Winneshiek County Pavement Analysis

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THE UNIVERSITY OF IOWA
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1.0. Current Pavement Condition

The portion of pavement our group was tasked with evaluating was U.S. Highway 52 in Winneshiek County, Iowa. The specific section is between mileposts 149.65 and 153.68. This 4 mile section runs from the junction of Iowa Highway 9 and U.S. Highway 52 on the southwest side of Decorah, Iowa to the intersection of College Road and U.S Highway 52 north of Decorah. This was part of Iowa DOT project number F-1112 completed in 1964. The surface consists of Portland Cement Concrete (PCC) at a thickness of 10 inches on 6 inches of rolled stone sub-base. The type of coarse aggregate sub-base is listed as Welken. The subgrade of the area was found to have a California Bearing Ratio (CBR) of 3, which is considered poor.

Current conditions for the pavement section of U.S. Highway 52 in question were found to be poor. The Iowa DOT lists the current pavement condition as poor according to the International Roughness Index (IRI), which can be seen in Figure 1. An Iowa DOT report from February 2014 gives the section of U.S. Highway 52 an IRI of 3.53 meters per kilometer, which equates to 224.6 inches per mile. This value of IRI places the pavement in poor condition. Other pavement measurements in the Iowa DOT report include relative crack and patch index (C&P), relative pavement index (RPI), and pavement condition index (PCI). The C&P value of the pavement was 17, which places in close to severe distress. A value of 13 was given for the RPI, which puts it near very poor condition. The PCI taken in 2011 was 20, which means the pavement is in poor condition and approaching very poor condition. This section of U.S. Highway 52 is already in poor condition without the frac-sand mine and has likely reached the end of its design life after being in use for 51 years without any rehabilitation.

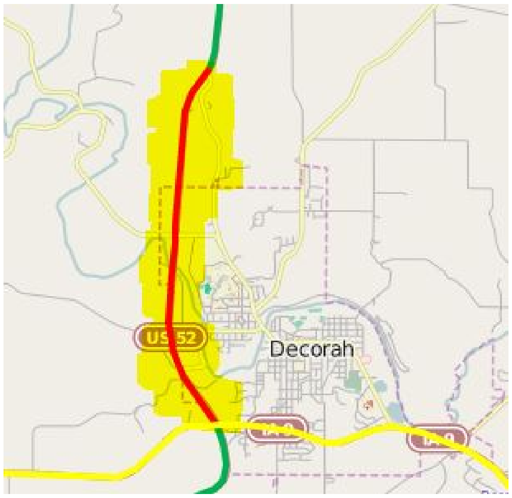

Figure 1: Pavement Condition (based on IRI) for U.S Highway 52 (highlighted in yellow) from Iowa DOT. (Good = green, Fair = yellow, and Poor = red)

The traffic on U.S. Highway 52 in Winneshiek County, Iowa is some of the heaviest in the region. The Iowa DOT estimates that the section of U.S. Highway 52 in question saw an annual average of 3,410 vehicles per day in 2012. The estimated truck traffic for this section of pavement was 400 trucks per day, which is almost 11.7% of the daily traffic. Iowa Highway 9, which intersects U.S. Highway 52, sees similar traffic volumes. The section of U.S. Highway 52 south of Iowa Highway 9 sees a slightly higher traffic volume with a similar daily truck traffic percentage. The traffic on U.S. Highway 52 north of the junction with Iowa Highway 9 has seen a consistent increase in annual average daily traffic since the Iowa DOT started recording data in 1988. The annual average daily traffic and truck traffic data from the Iowa DOT can be seen in Table 1. The truck traffic percentage has remained between 9 to 14 percent since the data was first recorded. The addition of a frac-sand mine would cause an increase in truck traffic percentage, and this increase was noted the pavement analyses, discussed further below.

Table 1: Annual Average Daily Traffic and Truck Traffic from Iowa DOT for U.S. Highway 52 north of the junction with Iowa Highway 9 in Winneshiek County.

Year	1988	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	Cumulative
Vehicle AADT (veh/day)	1,930	1,960	2,030	2,360	2,690	2,780	2,810	2,930	3,040	3,320	3,630	3,380	3,410	**72,540**
Truck Traffic (trucks/day)	240	290	300	300	300	360	360	420	430	330	330	400	400	**8,920**
Truck Percentage (truck/veh)	12.4%	14.8%	14.8%	12.7%	11.2%	12.9%	12.8%	14.3%	14.1%	9.9%	9.1%	11.8%	11.7%	**12.3%**

2.0. Estimated Future Traffic Loadings

In order to determine the impact of the mine truck traffic on US-52, the estimated additional traffic levels needed to be quantified. This analysis was performed from the perspective of looking at a future pavement design life, rather than looking how much more quickly the pavement would reach the end of its current design life. The analysis was performed in this manner due to the fact that the current pavement is in extremely poor condition, as previously mentioned, and has likely already reached the end of its design life.

Using data provided by the Urban and Regional Planning Department, four scenarios were studied: future traffic levels with no mine at all (“Baseline”), future traffic levels for a small sized mine at medium output (“Case 1”), future traffic levels for a medium sized mine at medium output (Case 2”), and future traffic levels for a large sized mine at medium output (“Case 3”). The estimated ESALs for a 20-year design life for these scenarios are 8,779,200 for Baseline, 9,061000 for Case 1, 9,853,400 for Case 2, and 10,663,600 for Case 3. The additional ESALs for the three mine sizes are approximately 0.28 Million, 1.07 Million, and 1.88 Million ESALs, respectively.

These additional ESALs were assumed to come solely from the truck traffic associated with the mine. After consulting with students from the Urban and Regional Planning group, and based on personal anecdotes from students who live in Winneshiek County, it was determined that the future traffic loadings would likely remain relatively steady over the 20-year design life, so a traffic growth factor was not factored into the calculation. Similarly, the frac-sand truck traffic is not expected to fluctuate, as the mines will be operating at capacity and will have a fixed output. Thus, the 20-year calculation was a relatively straightforward one.

The ESAL breakdown by each truck classification is shown in Table 2. The current traffic breakdowns were provided by the Urban and Regional Planning group. Once the future ESAL levels were determined for the three mine cases, the new truck traffic distribution was calculated. These specific classification breakdowns were incorporated into the Mechanistic-Empirical Pavement Design Guide (MEPDG) software calculations. As assumed by the Urban and Regional Planning Group, the trucks used by the frac sand mines would all be Class 10 trucks, with 6 or more axles and a maximum load of 96,000 pounds. For each of the three mine cases, the additional mine ESALs were added directly to the Baseline US-52 Class 10 ESALs to determine the new amount of Class 10 Truck ESALs. Then, the new ESAL distributions were able to be calculated. As shown in Table 2, the relative ESAL percentage for Class 10 Trucks increases from Baseline to Case 3, and all other percentages decrease.

Table 2: 20-year ESAL Breakdown by Truck Class

		Current Traffic		Case 1 (Small Mine)		Case 2 (Medium Mine)		Case 3 (Large Mine)	
Truck Classification	Description	ESALs	Distribution	ESALs	Distribution	ESALs	Distribution	ESALs	Distribution
Class 2	Car	23,400	0.3%	23,400	0.3%	23,400	0.2%	23,400	0.2%
Class 4	Busses	2,700	0.03%	2,700	0.03%	2,700	0.03%	2,700	0.03%
Class 5	2 Axle SU	1,512,900	17.2%	1,512,900	16.7%	1,512,900	15.4%	1,512,900	14.2%
Class 6	3 Axle SU	998,400	11.4%	998,400	11.0%	998,400	10.1%	998,400	9.4%
Class 7	4+ Axle SU	96,000	1.1%	96,000	1.1%	96,000	1.0%	96,000	0.9%
Class 8	4 Axle CU	460,200	5.2%	460,200	5.1%	460,200	4.7%	460,200	4.3%
Class 9	5 Axle CU	5,249,400	59.8%	5,249,400	57.9%	5,249,400	53.3%	5,249,400	49.2%
Class 10	6+ Axle CU	217,800	2.5%	499,600	5.5%	1,292,000	13.1%	2,102,200	19.7%
Class 12	Multiple Trailer	218,400	2.5%	218,400	2.4%	218,400	2.2%	218,400	2.0%
Total		8,779,200	100%	9,061,000	100%	9,853,400	100%	10,663,600	100%

3.0. Reduction in Pavement Life

A frac-sand mine development in Winneshiek County will add to the traffic seen on roadways in the area. This mine would specifically increase the truck traffic in the region and on the section of U.S. Highway 52 in question. The increase in ESALs and truck traffic can be seen in Table 2 for three different scenarios. Since the four mile section of U.S. Highway 52 being evaluated has likely reached the end of its pavement life, it is hard to measure the reduction caused by the addition traffic from the frac-sand mine.

If left alone, the pavement will continue towards severe distress and very poor conditions. The additional traffic from a frac-sand mine would cause the pavement condition to deteriorate quicker than the baseline case. As the ESAL amount grows, so will the stress on the pavement. This increase in stress caused by the trucks from the frac-sand mine would create a significantly worse pavement condition than what already exists.

U.S. Highway 52 between milepost 149.65 and 153.68 has likely reached and surpassed its design life after 51 years of use with increasing traffic amounts. Since information about the design life was not provided, it is assumed that the poor condition of the pavement means it is nearing the end of its life. Due to the end of the pavement life, the reduction of the additional traffic cannot be found correctly. Regardless of a frac-sand mine development in Winneshiek County, a rehabilitation of the pavement section of U.S. Highway 52 would be necessary. The section of U.S. Highway 52 south of the evaluated section has recently been overlaid and it is likely that plans for the section north of the junction of Iowa Highway 9 have already been made. It is important that plans for the rehabilitation of the pavement section account for the increased ESALs that would come from frac-sand mine development in the area.

4.0. Pavement Analysis

As the current road condition on US-52 is in a dire condition for rehabilitation, it was concluded that the road repair is required regardless of the potential mining development in Winneshiek County. In order to determine the overlay thickness differences in each scenario, structural design guides such as AASHTO93 and Mechanistic and Empirical Pavement Design Guide (MEPDG) have been used to calculate the thickness of asphalt overlay for each scenario. Once an overlay thickness was calculated by using AASHTO93 design guideline, MEPDG was then used to verify the calculated thickness to satisfy the various structural requirements with the given traffic.

Prior to designing a pavement overlay, evaluation of the mechanical strength of the current subgrade was conducted through the California Bearing Ratio (CBR) test. The CBR test is a penetration test that uses a standard piston which penetrates the soil as a standard rate of 0.05 in/min. A unit load is recorded at several penetration depth, typically 0.1 and 0.2 inch. The CBR value is computed by dividing the recorded unit load by a standard unit load that is required to penetration for a high-quality crushed stone material (Mallick at el. 2013).

$$CBR = \frac{P}{P_S} * 100$$

CBR = CBR (%)
P = Measured pressure for site soil (N/mm2)
Ps = Pressure to achieve equal penetration on standard soil (N/mm2)

The CBR test was conducted on the soils from Winneshiek County on April 12, 2015. Due to the limitation of our test methods, our CBR value was extremely low. More realistic result values were sheared other group in class and their result is shown in Table 3. According to Asphalt Pavement Association of Iowa (APAI)'s Asphalt Paving Design Guide, subgrade strength is considered poor with the CBR value of 3 to 5. As the test results indicate the soil condition is very poor, CBR value of 3% was used as the AASHTO 93 input.

Table 3: Raw data from CBR Testing

CBR Test Data (in 0.0001")							
	Boring #5						
Penetration	**Load**		**Load (LBF)**		**Stress (psi)**		
(inch)	Trial #1	Trial #2	Trial #1	Trial #2	Trial #1	Trial #2	Average
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
0.02	0.30	0.30	0.00	0.00	0.00	0.00	0.05
0.04	0.40	0.55	0.00	0.00	0.00	0.00	0.10
0.06	0.65	0.70	0.00	0.00	0.00	0.00	0.20
0.08	0.70	0.80	0.56	1.25	0.19	0.42	0.30
0.10	0.85	0.90	1.56	2.25	0.52	0.75	0.63
0.12	0.90	1.00	2.56	3.25	0.85	1.08	0.97
0.14	1.00	1.10	3.56	4.25	1.19	1.42	1.30
0.16	1.05	1.15	4.56	5.25	1.52	1.75	1.63

0.18	1.15	1.20	5.56	6.25	1.85	2.08	1.97
0.20	1.20	1.30	6.56	7.25	2.19	2.42	2.30
0.22	1.25	1.30	7.56	8.25	2.52	2.75	2.63
0.24	1.30	1.45	8.56	9.25	2.85	3.08	2.97
0.26	1.35	1.50	9.56	10.25	3.19	3.42	3.30
0.28	1.40	1.50	10.56	11.25	3.52	3.75	3.63
0.30	1.50	1.60	11.56	12.25	3.85	4.08	3.97
0.32	1.60	1.60	12.56	13.25	4.19	4.42	4.30
0.34	1.70	1.70	13.56	14.25	4.52	4.75	4.63
0.36	1.70	1.70	14.56	15.25	4.85	5.08	4.97

Penetration	CBR			
(inch)	#1	#2	Average	Max
0.1	0.05	0.07	0.06	0.15
0.2	0.15	0.16	0.15	

The CBR test was conducted on the soils from Winneshiek County on April 12, 2015. Due to the limitation of our test methods, our CBR value was extremely low. According to Asphalt Pavement Association of Iowa (APAI)'s Asphalt Paving Design Guide, subgrade strength is considered poor with the CBR value of 3 to 5. As the test results indicate the soil condition is very poor, CBR value of 3% was used in the AASHTO 93 input.

Considering the soil below the pavement is in poor condition, the AASHTO 93 design guide was used to calculate the pavement thickness required to handle the truck traffic volumes increased by the frac-sand mines.

The AASHTO 93 equation predicts a load that requires the number of 18-kip ESAL that will be carried by the pavement over its design life. With the concept of Present Serviceability Index (PSI), the AASHTO 93 equation is developed to relate such traffic to thickness as shown below. The equation is also mapped to a nomograph, an often used method from when computers were not yet common (Mallick at el. 2013).

$$\log_{10}(W_{18}) = Z_R \times S_o + 9.36 \times \log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left(\frac{\Delta PSI}{4.2-1.5}\right)}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 \times \log_{10}(M_R) - 8.07$$

where: W18 = predicted number of 80 kN (18,000 lb.) ESALs

ZR = standard normal deviate

So = combined standard error of the traffic prediction and performance prediction

SN = Structural Number (an index that is indicative of the total pavement thickness required)

= $a_1D_1 + a_2D_2M_2 + a_3D_3M_3 + \ldots a_iD_iM_i$ = ith layer coefficient, Di = ith layer thickness (inches), Mi = ith layer drainage coefficient

DPSI = difference between the initial design serviceability index, p_o, and the design terminal serviceability index, p_t

MR = subgrade resilient modulus (in psi)

For asphalt overlay, the parameters shown in Table 5 were used to calculate the thickness of surface layer of the pavement for each scenario.

Table 5: AASHTO 93 Equation Inputs

Parameter	**Value**
Initial Serviceability Index ($P0$)	4.2
Terminal Serviceability Index (Pt)	2.5
Analysis Period	20
Reliability (R%)	0.90
Overall Standard Deviation (So)	0.35
CBR	3
Mr	4118
Zr	-1.18

The structural number is an abstract number that represent the structural strength of a pavement as a function of layer thickness, layer coefficients and drainage coefficients. This equation is represented below.

$$SN = a_1D_1 + a_2D_2M_2 + a_3D_3M_3 \ldots$$

(Mallick at el. 2013, page 373).

The layer coefficient a_i is a measure of the relative ability of a unit thickness of a given material to function as a structural component of the pavement. Drainage coefficient m2 and m3 should be applied granular bases and sub bases to modify the layer coefficients but for our calculation they were both used as 1. Since the depths of the existing concrete layer and crushed stone are known, 10 inch and 6 inch, surface layer could be calculated by using the equation shown above. Even though the current concrete layer is damaged by high traffic on US-52, it can be used as a sub-base as if it is cracked and seated. The purpose of performing a crack and seat is to prevent any reflective cracking on joint areas from propagating through the new asphalt overlay.

The layer coefficient for surface layer, HMA layer was 0.44, for sub-base layer, crack and seat was 0.20, and crushed (graded) stone base was 0.11. With the given layer coefficient, the resilient modulus of crack and seat was calculated to be 42,857 psi. The relationship between layer coefficient and resilient modulus is shown below.

$$Mr = 30{,}000 * a_i/0.14$$

(Mallick at el. 2013, page 375).

With the 20 years of ESALs, the structure number was calculated by AASHTO 93 equation and the thickness of the surface layer was then calculated by using the structure number equation ($SN = a_1D_1 + a_2D_2M_2 + a_3D_3M_3$). Table 6 summarizes the calculated thickness for each scenario.

Table 6: AASHTO 93 Results Summary

	SN	Thickness (in)		
Baseline	4.2	6.500000	→	6.5
Case 1	4.205	6.511364	→	7.0
Case 2	4.3	6.727273	→	7.0
Case 3	4.305	6.738636	→	7.0

The thickness calculated by AASHTO 93 was verified against the structural requirements by Mechanical- Empirical Pavement Design Guide (MEPDG). MEPDG software was developed by National Cooperative Highway Research Program (NCHRP) and will be used by the Iowa DOT starting this year.

Existing Condition 6.5 inch overlay1

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Design Inputs

Design Life: 20 years
Design Type: Flexible Pavement

Base construction: May, 2016
Pavement construction: June, 2017
Traffic opening: September, 2017

Climate Data Sources (Lat/Lon): 42.554, -92.401

Design Structure

Layer type	Material Type	Thickness (in.):
Flexible	Default asphalt concrete	6.5
NonStabilized	A-1-a	10.0
NonStabilized	Crushed stone	6.0
Subgrade	A-7-6	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

Age (year)	Heavy Trucks (cumulative)
2017 (initial)	14,150
2027 (10 years)	2,584,140
2037 (20 years)	5,168,290

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	172.00	178.87	90.00	86.18	Fail
Permanent deformation - total pavement (in.)	0.75	0.70	90.00	96.40	Pass
AC bottom-up fatigue cracking (percent)	25.00	2.47	90.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	2347.18	90.00	19.70	Fail
AC top-down fatigue cracking (ft/mile)	2000.00	1729.01	90.00	93.17	Pass
Permanent deformation - AC only (in.)	0.25	0.37	90.00	45.03	Fail

Case 1 - Small Mine 7 inch overlay

File Name: D:\My ME Design\FINAL REPORT\Case 1 - Small Mine 7 inch overlay.dgpx

Design Inputs

Design Life: 20 years
Design Type: Flexible Pavement

Base construction: May, 2016
Pavement construction: June, 2017
Traffic opening: September, 2017

Climate Data Sources (Lat/Lon): 42.554, -92.401

Design Structure

Layer type	Material Type	Thickness (in.):
Flexible	Default asphalt concrete	7.0
NonStabilized	A-1-a	10.0
NonStabilized	Crushed stone	6.0
Subgrade	A-7-6	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

Age (year)	Heavy Trucks (cumulative)
2017 (initial)	14,605
2027 (10 years)	2,667,240
2037 (20 years)	5,334,480

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	172.00	176.93	90.00	87.32	Fail
Permanent deformation - total pavement (in.)	0.75	0.69	90.00	96.99	Pass
AC bottom-up fatigue cracking (percent)	25.00	2.15	90.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	2142.15	90.00	24.30	Fail
AC top-down fatigue cracking (ft/mile)	2000.00	1427.45	90.00	96.45	Pass
Permanent deformation - AC only (in.)	0.25	0.37	90.00	44.29	Fail

Case 2-Small Mine 7 inch overlay

File Name: D:\My ME Design\FINAL REPORT\Case 2-Small Mine 7 inch overlay.dgpx

Design Inputs

Design Life: 20 years
Design Type: Flexible Pavement

Base construction: May, 2016
Pavement construction: June, 2017
Traffic opening: September, 2017

Climate Data Sources (Lat/Lon): 42.554, -92.401

Design Structure

Layer type	Material Type	Thickness (in.):
Flexible	Default asphalt concrete	7.0
NonStabilized	A-1-a	10.0
NonStabilized	Crushed stone	6.0
Subgrade	A-7-6	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

Age (year)	Heavy Trucks (cumulative)
2017 (initial)	15,900
2027 (10 years)	2,903,740
2037 (20 years)	5,807,480

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	172.00	178.25	90.00	86.55	Fail
Permanent deformation - total pavement (in.)	0.75	0.72	90.00	94.27	Pass
AC bottom-up fatigue cracking (percent)	25.00	2.25	90.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	2142.15	90.00	24.30	Fail
AC top-down fatigue cracking (ft/mile)	2000.00	1568.56	90.00	94.97	Pass
Permanent deformation - AC only (in.)	0.25	0.39	90.00	37.73	Fail

Distress Charts

Case 3 - Large Mine 7 inch overlay

File Name: D:\My ME Design\FINAL REPORT\Case 3 - Large Mine 7 inch overlay.dgpx

Design Inputs

Design Life: 20 years
Design Type: Flexible Pavement

Base construction: May, 2016
Pavement construction: June, 2017
Traffic opening: September, 2017

Climate Data Sources (Lat/Lon): 42.554, -92.401

Design Structure

Layer type	Material Type	Thickness (in.):
Flexible	Default asphalt concrete	7.0
NonStabilized	A-1-a	10.0
NonStabilized	Crushed stone	6.0
Subgrade	A-7-6	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

Age (year)	Heavy Trucks (cumulative)
2017 (initial)	17,180
2027 (10 years)	3,137,500
2037 (20 years)	6,275,000

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	172.00	179.43	90.00	85.83	Fail
Permanent deformation - total pavement (in.)	0.75	0.75	90.00	90.72	Pass
AC bottom-up fatigue cracking (percent)	25.00	2.36	90.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	2142.15	90.00	24.30	Fail
AC top-down fatigue cracking (ft/mile)	2000.00	1691.31	90.00	93.60	Pass
Permanent deformation - AC only (in.)	0.25	0.41	90.00	32.28	Fail

We designed the pavement with the design life of 20 years that will support existing and increased truck traffic due to 1 small, 1 medium and 1 large mine respectively. With 6.5" overlay for existing condition and 7" overlay for all other cases, the new overlay will satisfy various criterions for pavement design with the reliability of 90%. The results are shown in the following Figures. More detailed MEPDG results are attached in Appendix A.

The designed pavement all passed the permanent deformation for total pavement and AC bottom-up fatigue cracking and top-down cracking thresholds. It failed to meet the requirement of Terminal International Roughness Index (IRI) with 90% reliability. However, the achieved reliability of Terminal IRI reached all above 85%, considering that the designed pavement will last close enough to the design life of 20 years to be considered satisfactory.

The reasons of this IRI failure could be due to the limitations and assumptions of ASSHTO 93 design guide. The AASHTO 93 empirical equation was developed on the specific pavement materials and roadbed soil present at the AASHO Road Test in Ottawa, Illinois and the environment was only considered in AASHO Road test only. Most importantly, the loads used to develop this equation were operating vehicles with identical axle loads as compared to mixed traffic. As we used various classes of vehicles as inputs on MEPDG, it understandably caused different roughness requirements between AASHTO 93 and MEPDG.

The designed pavement also failed AC thermal cracking and AC permanent deformation requirement with very low achieved reliability, below 50%. The reason of AC thermal cracking and AC permanent deformation failures is mainly because such cracking is occurred due to temperature, not due to loads. Cracking due to temperature can be hard to predict and often times unavoidable. For our analysis, we used typically used PG binder, PG 64-22. However using a different PG grade of asphalt binder may prevent AC permanent deformation failure.

Comparing the results of AASHTO 93 and MEPDG design guides showed that there are many possible combinations of layer thickness designs, therefore it would be important to understand the limitations of each design guide to avoid any impractical designs.

5.0. Rehabilitation Options

There are a few different options to consider when rehabilitating the concrete section of U.S. 52. Due to the poor condition of the existing concrete and extensive transverse and longitudinal cracking with PCI of 20, it has been determined that the best option is to crack and seat the pavement with an asphalt overlay. After running calculations depending on the truck traffic, the overlay will be 7 inches with all three mine cases. The overlay would be 6.5 inches with the existing traffic conditions. Another option would be to tear out the existing concrete and pour a new road. This would cost the most and take the most amount of time to complete. The final option would to just overlay the concrete with the asphalt. This option isn’t viable because after a few years the cracks in the concrete would reflect through the overlay, leading to a pavement that would require constant rehabilitation.

6.0. Cost Estimate

The potential of building frac-sand mines in Winneshiek County has brought attention to the condition of the roads on haul routes. The focus of our group was U.S. 52. The current state of U.S. 52 gives it a PCI of 20, this rating is well below the level where rehabilitation is recommended. Thus, our group is recommending that the road be replaced with or without a frac sand mine in the area. Calculations performed using AASHTO 93 and MEPDG software show that that the asphalt overlay of the road would need to be 6.5 inches to accommodate current traffic and 7 inches to accommodate new truck loadings, as previously mentioned. It was determined that due to very poor current concrete condition, the pavement should be crack and seated as a base layer for the asphalt. It was found that the cost to crack and seat is roughly $3,000 per lane mile. Using RS Means software, our group was able to determine the total cost of asphalt pavement per lane mile. RS Means is a cost estimating software that uses up to date, current market pricing on construction industry goods and services. The values given were for 6" and 8" of asphalt paving for roadways and large paved areas. The costs were given in terms of square yards and also include expenses for labor.

Table 7: RS Means Pricing for Asphalt Paving.

Material	Unit	Bare Material	Bare Labor	Bare Equipment	Bare Total	Total O&P
Asphalt paving, plant mixed asphaltic base course for roadways and large paved areas, 6" thick	SY	$ 24.20	$ 0.93	$ 0.69	$ 25.82	**$ 29.02**
Asphalt paving, plant mixed asphaltic base course for roadways and large paved areas, 8" thick	SY	$ 32.61	$ 1.15	$ 0.85	$ 34.61	**$ 38.47**

Interpolating the cost per square yard of the two pavement thicknesses shown it was determined that the cost per square yard of 7" asphalt would cost $33.75, while the cost of the 6.5" paving would be $31.38. Using the assumption of a 12' lane width with a 4' shoulder it was determined that the total cost to replace a lane mile with asphalt paving 6.5" deep was interpolated to be $297,554. The cost to pave 7" thick asphalt, which would be required with the added mine traffic was calculated to be $319,800. This means that the added cost per lane mile if frac-sand mines are implemented in the area would be $22,246. This means the added cost of replacing the road would be over $80,000 over the 4 mile stretch utilized by the potential sand hauling trucks.

$$\text{Total Cost}/_{Lane\ Mile} = [(\$\text{Asphalt}/\text{SY}) * (\text{Lane Width} + \text{Shoulder Width}) * (5280/9)] + \text{Crack and Seat}$$

$$6.5''\ Cost = \left[(\$31.28) * {}^{(12+4)}/_{3}\,yd * ({}^{5280}/_{3})yd\right] + \$3000 = {}^{\mathbf{\$297,554}}/_{\boldsymbol{lane\ mile}}$$

$$7''\ Cost = \left[(\$33.75) * {}^{(12+4)}/_{3}\,yd * ({}^{5280}/_{3})yd\right] + \$3000 = {}^{\mathbf{\$319,800}}/_{\boldsymbol{lane\ mile}}$$

Figure 2: Sample Calculations for Asphalt Cost.

References

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