Winneshiek County Frac Sand Haul Route Pavement Analysis

Pavement Engineering Class, Spring 2015

College of Engineering - Department of Civil and Environmental Engineering

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Design Objective

- Evaluate the current pavement condition on potential haul routes for hydraulic fracturing sand mining in Winneshiek County, Iowa
- Determine the extent of pavement deterioration due to the estimated additional mining truck traffic
- Estimate the future pavement rehabilitation costs due to the added mining truck traffic

Background

- As the frac sand mining industry is growing fast in Midwest, Winneshiek County considers potential frac sand mining development in their community. Prior to a development plan, Winneshiek County has requested an impact study from the Iowa Initiative for Sustainable Communities and students and faculty from University of Iowa College of Engineering
- In CEE 4560: Pavement Engineering course at the University of Iowa, students were divided into three groups to investigate different types of existing pavements with Portland Cement Concrete (PCC), PPC with asphalt overlay and asphalt on potential truck routes, U.S. Route 52 and Big Canoe Road in the north of Decorah, in Winneshiek County
- First, each group conducted literature reviews on similar case studies in other States to better understand the potential impact of increased truck traffic on the roads.
- Second, they evaluated the properties of the subgrade materials that support pavements from underneath by performing laboratory testing such as the California Bearing Ratio (CBR) test. Based on the laboratory results, they used AASHTO soil classification system to determine its suitability for a pavement subgrade.
- Lastly, AASHTO 93 design guide and M-E software were utilized to analyze the traffic impact by increased truck traffic from sand mines. Based on these results, recommended options for future pavement construction due to sand mine development were generated based on the expected Equivalent Standard Axle Loads (ESALs).

Big Canoe Road

Pavement Information

- Reconstructed in 2008
- 5 inches Hot Mix Asphalt (HMA) on 5 inches cold-in-place recycled asphalt on 6 inches rolled stone base
- Cracks have been sealed every year since 2008, pavement is in relatively good condition

US – 52 (Concrete)

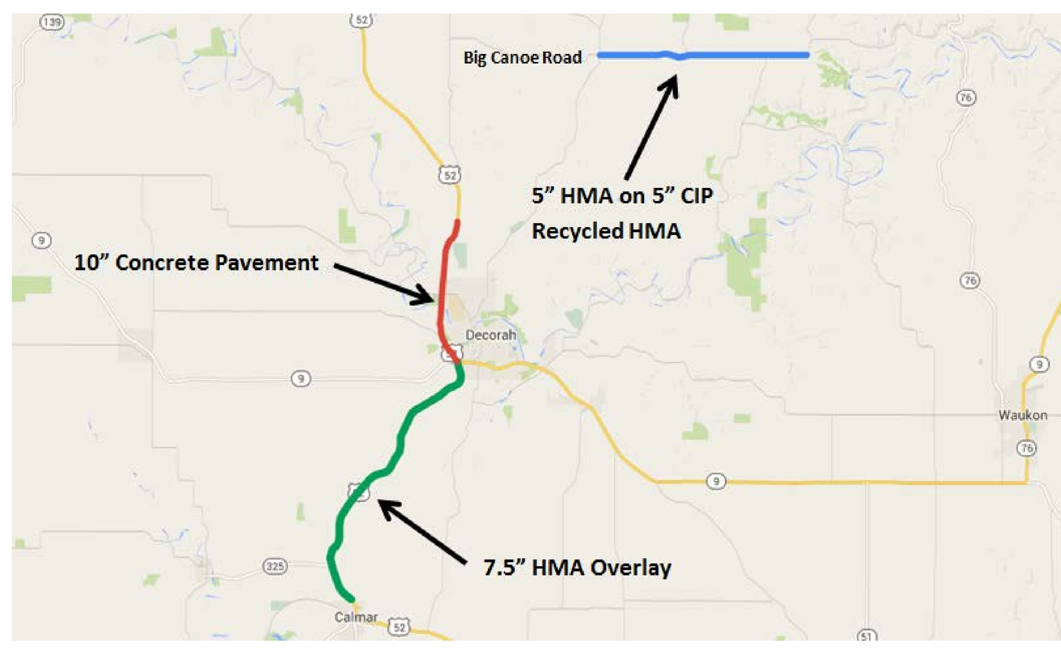
Pavement Information

- Constructed in 1964
- 10 inch concrete slab on 6 inch rolled stone base
- Pavement Condition Index measured to be 20 (100 is best , 0 is worst, <55 is considered "poor")
- Pavement is in urgent need of rehabilitation

US – 52 (Asphalt)

Pavement Information

- Constructed in 1961, rehabilitated in 2012
- 10 in. concrete slab on 6 in. rolled stone base (1961)
- 7.5 inch HMA overlay after crack and seating of concrete (2012)



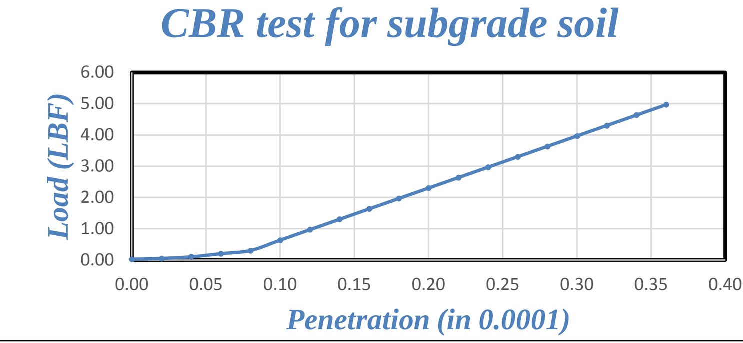
California Bearing Ratio (CBR) Test

This test evaluated the properties of the subgrade soils which lie underneath the existing pavement. CBR test results were used to check its suitability for potential pavement construction.

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	Avg.
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

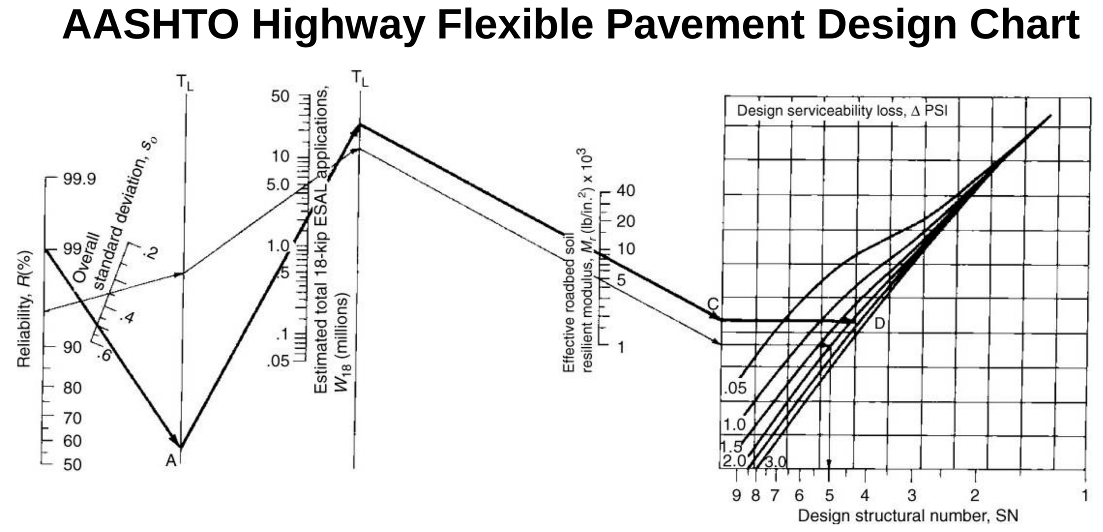
CBR test for subgrade soil



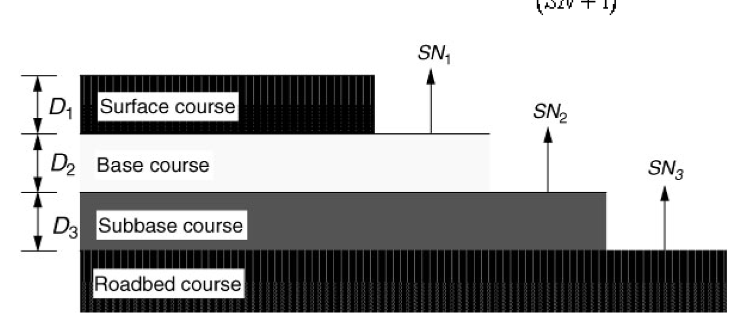
Penetration	CBR			
(inch)	#1	#2	Avg.	Max
0.1	0.05	0.07	0.06	0.15
0.2	0.15	0.16	0.15	
CBR value rounded to 3 for typical number for Iowa soil.				

AASHTO 93 Structural Design Guide

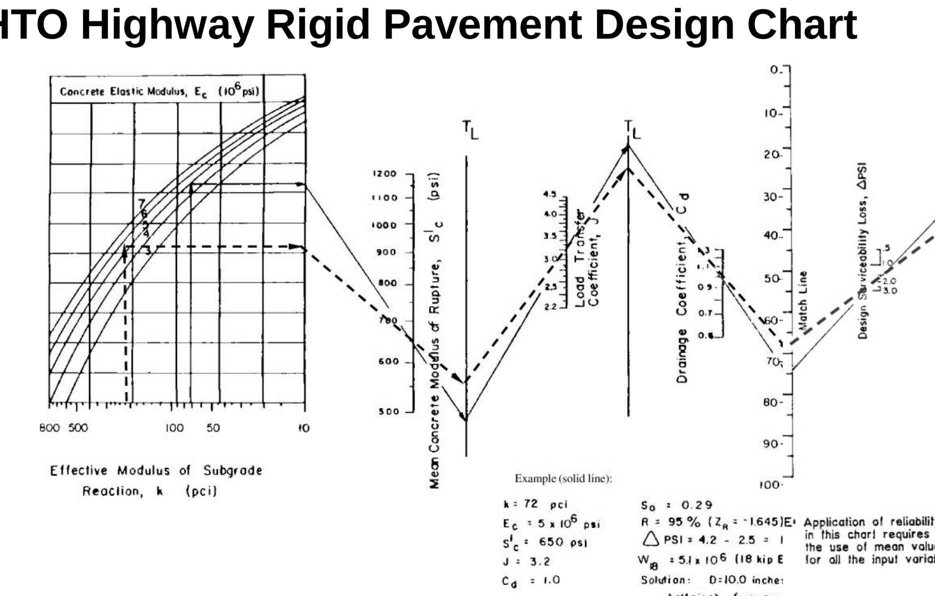
AASHTO Highway Flexible Pavement Design Chart

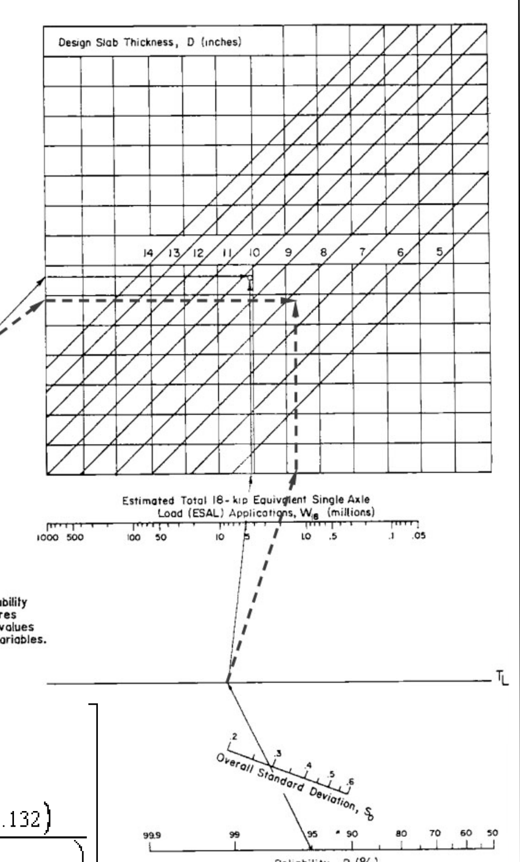


$$\log_{10}(W_{18}) = Z_R \times S_o + 9.36 \times \log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left(\frac{\Delta PSI}{4.2-1.5}\right)}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 \times \log_{10}(M_R) - 8.07$$



AASHTO Highway Rigid Pavement Design Chart





$$\log_{10}(W_{18}) = Z_R \times S_o + 7.35 \times \log_{10}(D+1) - 0.06 + \frac{\log_{10}\left(\frac{\Delta PSI}{4.5-1.5}\right)}{1 + \frac{1.624 \times 10^7}{(D+1)^{8.46}}} + (4.22 - 0.32 p_t) \times \log_{10}\left[\frac{(S'_c)(C_d)(D^{0.75} - 1.132)}{215.63(J)\left(D^{0.75} - \frac{18.42}{\left(E_c/k\right)^{0.25}}\right)}\right]$$

	Case 1	Case 2	Case 3
	S+M+L	2S+2M+2L	3S+3M+3L
ESALs (current)	658440	658440	658440
ESALs (increased due to mine)	820460	982480	1144500
Traffic due to mine	162020	324040	486060
Slab Thickness (current)	6.745 (7.0) in	6.745 (7.0) in	6.745 (7.0) in
Slab Thickness (increased due to mine)	7.045 (7.5) in	7.245 (7.5) in	7.495 (7.5) in

Mechanistic-Empirical Pavement Design Guide

Pavement

File Name: D:\Pavement.dgpx

Design Inputs

Design Life:	20 years	Existing construction:	May, 2016	Climate Data Sources (Lat/Lon)	42.554, -92.401
Design Type:	AC over JPCP	Pavement construction:	June, 2017		
		Traffic opening:	September, 2017		

Design Structure

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

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

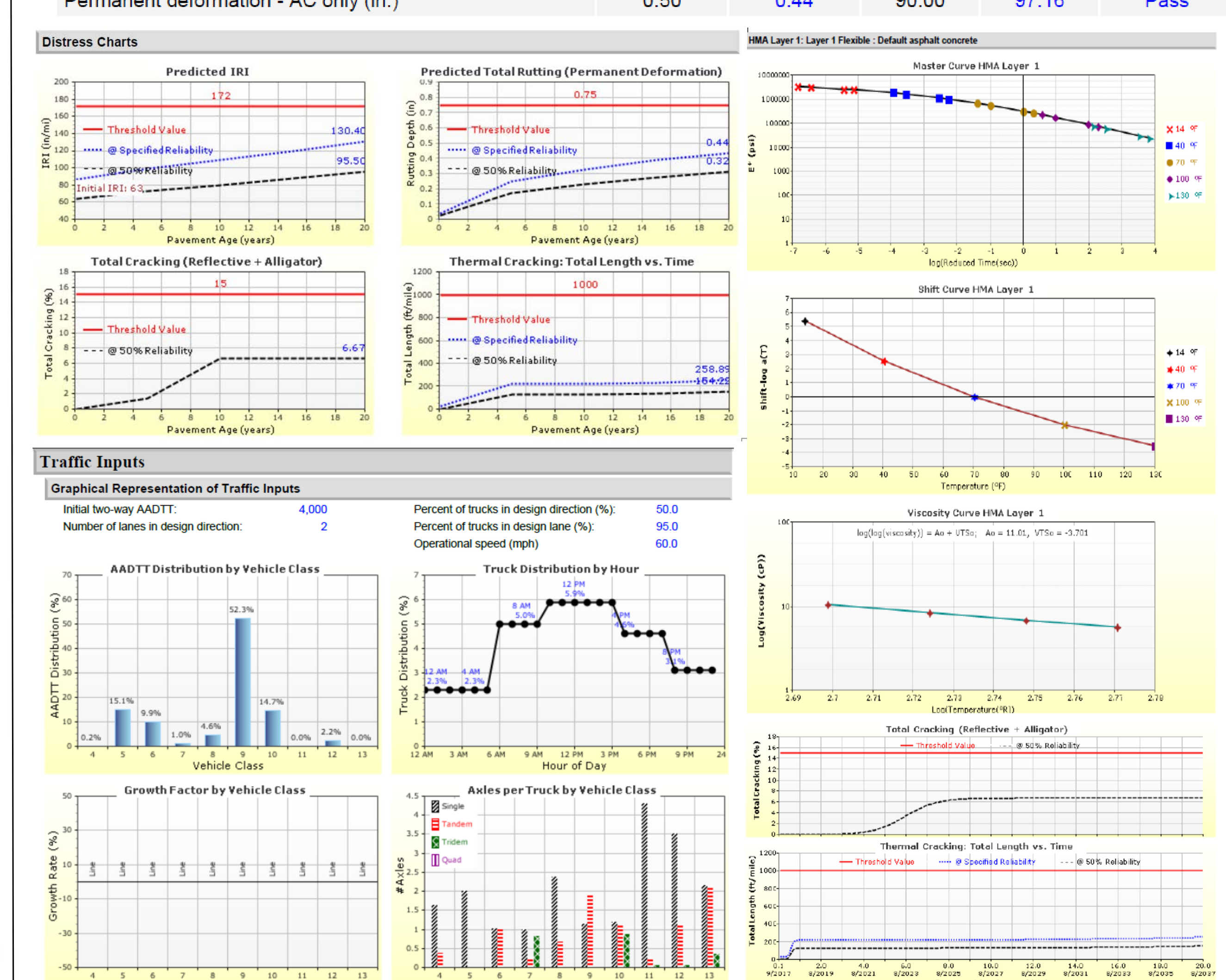
Traffic

Age (year)	Heavy Trucks (cumulative)
2017 (initial)	4,000
2027 (10 years)	6,939,750
2037 (20 years)	13,879,500

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	172.00	130.35	90.00	99.76	Pass
Permanent deformation - total pavement (in.)	0.75	0.44	90.00	100.00	Pass
Total Cracking (Reflective + Alligator) (percent)	15	6.67	-	-	Pass
AC thermal cracking (ft/mile)	1000.00	258.89	90.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	3.83	90.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	25.00	1.45	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	1939.93	90.00	90.70	Pass
Permanent deformation - AC only (in.)	0.50	0.44	90.00	97.16	Pass



Recommended Options

- Assumed 12' lane with 4' wide shoulder (16' wide lane)
- 16' * 5280' (1mile) = 84480 sf = 9387 yards^2
- For 4" overlay cost: $25 /yards^2
- For 5" overlay cost: $40 /yards^2