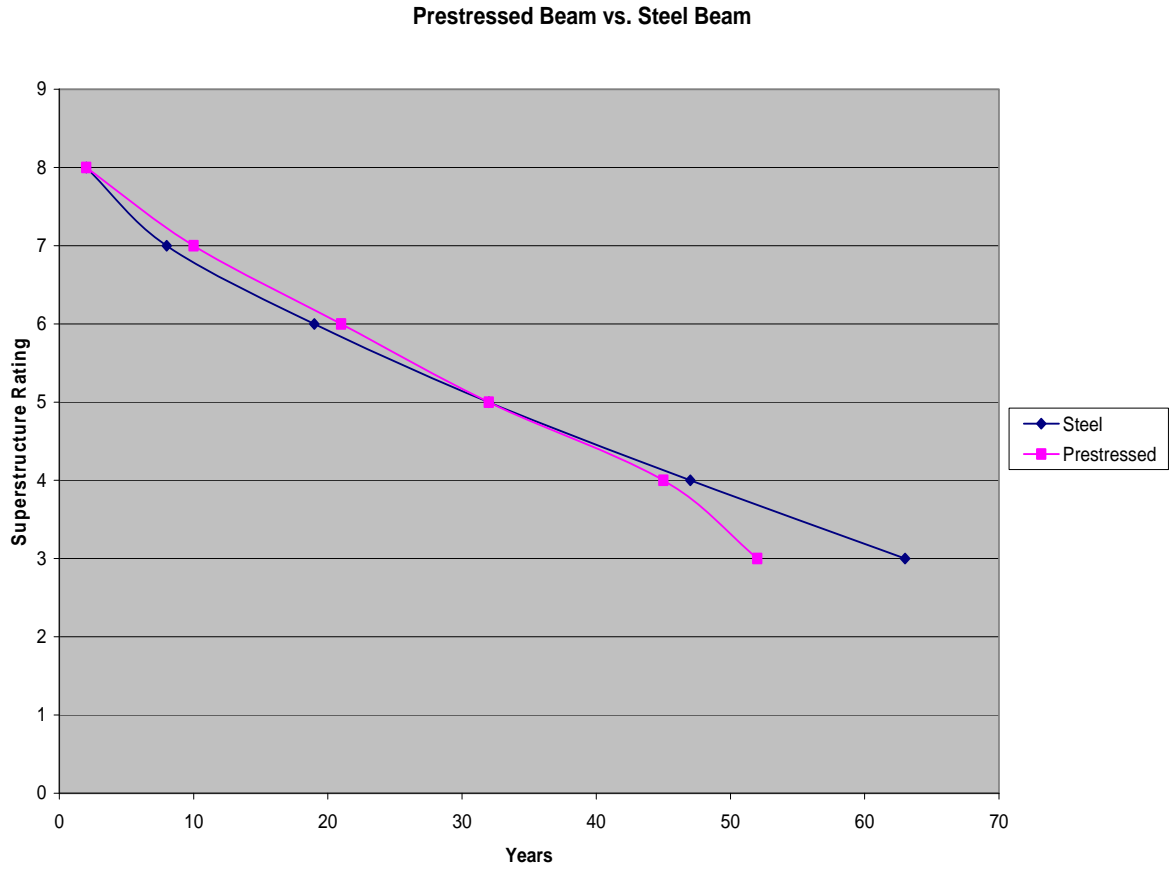**Prestressed Beam vs. Steel Beam**

Figure 2-5: Prestressed Beams vs. Steel Beams Deterioration Curves

Figure 2-5 displays the deterioration curves of both prestressed beams and steel beams within the same plot. Notice how similar the deterioration curves are until poor condition is reached.
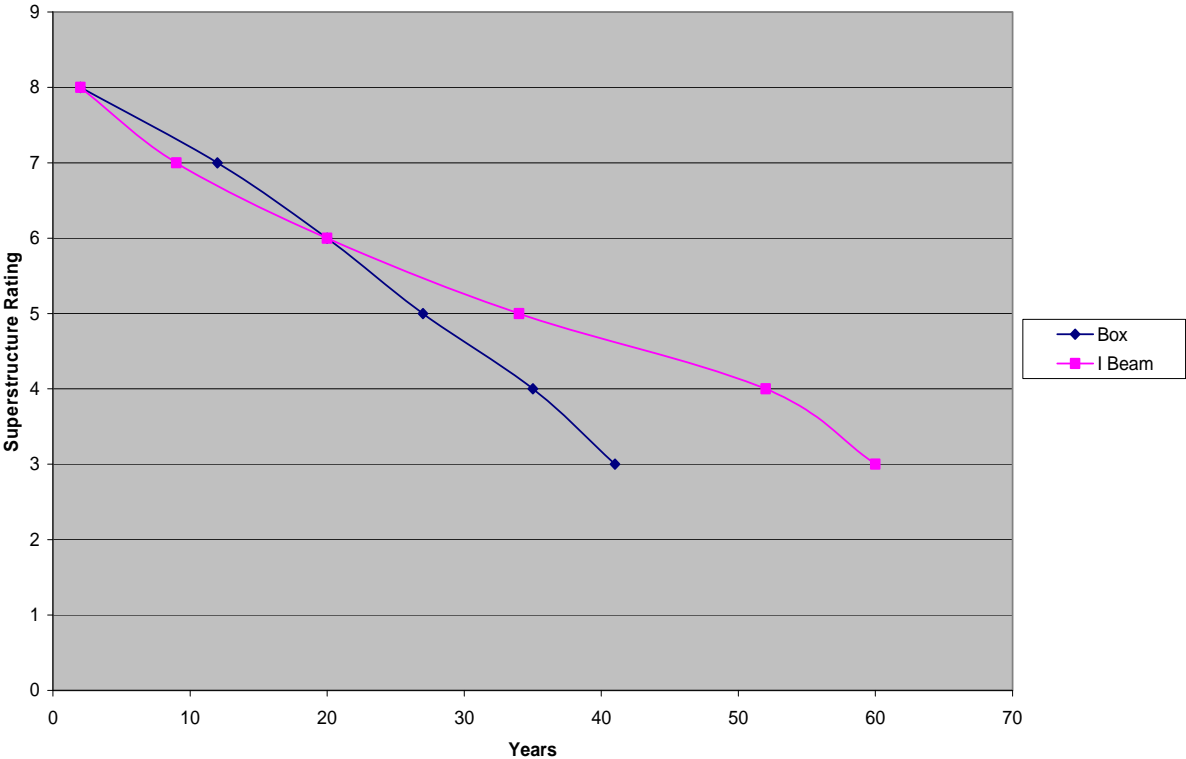
Box Beam vs. I-Beam

Figure 2-6: Box Beams vs. I-Beams Deterioration Curves

Figure 2-6 displays the deterioration curves of both prestressed box beams and prestressed I-beams within the same plot.

Discussion

3.1 Expected Service Life of Beams

Sample sizes for the data were fairly large (800+) with the exception of prestressed box beams (390). Larger sample sizes resulted in more accurate and complete transition probability matrices. In return, more complete matrices produced a more consistent deterioration curve. The data set and sample sizes used within this study seem to be more than efficient for producing the probability matrices and deterioration curves.

3.1.1 Steel vs. Prestressed Beams

Figures 2-1 and *2-2* show the deterioration rates for steel beams and prestressed beams separate. According to *Figure 2-1*, steel beams reach poor condition at 47 years. *Figure 2-2* shows that prestressed beams reach poor condition in 45 years. The difference in the expected service life between the two beams is only 2 years. Both steel and prestressed beam deterioration curves are shown within *Figure 2-5*. It appears as if the deterioration curves for both types of beams are nearly identical until poor condition is reached.

3.1.2 Prestressed Box Beams vs. Prestressed I-Beams

Prestressed beams were separated by box beams and I-beams to evaluate their performance individually. *Figure 2-3* shows that box beams reach poor condition at 35 years. *Figure 2-4* shows that prestressed I-beams reach poor condition at 52 years. *Figure 2-6* displays both deterioration curves within the same plot. Notice how the box beam deterioration curve is almost linear as compared to all the other deterioration curves. Typically an element will deteriorate more rapidly at first and then slow down as time moved forward. Unlike the other curves, box beams appear to deteriorate at an almost constant rate. Overall prestressed I-beams deteriorate significantly slower as compared to prestressed box beams.

Conclusion

The study has yielded the following conclusions:

- The service life of a steel beam is estimated to be 47 years.
- The service life of a prestressed beam is estimated to be 45 years.
- The service life of a prestressed box beam is estimated to be 35 years.
- The service life of a prestressed I-beam is estimated to be 52 years.

Prestressed I-beams appear to have the longest service life of the group. Prestressed box beams service life is approximately 17 years less than that of prestressed I-beams. Steel beams and prestressed beams deteriorate almost identically and have an overall service life of 45 to 47 years.

References

[1] Devaraj, Dinesh, and Fu, Gongkang. *Methodology of Homogeneous and Non-Homogeneous Markov Chains for Modeling Bridge Element Deterioration.* Detroit, MI: Wayne State University Press, 1998. Print

[2] Juntunen, Dave. *BMS: Domestic Scan on Bridge Management.* Lansing, MI: Michigan Department of Transportation, 19 Nov 2009. Powerpoint.

Appendix

5.1 Steel Beam Transition Probability Matrices & Deterioration Curves

Table 5-1: 2004-2005 Steel Beam Transition Probability Matrix

Bridge Condition Change Matrix

2004 \ 2005	0	1	2	3	4	5	6	7	8	9	Went up	Sample Size
9								8	8	22	0	38
8							4	34	232		2	270
7					1	17	67	856			20	941
6					9	56	618				32	683
5				4	22	375					56	401
4				5	85						33	90
3			0	44							5	44
2		0	0									
1	0	0										
0	0											
											148	2467

Transition Probability Matrix

Percent

2004 \ 2005	0	1	2	3	4	5	6	7	8	9
9	0	0	0	0	0	0	0	0.210526	0.210526	0.578947
8	0	0	0	0	0	0	0.014815	0.125926	0.859259	1.268237
7	0	0	0	0	0.001063	0.018066	0.071201	0.909671	4.569661	
6	0	0	0	0.009975	0.013177	0.081991	0.904832	7.321506	5.837899	
5	0	0	0	0.055556	0.054863	0.935162	6.931028	13.1594		
4	0	0	0	0.944444	0.944444	10.34002	20.09043			
3	0	0	1	1	12.12677	30.43045				
2	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	42.55722					
1	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!						

Unrated

Figure 5-1: 2004-2005 Steel Beam Deterioration Curve

Deterioration Curve — NBI Rating vs. Years:
(1, 8), (6, 7), (13, 6), (20, 5), (30, 4), (43, 3)

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Table 5-2: 2005-2006 Steel Beam Transition Probability Matrix

Bridge Condition Change Matrix

Went up	Sample Size	2005-2006 9	8	7	6	5	4	3	2	1	0
	34	23										(9)
11	281	9	238									(8)
41	936	2	41	870								(7)
45	685		2	52	652							(6)
20	414			11	22	396						(5)
22	98			3	8	15	94					(4)
	31				3	3	4	31				(3)
									0			(2)
										0		(1)
												(0)
139	**2479**										

Transition Probability Matrix

	0	1	2	3	4	5	6	7	8	9
9	0	0	0	0	0	0	0	0.0588235	0.2647059	0.6764706
8	0	0	0	0	0	0	0.0071174	0.1459075	0.8469751	1.7733613
7	0	0	0	0	0.0032051	0.0117521	0.0555556	0.9294872	4.1734737	
6	0	0	0	0.0043796	0.0116788	0.0321168	0.9518248	9.4792904	5.9468349	
5	0	0	0	0.0072464	0.0362319	0.9565217	14.03863	15.426125		
4	0	0	0	0.0408163	0.9591837	15.593244	29.464755			
3	0	0	1	16.633125	45.057999					
2	#DIV/0!	#DIV/0!	#DIV/0!	61.691124						
1	#DIV/0!	#DIV/0!	#DIV/0!							
Unrated										

Percent

Deterioration Curve

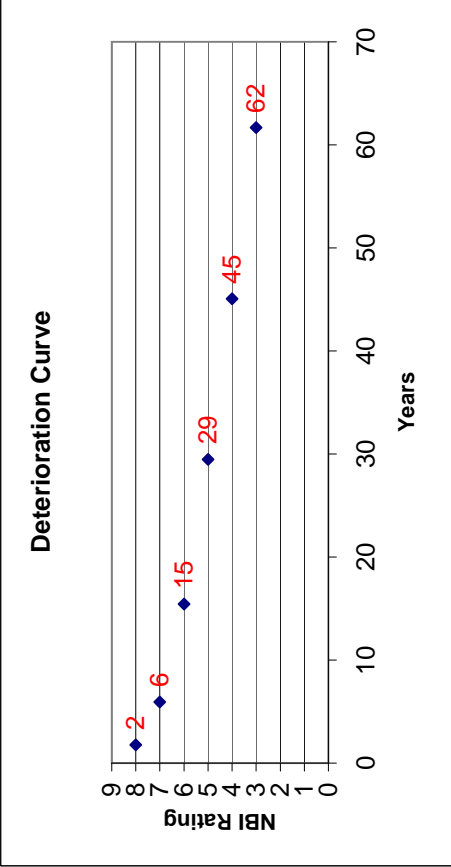NBI Rating vs. Years — plotted points: 2, 6, 15, 29, 45, 62

Figure 5-2: 2005-2006 Steel Beam Deterioration Curve

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Table 5-3: 2006-2007 Steel Beam Transition Probability Matrix

Bridge Condition Change Matrix

Went up	Sample Size	2006-2007									
		0	1	2	3	4	5	6	7	8	9
0	26									8	18
7	277							2	22	253	
30	968				1		5	49	913		
49	716				1	2	25	688			
30	392				6	17	369				
17	91				5	86					
	24				24						
				0							
			0								
		0									
133	2494										

Transition Probability Matrix

Percent

Unrated	0	1	2	3	4	5	6	7	8	9
9	0	0	0	0	0	0	0	0	0.3076923	0.6923077
8	0	0	0	0	0	0	0.0072202	0.0794224	0.9133574	1.8849618
7	0	0	0	0.0010331	0	0.0051653	0.0506198	0.9431818	7.648266	9.5332278
6	0	0	0	0.0013966	0.0027933	0.0349162	0.9608939	11.849438	21.382666	
5	0	0	0	0.0153061	0.0433673	0.9413265	17.375886	38.758552		
4	0	0	0	0.0549451	0.9450549	11.463573	50.222125			
3	1	0	0	1	12.265441	62.487566				
2	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!						
1	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!						

Deterioration Curve

NBI Rating vs Years — data points:

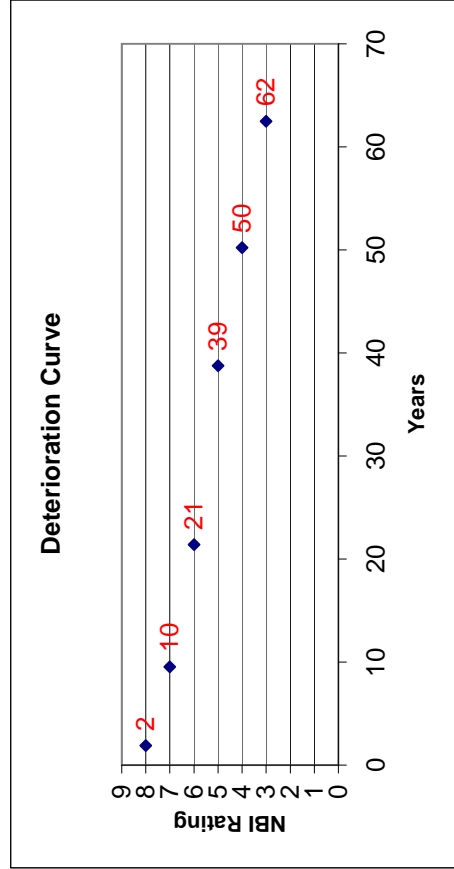| Years	2	10	21	39	50	62
NBI Rating	8	7	6	5	4	3

Figure 5-3: 2006-2007 Steel Beam Deterioration Curve

Table 5-4: 2007-2008 Steel Beam Transition Probability Matrix

Bridge Condition Change Matrix

Went up	Sample Size		9	8	7	6	5	4	3	2	1	0	2007-2008
0	22	9	17	3	2								
2	275	8		260	14	1							
11	980	7			930	42	5	1	2				
40	740	6				708	29	3					
42	372	5					355	15	2				
36	71	4						67	4				
9	28	3							28				
		2								0			
		1									0		
		0											
140	**2488**												

Transition Probability Matrix

		9	8	7	6	5	4	3	2	1	0	Percent	
	9	0.7727273	0.1363636	0.0909091	0	0	0	0	0	0	0		
	8		0.9454545	0.0509091	0.0036364	0	0	0	0	0	0	2.6883977	
	7			0.9489796	0.0428571	0.005102	0.0010204	0.0020408	0	0	0	12.357885	15.046283
	6				0.9567568	0.0391892	0.0040541	0.0053763	0	0	0	13.236086	28.282369
	5					0.9543011	0.0403226	0.056338	0	0	0	15.679902	43.962271
	4						0.943662	0.943662	0	0	0	14.818416	58.780687
	3							1	0	0	0	11.95344	70.734126
	2						#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
	1						#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
Unrated													

Deterioration Curve

Data points (Years, NBI Rating): (3, 8), (15, 7), (28, 6), (44, 5), (59, 4)

x-axis: Years (0 – 70)
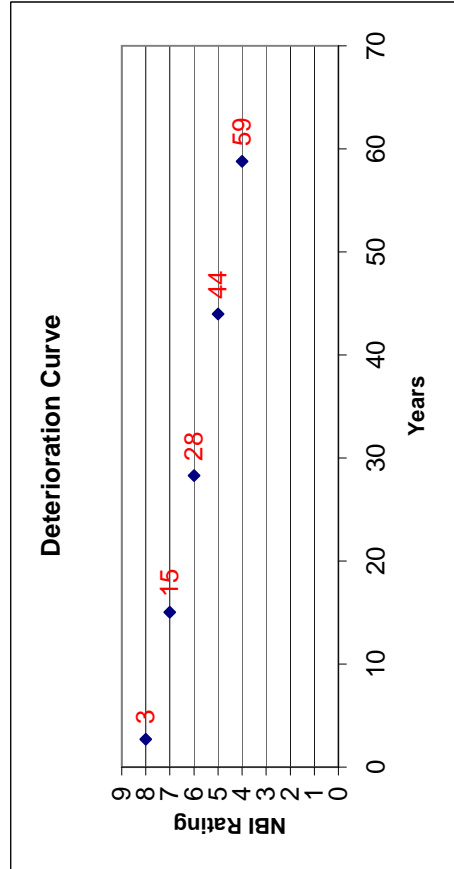y-axis: NBI Rating (0 – 9)

Figure 5-4: 2007-2008 Steel Beam Deterioration Curve

Table 5-5: 2008-2009 Steel Beam Transition Probability Matrix

Bridge Condition Change Matrix

Went up	Sample Size		0	1	2	3	4	5	6	7	8	9
0	34	9									8	26
3	279	8						1		26	252	
38	1007	7				2	2	6	43	958		
26	738	6				5	8	32	702			
21	379	5			1	1	66	366				
19	67	4	0	0	0	16						
	17	3			1							
		2		0								
		1	0									
		0										
107	**2521**											

Transition Probability Matrix

	0	1	2	3	4	5	6	7	8	9
9	0	0	0	0	0	0	0	0	0.2352941	0.7647059
8	0	0	0	0	0	0.0035842	0	0.09319	0.9032258	2.5838249
7	0	0	0	0	0	0.0059583	0.0427011	0.9513406	6.8100691	
6	0	0	0	0.00271	0.00271	0.0433604	0.9512195	13.895427	9.393894	
5	0	0	0	0.0131926	0.0211082	0.9656992	13.860055	23.289321		
4	0	0	0	0.0149254	0.9850746	19.859317	37.149376			
3	0	0	0.0588235	0.9411765	46.093419	57.008693				
2	#DIV/0!	#DIV/0!	#DIV/0!	11.433427	103.10211					
1	#DIV/0!	#DIV/0!	114.53554							

Percent

Deterioration Curve

Figure title: Deterioration Curve

Y-axis: NBI Rating (9, 8, 7, 6, 5, 4, 3, 2, 1, 0)
X-axis: Years (0, 10, 20, 30, 40, 50, 60, 70)

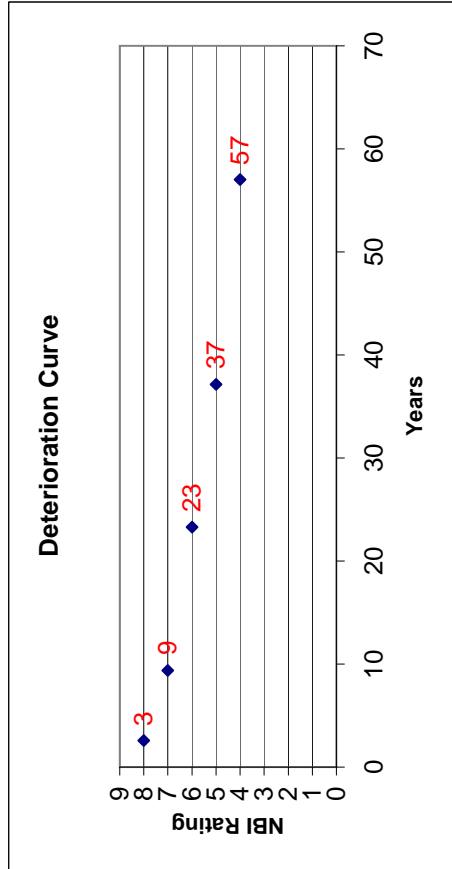Data point labels: 3, 9, 23, 37, 57

Figure 5-5: 2008-2009 Steel Beam Deterioration Curve

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Table 5-6: 2009-2010 Steel Beam Transition Probability Matrix

Bridge Condition Change Matrix

	Sample Size	Went up	0	1	2	3	4	5	6	7	8	9 (2009-2010)
9	28									3	5	20
8	275	17								25	250	
7	1024	46						7	64	953		
6	712	47				1	2	25	684			
5	377	23				1	6	370				
4	53	7				1	52					
3	17	1			0	17						
2					0							
1	1	1		0								
0			0									
	2486	142										

Transition Probability Matrix

	0	1	2	3	4	5	6	7	8	9
9	0	0	0	0	0	0	0	0.1071429	0.1785714	0.7142857
8	0	0	0	0	0	0	0	0.0909091	0.9090909	
7	0	0	0	0	0	0.0068359	0.0625	0.9306641		
6	0	0	0	0.0014045	0.002809	0.0351124	0.9606742			
5	0	0	0	0.0026525	0.0159151	0.9814324				
4	0	0	0	0.0188679	0.9811321					
3	0	0	0	1						
2	#DIV/0!	#DIV/0!	#DIV/0!							
1	#DIV/0!	#DIV/0!	#DIV/0!							
Unrated	#DIV/0!	#DIV/0!	#DIV/0!							

Percent (2009-2010)

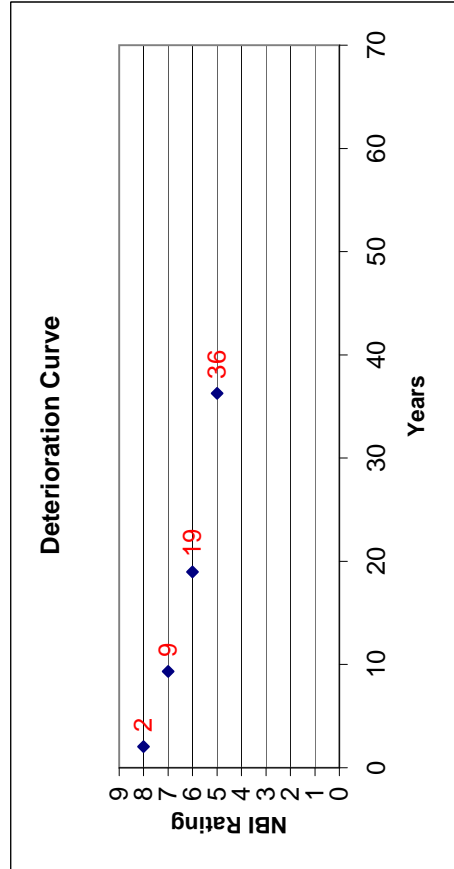|	3	4	5	6	7	8	9
9					0.1071429	0.1785714	0.7142857
8					0.0909091	0.9090909	2.0600427
7			0.0068359	0.0625	0.9306641	7.2725409	9.3325836
6	0.0014045	0.002809	0.0351124	0.9606742	9.6462158	18.978799	
5	0.0026525	0.0159151	0.9814324	17.276852	36.255651		
4	0.0188679	0.9811321	36.983271	73.238922			
3	1	36.389127	109.62805				

Deterioration Curve

Figure 5-6: 2009-2010 Steel Beam Deterioration Curve

5.2 Prestressed Beam Transition Probability Matrices & Deterioration Curves

Table 5-7: 2004-2005 Prestressed Beam Transition Probability Matrix

Bridge Condition Change Matrix

Went up	Sample Size		0	1	2	3	4	5	6	7	8	9	2004-2005
0	132	9										73	
4	380	8									49	354	
3	266	7								10	21	232	
6	164	6							5	18	147		
11	100	5						13	15	91			
11	52	4					3	1	7	44			
6	19	3				1	2	8	19				
1		2			0								
1		1		0									
0		0	0										
43	1113												

Transition Probability Matrix

Unrated			0	1	2	3	4	5	6	7	8	9	Percent
		9	0	0	0	0	0	0	0	0.075758	0.371212	0.55303	
		8	0	0	0	0	0	0	0.013158	0.055263	0.931579	1.17018	
		7	0	0	0	0	0	0.048872	0.067669	0.87218	9.779946		
		6	0	0	0	0.006098	0.011278	0.091463	0.896341	5.068387	10.95013		
		5	0	0	0	0.006098	0.006098	0.91	6.333938	16.01851			
		4	0	0	0	0.02	0.07	7.349615	22.35245				
		3	0	0	0	0.153846	0.846154	29.70207					
		2	#DIV/0!	#DIV/0!	#DIV/0!	1	4.149238						
		1	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	33.8513						

Deterioration Curve

NBI Rating (0–9) vs. Years (0–70)

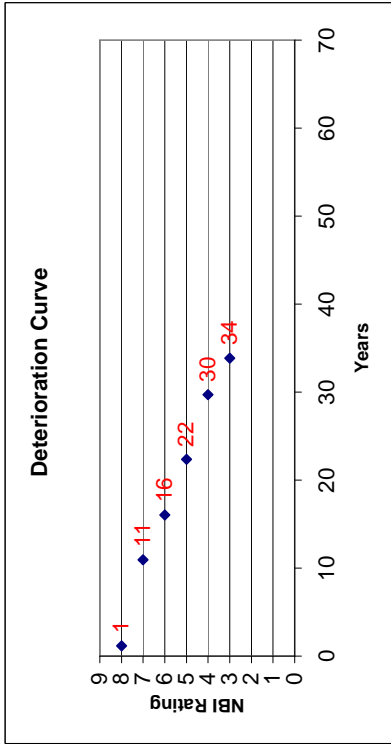Data point labels: 1, 11, 16, 22, 30, 34

Figure 5-7: 2004-2005 Prestressed Beam Deterioration Curve

Table 5-8: 2005-2006 Prestressed Beam Transition Probability Matrix

Bridge Condition Change Matrix

Went up	Sample Size		0	1	2	3	4	5	6	7	8	9
												2005-2006
0	99	9								1	25	73
4	414	8							1	30	383	
	270	7					1	4	15	250		
6	173	6				2	1	14	156			
12	114	5				1	4	109				
7	49	4				9	40					
8	22	3				22						
		2			0							
		1		0								
		0										
37	1141											

Transition Probability Matrix

		0	1	2	3	4	5	6	7	8	9
											Percent
	9				0	0	0	0	0.010101	0.2525253	0.7373737
	8				0	0	0	0.0024155	0.0724638	0.9251208	2.2751469
	7				0	0.0037037	0.0148148	0.0555556	0.9259259	8.9058	
	6				0.0115607	0.0057803	0.0809249	0.9017341	9.0064683	11.180947	
	5				0.0087719	0.0350877	0.9561404	6.7012447	20.187415		
	4				0.1836735	0.8163265	15.454592	26.88866			
	3			0	1	3.4155134	42.343251				
	2	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	45.758765					
	1	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!						
Unrated											

Deterioration Curve

NBI Rating (vertical axis, 9 to 0) vs. Years (horizontal axis, 0 to 70)
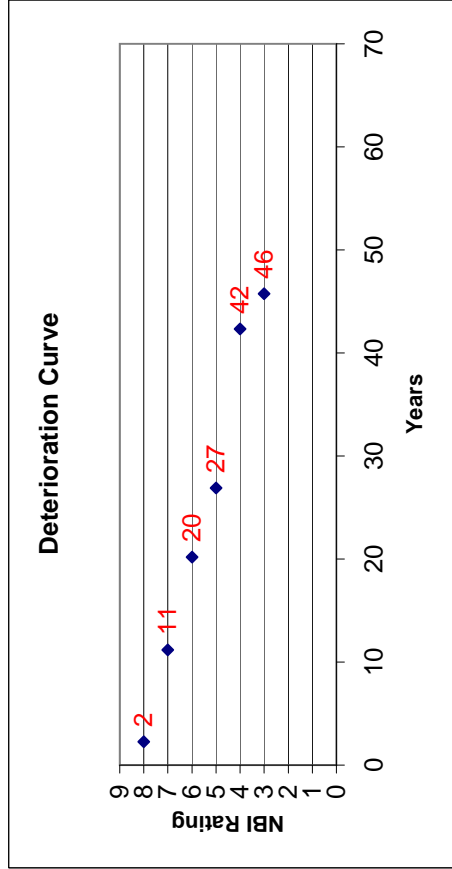
Data points: 2, 11, 20, 27, 42, 46

Figure 5-8: 2005-2006 Prestressed Beam Deterioration Curve

Table 5-9: 2006-2007 Prestressed Beam Transition Probability Matrix

Bridge Condition Change Matrix

Went up	Sample Size	0	1	2	3	4	5	6	7	8	9	2006-2007
0	88								1	26	61	9
2	420						1	4	33	382		8
1	288						2	4	282			7
7	171					1	7	163				6
30	99				1	1	97					5
11	36				2	34						4
6	28			1	27							3
			0	0								2
			0									1
		0										0
57	1130											

Transition Probability Matrix

Percent

	0	1	2	3	4	5	6	7	8	9	
9	0	0	0	0	0	0	0	0.0113636	0.2954545	0.6931818	9
8	0	0	0	0	0	0.002381	0.0095238	0.0785714	0.9095238	1.8914523	8
7	0	0	0	0	0	0.0069444	0.0138889	0.9791667	7.3090498		7
6	0	0	0	0	0.005848	0.0409357	0.9532164	32.923275	9.2005021		6
5	0	0	0	0.010101	0.010101	0.979798	14.46668	42.123777			5
4	0	0	0	0.0555556	0.9444444	33.963033	56.590457				4
3	0	0	0.0357143	0.9642857	12.126774	90.55349					3
	0	0	#DIV/0!	19.059447	102.68026						2
Unrated	#DIV/0!	#DIV/0!	#DIV/0!	121.73971							1

Deterioration Curve

NBI Rating (y-axis): 9, 8, 7, 6, 5, 4, 3, 2, 1, 0
Years (x-axis): 0, 10, 20, 30, 40, 50, 60, 70
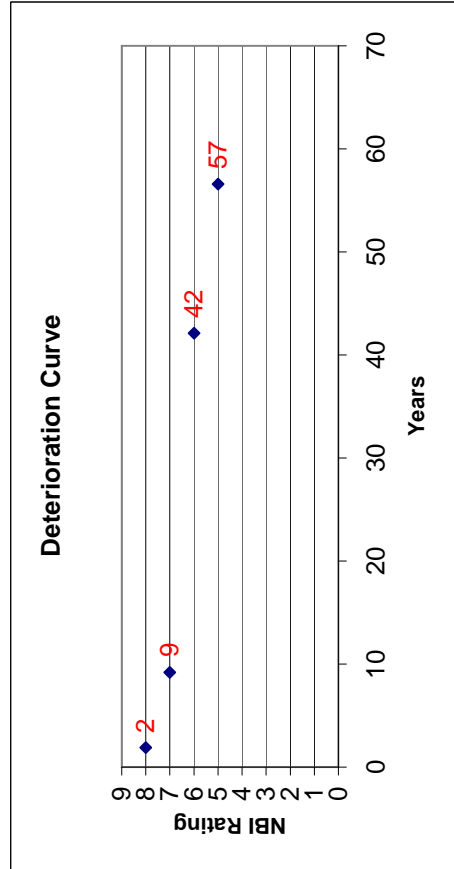
Data point labels: 2, 9, 42, 57

Figure 5-9: 2006-2007 Prestressed Beam Deterioration Curve

Table 5-10: 2007-2008 Prestressed Beam Transition Probability Matrix

Bridge Condition Change Matrix

	Went up	Sample Size	0	1	2	3	4	5	6	7	8	9	2007-2008
9	0	74								1	22	51	
8	7	410					1	2	2	13	392		
7	2	323						7	23	293			
6	13	179					1	5	173				
5	9	104					7	97					
4	7	30				3	27						
3	11	19				19							
2	1				0								
1				0									
0													
	50	1139											

Transition Probability Matrix — Percent

	0	1	2	3	4	5	6	7	8	9
9	0	0	0	0	0	0	0	0.0135135	0.2972973	0.6891892
8	0	0	0	0	0.002439	0.004878	0.004878	0.0317073	0.9560976	1.8621002
7	0	0	0	0	0	0.0216718	0.0712074	0.9071207	15.439186	
6	0	0	0	0	0.0055866	0.027933	0.9664804	7.1106813	17.301286	
5	0	0	0	0	0.0673077	0.9326923	20.330348	24.411967		
4	0	0	0	0.1	0.9	9.9475885	44.742315			
3	0	0	0	1	6.5788135	54.689904				
2	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	61.268717					
1	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!						
Unrated										

Deterioration Curve

NBI Rating (vertical axis: 0–9) vs. Years (horizontal axis: 0–70)

Data point labels: 2, 17, 24, 45, 55, 61

Figure 5-10: 2007-2008 Prestressed Beam Deterioration Curve

Table 5-11: 2008-2009 Prestressed Beam Transition Probability Matrix

Bridge Condition Change Matrix

Went up	Sample Size	0	1	2	3	4	5	6	7	8	9 (2008-2009)
		0									
9	78								2	21	55
8	420							3	36	381	
7	319						1	10	308		
6	192						10	182			
5	101				4	3	94				
4	31			0	1	30					
3	15		0	0	15						
2											
1											
0											
	36 1156										

Transition Probability Matrix

	0	1	2	3	4	5	6	7	8	9
9	0	0	0	0	0	0	0	0.025641	0.2692308	0.7051282
8	0	0	0	0	0	0	0.0071429	0.0857143	0.9071429	
7	0	0	0	0	0	0.0031348	0.031348	0.9655172		
6	0	0	0	0	0	0.0520833	0.9479167			
5	0	0	0	0.039604	0.029703	0.9306931				
4	0	0	0	0.0322581	0.9677419					
3	0	0	0	1						
2	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!						
1	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!						
Unrated										

Percent

9		1.9839597
8	7.11246	9.0964197
7	19.752668	28.849087
6	12.958763	41.80785
5	9.6504016	51.458252
4	21.139095	72.597347

Deterioration Curve

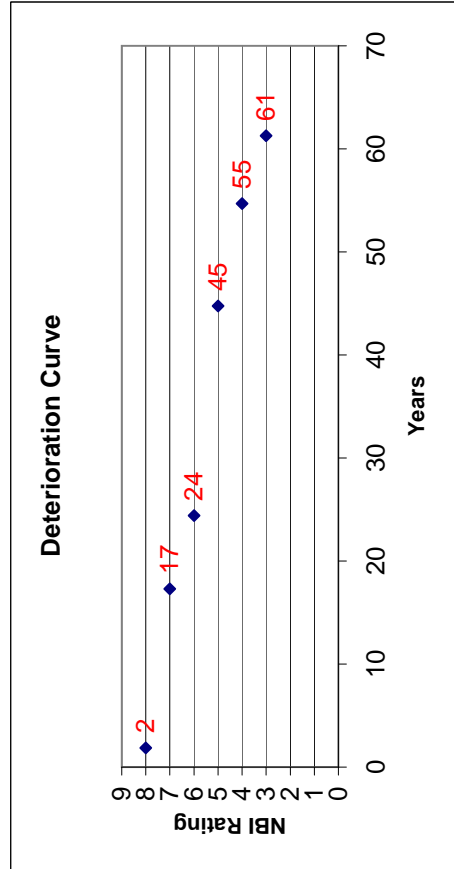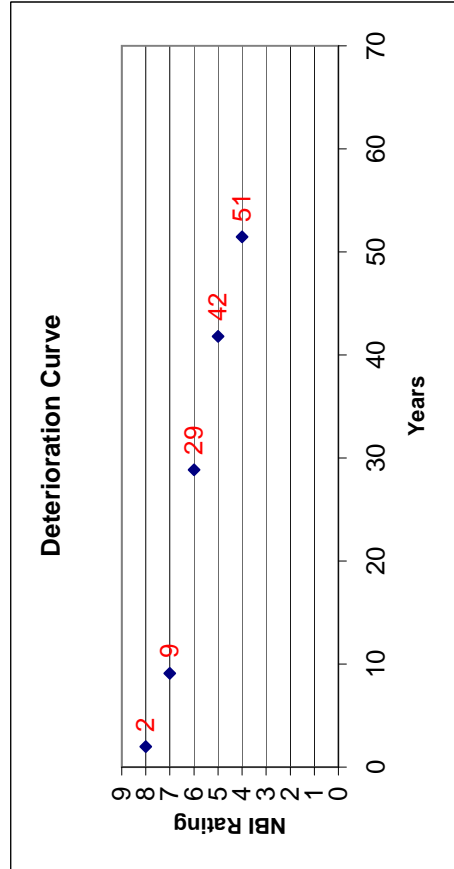(NBI Rating vs. Years; plotted points: 2, 9, 29, 42, 51)

Figure 5-11: 2008-2009 Prestressed Beam Deterioration Curve

Table 5-12: 2009-2010 Prestressed Beam Transition Probability Matrix

Bridge Condition Change Matrix

	Went up	Sample Size	0	1	2	3	4	5	6	7	8	9	2009-2010
9		74									13	61	
8	3	401							3	37	361		
7	3	356						3	14	339			
6	12	187					2	4	183				
5	10	97					2	95					
4	5	28				12	28						
3	9	12			0	12							
2					0								
1				0									
0													
	42	1155											

Transition Probability Matrix

	0	1	2	3	4	5	6	7	8	9
9	0	0	0	0	0	0	0	0	0.1756757	0.8243243
8	0	0	0	0	0	0	0.0074813	0.0922693	0.9002494	
7	0	0	0	0	0	0.008427	0.0393258	0.9522472		
6	0	0	0	0	0	0.0213904	0.9786096			
5	0	0	0	0	0.0206186	0.9793814				
4	0	0	0	0	1					
3	0	0	0	1						
2	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!						
1	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!						
Unrated										

Percent

	0	1	2	3	4	5	6	7	8	9
9	0	0	0	0	0	0	0	0	0.1756757	0.8243243
8	0	0	0	0	0	0	0.0074813	0.0922693	0.9002494	3.5878812
7	0	0	0	0	0	0.008427	0.0393258	0.9522472	6.5961582	
6	0	0	0	0	0	0.0213904	0.9786096	10.184039		
5	0	0	0	0	0.0206186	0.9793814	14.165918	24.349957		
4	0	0	0	0	1	32.056808	56.406765			
3	0	0	0	1	33.269861	89.676626				
2	#DIV/0!	#DIV/0!								
1	#DIV/0!	#DIV/0!								

Deterioration Curve

NBI Rating (y-axis: 0–9) vs. Years (x-axis: 0–70)
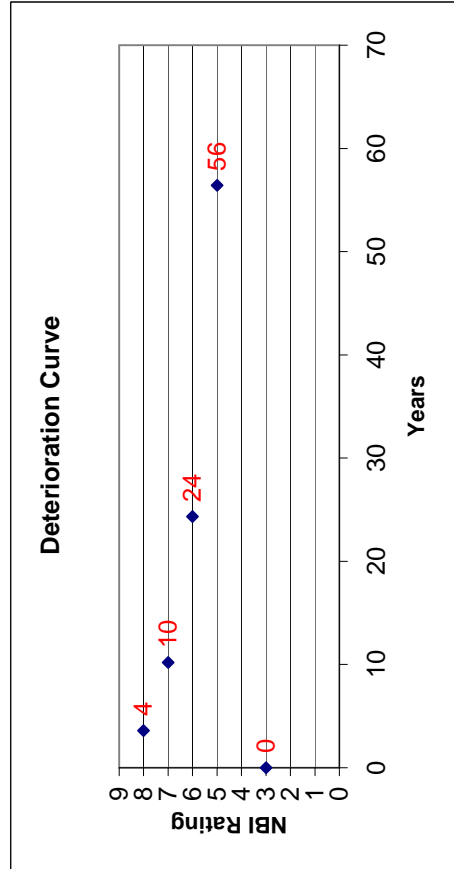
Data point labels: 4, 10, 24, 56, 0

Figure 5-12: 2009-2010 Prestressed Beam Deterioration Curve

5.3 Prestressed Box Beam Transition Probability Matrices & Deterioration Curves

Table 5-13: 2004-2005 Prestressed Box Beam Transition Probability Matrix

Bridge Condition Change Matrix

Went up	Sample Size		0	1	2	3	4	5	6	7	8	9 (2004-2005)
0	55	9										38
3	144	8								1	16	140
2	45	7							1	3		41
	35	6				1		2	4			32
7	38	5				1	5	32	32			
3	25	4				5	20					
5	10	3				10						
		2			0							
1	1	1		0								
21	352	0	0									

Transition Probability Matrix

	Unrated		0	1	2	3	4	5	6	7	8 (Percent)	9
		9	0	0	0	0	0	0	0	0.0181818	0.2909091	0.6909091
		8	0	0	0	0	0	0	0.0069444	0.0208333	0.9722222	1.8746525
		7	0	0	0	0	0	0	0.0888889	0.9111111	24.605098	26.47975
		6	0	0	0	0.0285714	0	0.0571429	0.9142857	7.4459559	33.925706	
		5	0	0	0	0.0263158	0.1315789	0.8421053	7.734968	41.660674		
		4	0	0	0	0.2	0.8	4.033437				
		3	0	0	1	3.1062837	45.694111					
		2	#DIV/0!	#DIV/0!	#DIV/0!	48.800395						
		1	#DIV/0!	#DIV/0!	#DIV/0!							

Deterioration Curve

Data points (Years, NBI Rating): (2, 8), (26, 7), (34, 6), (42, 5), (46, 4), (49, 3)

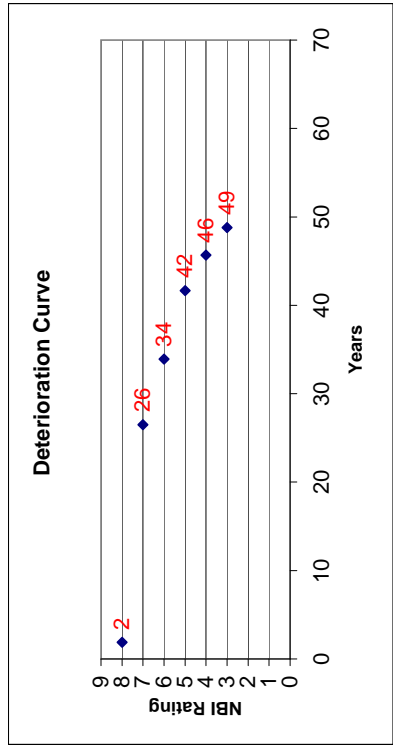X-axis: Years (0–70)
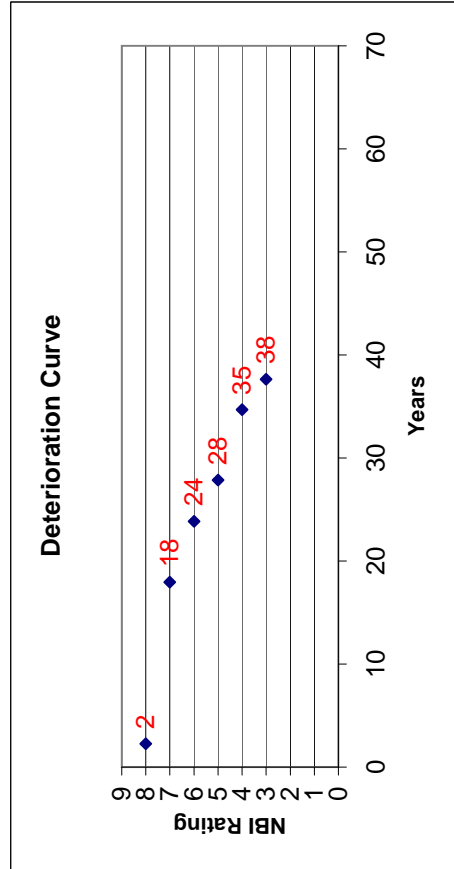Y-axis: NBI Rating (0–9)

Figure 5-13: 2004-2005 Prestressed Box Beam Deterioration Curve

Table 5-14: 2005-2006 Prestressed Box Beam Transition Probability Matrix

Bridge Condition Change Matrix

From \ To (2005–2006)	Sample Size	0	1	2	3	4	5	6	7	8	9
9	53								1	13	39
8	162							1	6	155	
7	45						1	4	40		
6	38				1	1	4	32			
5	31				1	2	28				
4	24				5	19					
3	13				13						
2				0							
1			0								
0		0									
	366										

Went up: 3 Total: 16

Transition Probability Matrix

Percent (2005–2006)

From \ To	0	1	2	3	4	5	6	7	8	9
9	0	0	0	0	0	0	0	0.0188679	0.245283	0.7358491
8	0	0	0	0	0	0	0.0061728	0.037037	0.9567901	
7	0	0	0	0	0	0.0222222	0.0888889	0.8888889		
6	0	0	0	0.0263158	0.0263158	0.1052632	0.8421053			
5	0	0	0	0.0322581	0.0645161	0.9032258				
4	0	0	0	0.2083333	0.79166667					
3	0	0	0	1						
2	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!						
1	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!						
Unrated										

Incremental / cumulative years:

State	Increment	Cumulative
9		2.2597939
8	15.692281	17.952075
7	5.8849492	23.837024
6	4.033437	27.870461
5	6.8100691	34.68053
4	2.967051	37.647581

Deterioration Curve

NBI Rating (y-axis: 0–9) vs. Years (x-axis: 0–70)

Data point labels: 2, 18, 24, 28, 35, 38

Figure 5-14: 2005-2006 Prestressed Box Beam Deterioration Curve

26

Table 5-15: 2006-2007 Prestressed Box Beam Transition Probability Matrix

Bridge Condition Change Matrix

Went up	Sample Size	Rating	0	1	2	3	4	5	6	7	8	9 (2006-2007)
0	47	9								1	10	36
2	175	8						1	2	11	161	
	48	7						2	1	45		
1	38	6				1	1	2	35			
4	31	5				1		30				
5	17	4				1	16					
2	18	3			1	17						
		2			0							
		1		0								
		0	0									
14	374											

Transition Probability Matrix   Percent

Rating	0	1	2	3	4	5	6	7	8	9
9	0	0	0	0	0	0	0	0.0212766	0.212766	0.7659574
8	0	0	0	0	0	0.0057143	0.0114286	0.0628571	0.92	2.5996724
7	0	0	0	0	0	0.0416667	0.0208333	0.9375	8.3129504	
6	0	0	0	0	0.0263158	0.0526316	0.9210526	10.740054	10.912623	
5	0	0	0	0.0322581	0	0.9677419	8.428541	21.652676		
4	0	0	0	0.0588235	0.9411765	21.139095	30.081217			
3	0	0	0.0555556	0.9444444	11.433427	51.220312				
2	#DIV/0!	#DIV/0!	#DIV/0!	12.126774	62.653739					
1	#DIV/0!	#DIV/0!	#DIV/0!	74.780514						
Unrated										

Deterioration Curve

Data points (Years, NBI Rating): (3, 8), (11, 7), (22, 6), (30, 5), (51, 4), (63, 3)
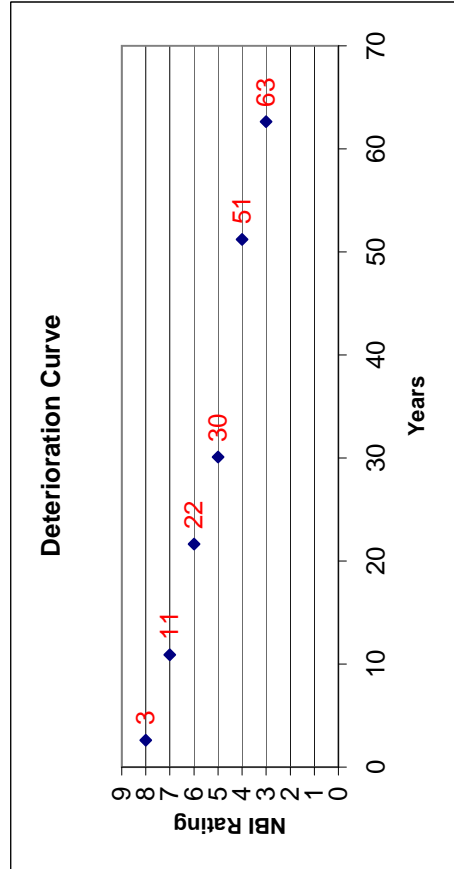
Figure 5-15: 2006-2007 Prestressed Box Beam Deterioration Curve

Table 5-16: 2007-2008 Prestressed Box Beam Transition Probability Matrix

Bridge Condition Change Matrix

Went up	Sample Size		2007-2008									
			9	8	7	6	5	4	3	2	1	0
0	42	9	27									
1	174	8		163	7	1	2	1				
2	55	7			49	2	4					
6	33	6				29	3	1				
3	35	5					33	2				
3	14	4						13	1			
7	12	3							12			
1		2								0		
		1									0	
		0										0
23	365											

Transition Probability Matrix — Percent

	9	8	7	6	5	4	3	2	1	0
9	0.6428571	0.3333333	0.0238095	0	0	0	0	0	0	0
8		0.9367816	0.0402299	0.0057471	0.0114943	0.0057471	0	0	0	0
7			0.8909091	0.0363636	0.0727273	0	0	0	0	0
6				0.8787879	0.0909091	0.030303	0	0	0	0
5					0.9428571	0.0571429	0	0	0	0
4						0.9285714	0.0714286	0	0	0
3							1	0	0	0
2						#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
1						#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	1.5687999	10.613983	6.0006048	5.3644292	11.780104	9.3532067				
Unrated		12.182783	18.183387	23.547816	35.32792	44.681127				

Deterioration Curve

Deterioration Curve — NBI Rating vs. Years

Data points (Years, NBI Rating): (2, 8), (12, 7), (18, 6), (24, 5), (35, 4), (45, 3)

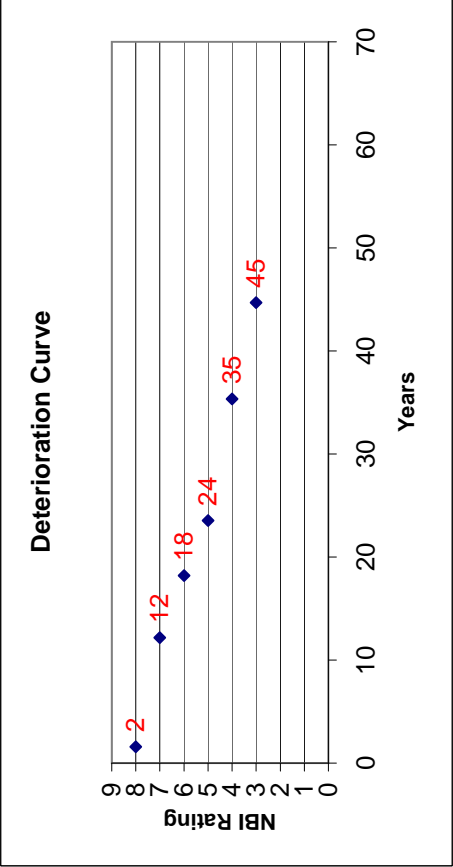X-axis: Years (0–70); Y-axis: NBI Rating (0–9)

Figure 5-16: 2007-2008 Prestressed Box Beam Deterioration Curve

Table 5-17: 2008-2009 Prestressed Box Beam Transition Probability Matrix

Bridge Condition Change Matrix

Went up	Sample Size		2008-2009									
			0	1	2	3	4	5	6	7	8	9
0	43	9								1	10	32
2	180	8							1	15	164	
1	58	7							2	56		
2	31	6						2	29			
2	40	5				4	1	35				
4	17	4				1	16					
	9	3				9						
		2			0							
		1		0								
		0	0									
11	378											

Transition Probability Matrix

Percent

	2008-2009									
Unrated	0	1	2	3	4	5	6	7	8	9
9	0	0	0	0	0	0	0	0.0232558	0.2325581	0.744186
8	0	0	0	0	0	0	0.0055556	0.0833333	0.9111111	2.3459598
7	0	0	0	0	0	0	0.0344828	0.9655172	7.4459559	9.7919157
6	0	0	0	0	0	0.0645161	0.9354839	19.752668	29.544583	
5	0	0	0	0.1	0.025	0.875	10.393356	39.937939		
4	0	0	0	0.0588235	0.9411765	5.1908931	45.128832			
3	0	0	0	1	11.433427	56.562259				
2	#DIV/0!	#DIV/0!	0	#DIV/0!						
1	#DIV/0!	#DIV/0!	0	#DIV/0!						

Deterioration Curve

NBI Rating vs. Years — plotted points: (2, 8), (10, 7), (30, 6), (40, 5), (45, 4), (57, 3)
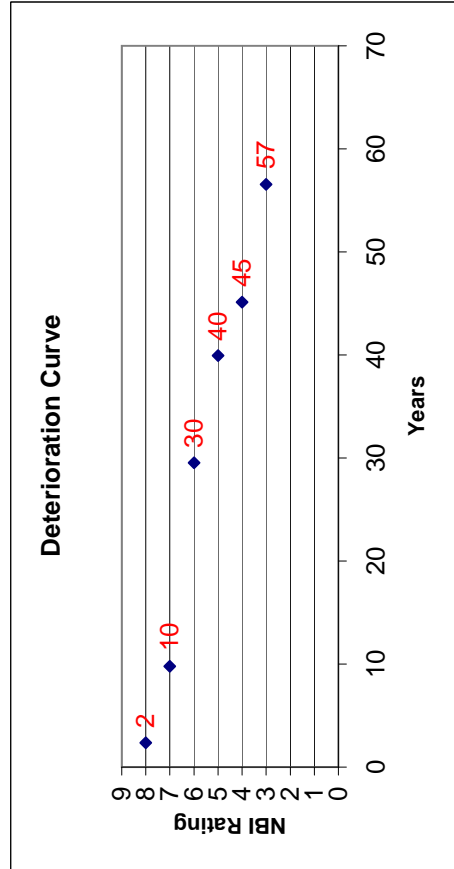
Figure 5-17: 2008-2009 Prestressed Box Beam Deterioration Curve

Table 5-18: 2009-2010 Prestressed Box Beam Transition Probability Matrix

Bridge Condition Change Matrix

	Went up	Sample Size	2009-2010									
			0	1	2	3	4	5	6	7	8	9
9	0	39									8	31
8	1	175							3	16	156	
7	1	71						1	5	65		
6	4	30						2	28			
5	3	35						35				
4	2	15					15					
3	8	7				7						
2					0							
1				0								
0												
	19	372										

Transition Probability Matrix

	Unrated	0	1	2	3	4	5	6	7	8	9	Percent
9		0	0	0	0	0	0	0	0	0.2051282	0.7948718	3.0192698
8		0	0	0	0	0	0	0.0171429	0.0914286	0.8914286		6.0310396
7		0	0	0	0	0	0.0140845	0.0704225	0.915493			7.8505687
6		0	0	0	0	0	0.0666667	0.9333333				9.0503094
5		0	0	0	0	0	1	10.046649	16.900878			
4		0	0	0	0	1	26.947527					
3		0	0	0	1	#DIV/0!	#DIV/0!					
2	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!						
1	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!						

Deterioration Curve

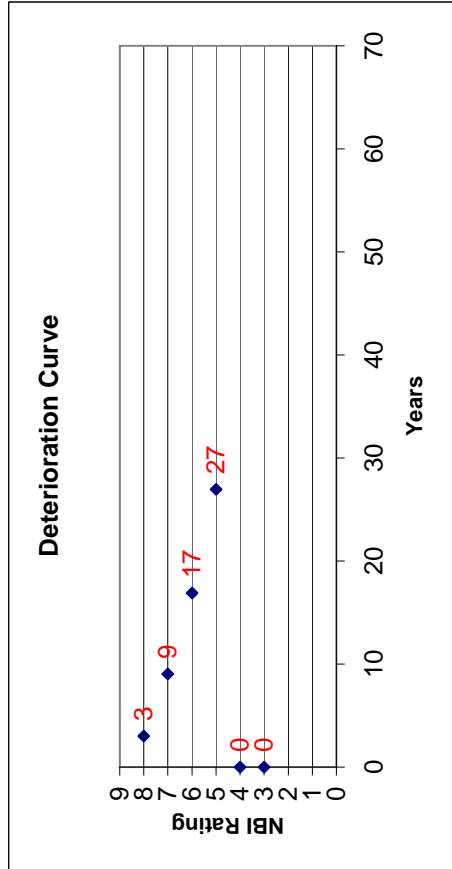NBI Rating (0–9) vs Years (0–70). Data point labels: 3, 9, 17, 27, 0, 0.

Figure 5-18: 2009-2010 Prestressed Box Beam Deterioration Curve

5.4 Prestressed I-Beam Transition Probability Matrices & Deterioration Curves

Table 5-19: 2004-2005 Prestressed I Beam Transition Probability Matrix

Bridge Condition Change Matrix (2004-2005)

Went up	Sample Size	0	1	2	3	4	5	6	7	8	9
0	77								9	33	35
1	236							4	18	214	
1	216					3	13	14	186		
5	129					1	13	115			
4	62				1	2	59				
8	27				3	24					
1	9				9						
1				0							
1			0								
		0									
22	756										

Transition Probability Matrix

	0	1	2	3	4	5	6	7	8	9	Percent
9	0	0	0	0	0	0	0	0.1168831	0.4285714	0.4545455	
8	0	0	0	0	0	0	0.0169492	0.0762712	0.9067797	0.8791182	
7	0	0	0	0	0.0138889	0.0601852	0.0648148	0.8611111	7.0833538	7.9624719	
6	0	0	0	0	0.0077519	0.1007752	0.8914729	4.635452	12.597924		
5	0	0	0	0.016129	0.0322581	0.9516129	6.0336483	18.631572			
4	0	0	0	0.1111111	0.8888889	13.975603	32.607176				
3	0	0	0	1	5.8849492	38.492125					
2	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!							
1	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!							
Unrated											

Deterioration Curve

Figure axes: NBI Rating (0–9) vs Years (0–70). Plotted data points (years): 1, 8, 13, 19, 33, 38.
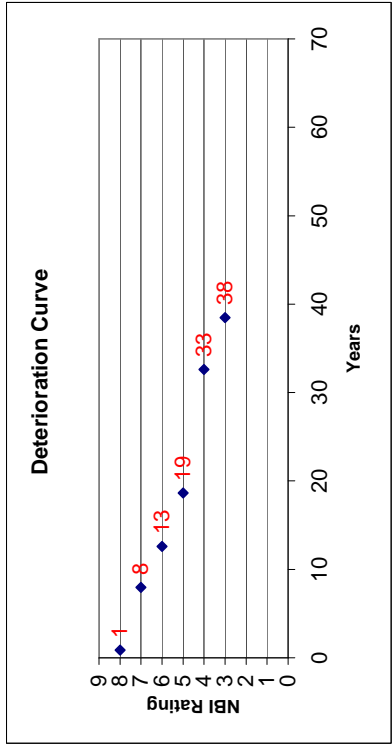
Figure 5-19: 2004-2005 Prestressed I Beam Deterioration Curve

Table 5-20: 2005-2006 Prestressed I Beam Transition Probability Matrix

Bridge Condition Change Matrix

	Went up	Sample Size	0	1	2	3	4	5	6	7	8	9
9	0	46									12	34
8	1	252								24	228	
7		219				1	1	3	11	204		
6	5	134				1		10	123			
5	6	82					2	80				
4	5	25				4	21					
3	4	9			0	9						
2					0							
1				0								
0			0									
	21	767										

Transition Probability Matrix — Percent

	0	1	2	3	4	5	6	7	8	9
9	0	0	0	0	0	0	0	0	0.2608696	0.7391304
8	0	0	0	0	0	0	0	0.0952381	0.9047619	2.2930567
7	0	0	0	0	0.0045662	0.0136986	0.0502283	0.9315068	6.9256917	
6	0	0	0	0.0074627	0	0.0746269	0.9179104	9.7692773	9.2187484	
5	0	0	0	0	0.0243902	0.9756098	8.0922723	18.988026		
4	0	0	0	0.16	0.84	28.071035	27.080298			
3	0	0	0	1	3.9755303	55.151333				
2	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	59.126863					
1	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!						
Unrated										

Deterioration Curve

NBI Rating (y-axis: 0–9) vs Years (x-axis: 0–70)

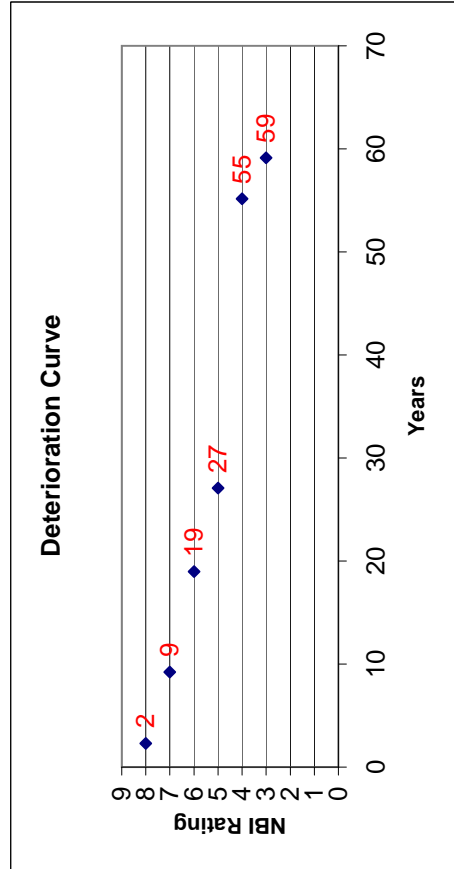Data points: 2, 9, 19, 27, 55, 59

Figure 5-20: 2005-2006 Prestressed I Beam Deterioration Curve

Table 5-21: 2006-2007 Prestressed I Beam Transition Probability Matrix

Bridge Condition Change Matrix

Went up	Sample Size		0	1	2	3	4	5	6	7	8	9	2006-2007
0	41	9									16	25	
1	244	8							2	22	220		
6	234	7							1	233			
26	132	6						5	127				
6	67	5					1	66					
4	19	4				1	18						
	10	3				10							
		2			0								
		1		0									
		0	0										
43	747												

Transition Probability Matrix

Percent

		0	1	2	3	4	5	6	7	8	9
	9	0	0	0	0	0	0	0	0	0.3902439	0.6097561
	8	0	0	0	0	0	0	0.0081967	0.0901639	0.9016393	1.4011572
	7	0	0	0	0	0	0	0.0042735	0.9957265	6.6944431	
	6	0	0	0	0	0	0.0378788	0.9621212	161.84962	8.0956002	
	5	0	0	0	0	0.0149254	0.9850746	17.950282	169.94522		
	4	0	0	0	0.0526316	0.9473684	46.093419	187.8955			
	3	0	0	0	1	12.8201	233.98892				
	2	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	246.80902					
	1	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!						
Unrated											

Deterioration Curve

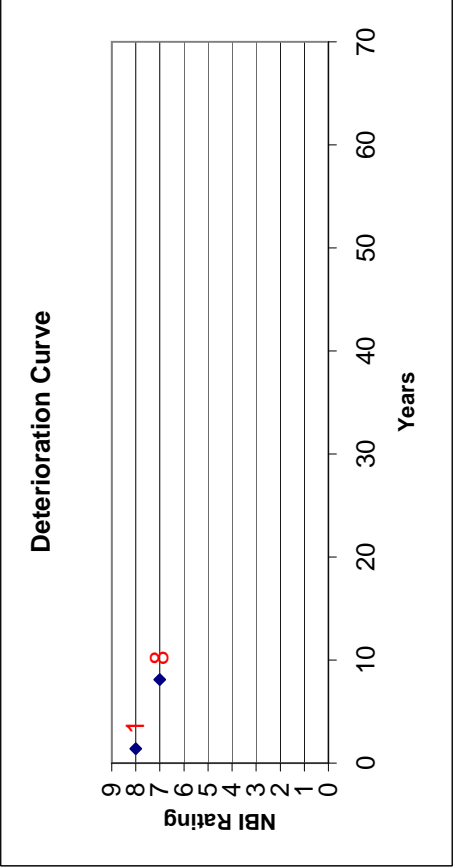NBI Rating (9–0) vs. Years (0–70). Plotted points: 1, 8

Figure 5-21: Prestressed 2006-2007 I Beam Deterioration Curve

Table 5-22: 2007-2008 Prestressed I Beam Transition Probability Matrix

Bridge Condition Change Matrix

2007-2008	Went up	Sample Size	0	1	2	3	4	5	6	7	8	9
9	0	32									8	24
8	6	235							1	5	229	
7		264						3	21	240		
6	7	143						2	141			
5	6	68					5	63				
4	4	16				2	14					
3	4	7			0	7						
2				0	0							
1				0								
0												
	27	765										

Transition Probability Matrix

Percent	0	1	2	3	4	5	6	7	8	9
9	0	0	0	0	0	0	0	0	0.25	0.75
8	0	0	0	0	0	0	0.0042553	0.0212766	0.9744681	2.4094208
7	0	0	0	0	0	0.0113636	0.0795455	0.9090909	26.800197	29.209618
6	0	0	0	0	0	0.013986	0.986014	7.2725409	36.482159	
5	0	0	0	0	0.0735294	0.9264706	49.212636	85.694795		
4	0	0	0	0.125	0.875	9.075817	94.770612			
3	0	0	0.125	1	5.1908931	99.961505				
2	#DIV/0!	#DIV/0!	1	5.1908931	99.961505					
1	#DIV/0!	#DIV/0!								
Unrated	#DIV/0!	#DIV/0!								

Deterioration Curve

NBI Rating (9–0) vs. Years (0, 10, 20, 30, 40, 50, 60, 70)

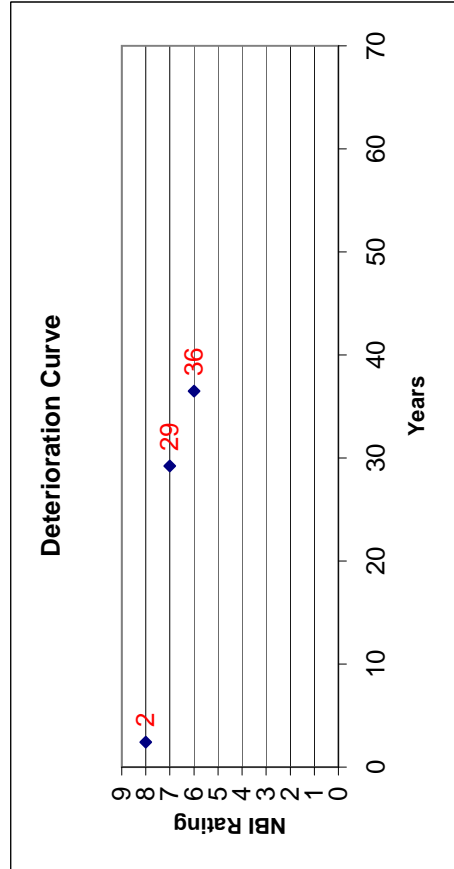Data point labels: 2, 29, 36

Figure 5-22: 2007-2008 Prestressed I Beam Deterioration Curve

34

Table 5-23: 2008-2009 Prestressed I Beam Transition Probability Matrix

Bridge Condition Change Matrix

	Sample Size	2008-2009									
Went up		9	8	7	6	5	4	3	2	1	0
9	35	23	11	1							
8	240		217	21	2						
7	256			247	8	1					
6	158				150	8					
5	60					58	2				
4	14						14				
3	6							6			
2									0		
1										0	
0											0
	25										
	769										

Transition Probability Matrix

Percent	9	8	7	6	5	4	3	2	1	0
9	0.6571429	0.3142857	0.0285714	0	0	0	0	0	0	
8	1.6509249	0.9041667	0.0875	0.0083333	0	0	0	0	0	
7	6.8804485	0.9648438	0.0039063	0.03125	0.0039063	0	0	0	0	
6	8.5313734	19.367546	0.9493671	0.0506329	0	0	0	0	
5	27.898919	13.340082	0.9666667	0.0333333	0	0	0	
4	41.239001	20.445884	1	0	0	0	
3	61.684885	1	1	0	0	
2	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
1	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
Unrated										

Deterioration Curve

NBI Rating (y-axis, 0–9) vs. Years (x-axis, 0–70)

Data points (Years, NBI Rating): 2 (8), 9 (7), 28 (6), 41 (5), 62 (4), 0 (3)
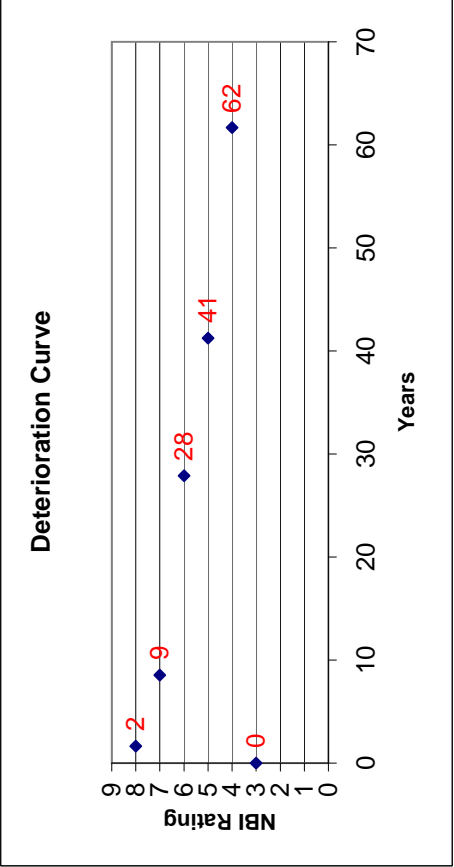
Figure 5-23: 2008-2009 Prestressed I Beam Deterioration Curve

Table 5-24: 2009-2010 Prestressed I Beam Transition Probability Matrix

Bridge Condition Change Matrix

2009	Went up	Sample Size	0	1	2	3	4	5	6	7	8	9 (2009-2010)
9	0	35									5	30
8	2	226								21	205	
7	2	280							9	269		
6	8	154						2	152			
5	7	61					2	59				
4	3	13					13					
3	1	5				5						
2					0							
1				0								
0			0									
Total	23	774										

Transition Probability Matrix

2009	0	1	2	3	4	5	6	7	8	9	Percent
9	0	0	0	0	0	0	0	0	0.1428571	0.8571429	4.4965561
8	0	0	0	0	0	0	0	0.0929204	0.9070796		7.107378
7	0	0	0	0	0	0.0071429	0.0321429	0.9607143			11.603934
6	0	0	0	0	0	0.012987	0.987013				17.294858
5	0	0	0	0	0.0327869	0.9672131					20.79249
4	0	0	0	0	1						28.898792
3	0	0	0	1							53.025004
2	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!							81.923796
1	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!							102.71629
Unrated											

Deterioration Curve

NBI Rating (y-axis: 0–9) versus Years (x-axis: 0, 10, 20, 30, 40, 50, 60, 70)
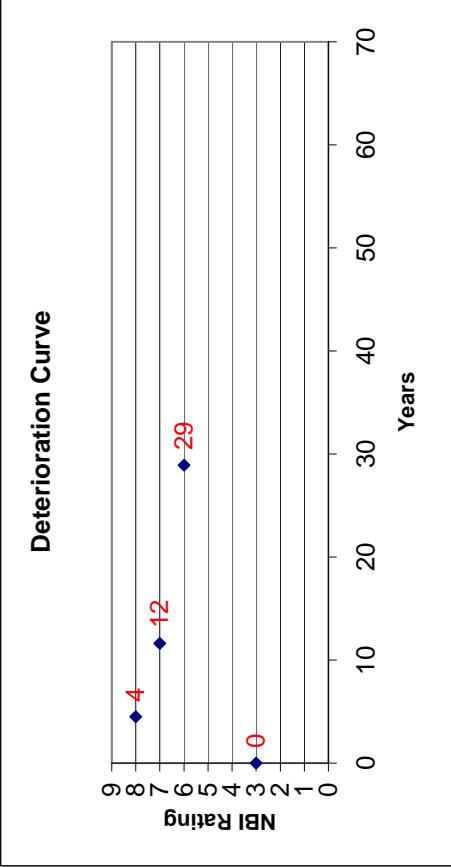
Data point labels: 4, 12, 29, 0

Figure 5-24: 2009-2010 Prestressed I Beam Deterioration Curve