Implementation of MEPDG-Subgrade Soils focusing on Resilient Modulus

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The New M-E Pavement Design Guide

New M-E Design: hierarchical design approach

- Level 1: Obtain k1, k2, k3 through Lab Resilient modulus Test
- Level 2: Correlations with other material properties
- Level 3): Typical resilient modulus value

What we did for MEPDG?

- Developed a predictive model based on UC strength tests and resilient modulus tests.

$$Mr = 11267.7\times\ln(E_t)+3217.239\times\ln(q_u)-76.9/\ \varepsilon_y + -8725.31\times\ln(E_f)-2587.73\times\ln(q_y)+127.5/\varepsilon_y-13513.9 \quad (12)$$

Where E = tangent elastic modulus, q_u = unconfined compressive strength, E_f = Secant modulus at failure, ε_y = strain at yield stress, Mr = Resilient modulus at a confining stress of 2 psi and a deviator stress of 6 psi.

What we did for MEPDG?

- Developed a predictive model based on Mr tests and soils properties

$$Mr = k_1 p_a \left(\frac{\theta}{p_a}\right)^{k_2} \left(\frac{\tau_{oct}}{p_a} + 1\right)^{k_3}$$

Log k_1=6.660876 - 0.22136 x OMC - 0.04437 x MC - 0.92743 x MCR - 0.06133 x DD + 10.64862 x %COMP + 0.328465 x SATU - 0.04434 x %SAND - 0.04349 x %SILT - 0.01832 x %CLAY + 0.027832 x LL - 0.01665 x PI

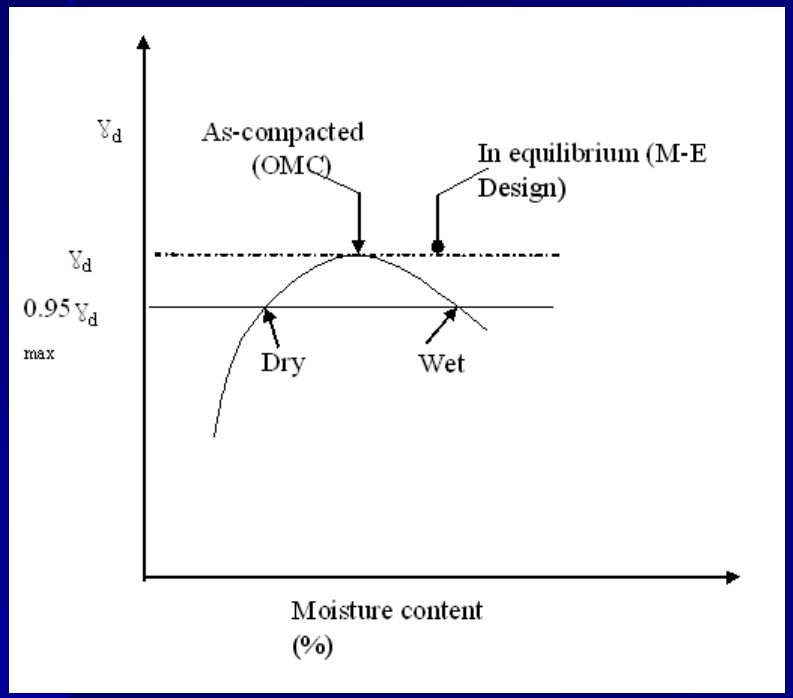
k_2=3.952635 - 0.33897 x OMC + 0.076116 x MC - 2.45921 x MCR - 0.06462 x DD + 6.012966 x %COMP + 1.559769 x SATU + 0.020286 x %SAND + 0.002321 x %SILT + 0.011056 x %CLAY + 0.077436 x LL - 0.05367 x PI

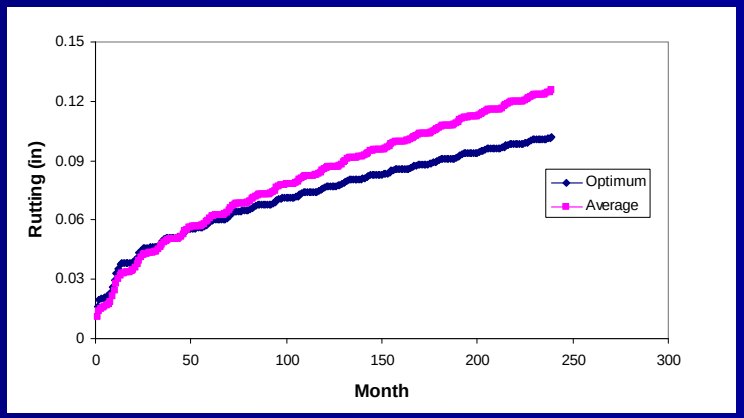
k_3=2.634084 + 0.124471 x OMC - 0.09277 x MC + 0.366778 x MCR - 0.01168 x DD - 1.32637 x %COMP + 1.297904 x SATU - 0.01226 x %SAND - 0.00512 x %SILT - 0.00492 x %CLAY - 0.05083 x LL + 0.018864 x PI (13)

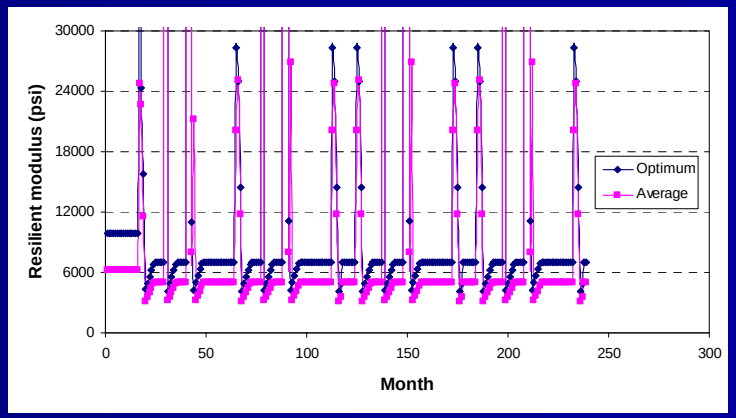
where; OMC (Optimum Moisture Content), MC (Moisture Content), MCR (Moisture Content Ratio = Moisture Content/ Optimum Moisture Content), DD (Dry Density), %COMP (Percent Compaction = Dry Density/ Maximum Dry Density), SATU (Degree of Saturation), %SAND (Percent Sand in Particle Size Distribution Curve), %SILT (Percent Silt in Particle Size Distribution Curve), %CLAY (Percent Clay in Particle Size Distribution Curve), LL (Liquid Limit) and PI (Plasticity Index).

What we did for MEPDG?

- Sensitivity Analysis and extensive review of the MEPDG Software







What we are doing for MEPDG?

- Calibration between Lab Mr. and In-situ FWD back-calculated modulus for existing pavements (12 sections) and newly constructed pavements (5 sections)
- Seasonal variations

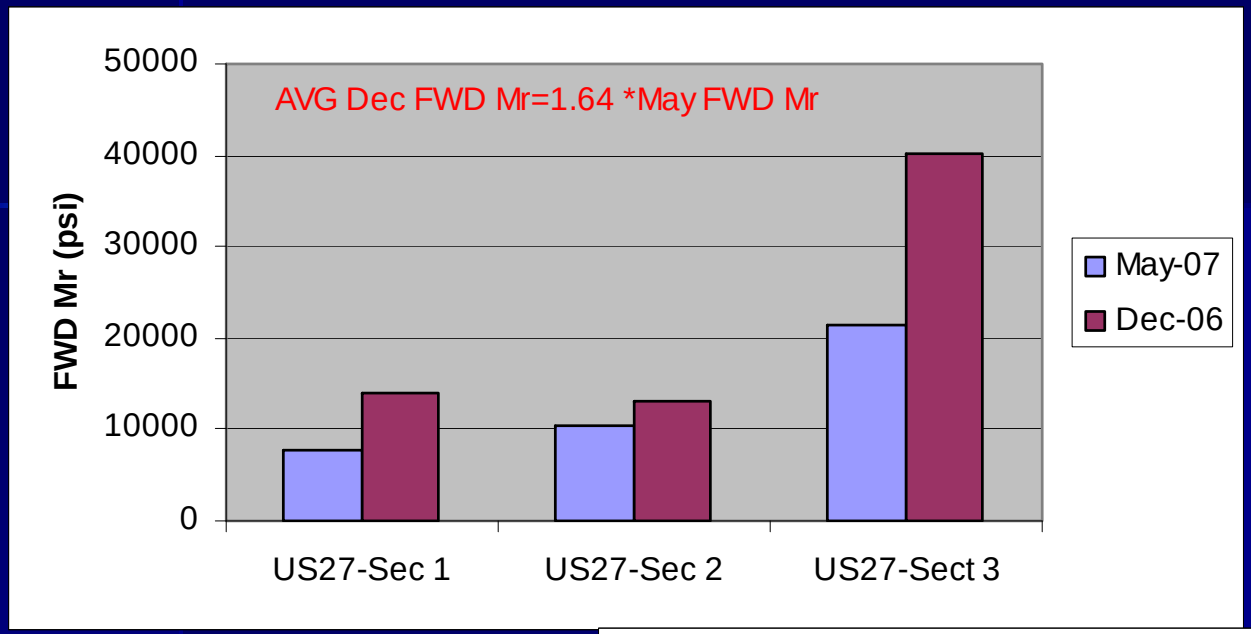
What we are doing for MEPDG?

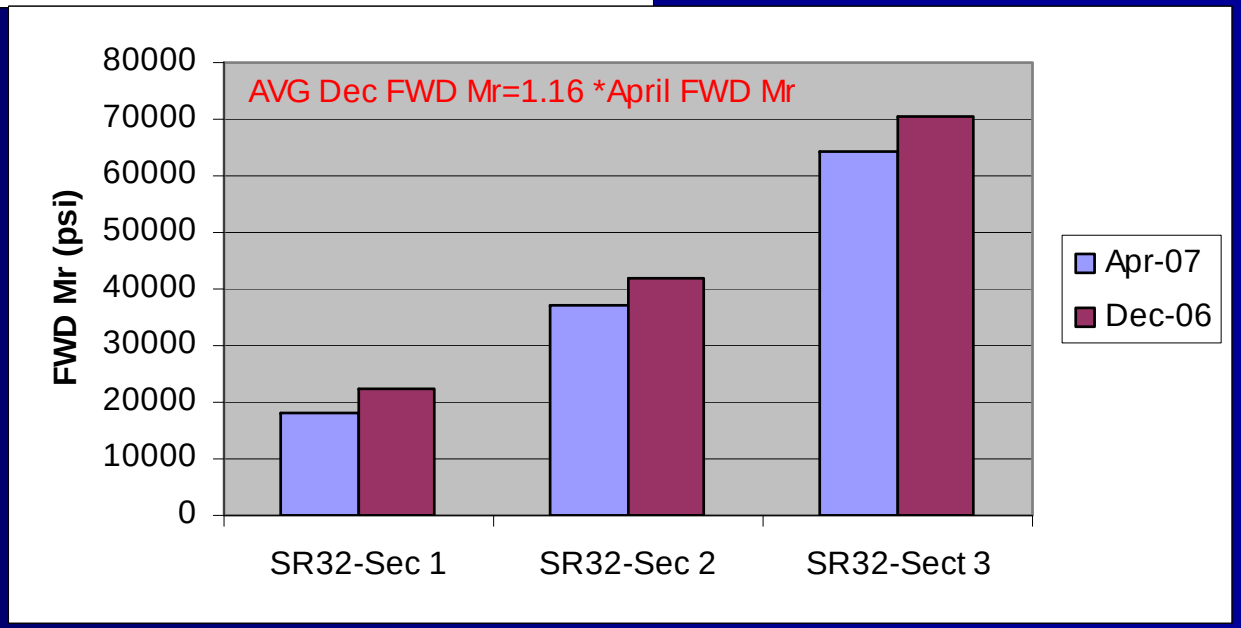
- Calibration between Lab Mr. and In-situ FWD back-calculated modulus

	Test Date	Bulk	Vertical	Horizontal	MR	avg lab Mr	FWD-backcalculated	FWD/LAB
us27-sec1	10/18/06	13	5	4	8799	8799	14076	1.6
us27-sec2	10/18/06	14	5	4	13074	13074	13111	1.0
us27-sec3	10/18/06	13	5	4	6905	6905	40277	5.8
us27-sec1-85.06-OMC	05/24/07	13	5	4	5632	8112	7804	1.0
us27-sec2-85.42-OMC	05/24/07	14	5	5	11759	12949	10539	0.8
us27-sec3-85.42-OMC	05/24/07	14	5	5	5360	6706	21455	3.2
SR32-sec1-58.66-OMC	11/01/06	13	5	4	10648	8995	22450	2.5
SR32-sec2-59.20-OMC	11/01/06	10	4	3	4445	4495	41950	9.3
SR32-sec3-59.74-OMC	11/02/06	11	4	4	4647	4601	70504	15.3
SR32-sec1-58.66-OMC	04/16/07	13	5	4	10590	8944	18011	2.0
SR32-sec2-59.20-OMC	04/16/07	11	4	3	4440	4500	37227	8.3
SR32-sec3-59.74-OMC	04/16/07	12	4	4	4648	4615	64166	13.9
SR69-sec1-27.06-OMC	10/24/06	13	5	4	4957	6164	50602	8.2
SR69-sec2-28.07-OMC	10/24/06	13	5	4	6380	7147	49911	7.0
SR69-sec3-29.10-OMC	10/24/06	12	4	4	6665	7723	52035	6.7
SR69-sec1-27.06-OMC	05/24/07	17	6	5	4986	6261	36554	5.8
SR69-sec2-28.07-OMC	05/24/07	16	6	5	6617	7207	38552	5.3
SR69-sec3-29.10-OMC	05/24/07	13	5	4	6773	7898	25644	3.2
Test Rd-Apr-06		16	6	5	10994	10994	10016	0.9
Test Rd-Jul-06		19	7	6	10931	10931	10807	1.0
Test Rd-OCT-06		13	5	4	11055	11055	12809	1.2
Test Rd-Dec-06		12	4	4	11070	11070	13855	1.3
SR-67	06/20/07	18	7	6	7185	7185	27047	3.8
SR-69 (conc)		10	4	3	5388	5388	33377	6.2
SR-28 site A	05/09/06	24	8	8	9128	9128	7654	0.8
SR-28 site B	05/09/06	31	11	10	9760	9760	6354	0.7
Ronal-Regan sec1	8/2/2006	27	9	9	7552	7552	13500	1.8
Ronal-Regan sec2	8/2/2006	18	6	6	15048	15048	4600	0.3
Ronal-Regan sec3	8/2/2006	27	9	9	10494	10494	3003	0.3
					average	8883	23313	3.2

What we are doing for MEPDG?

- Seasonal variations





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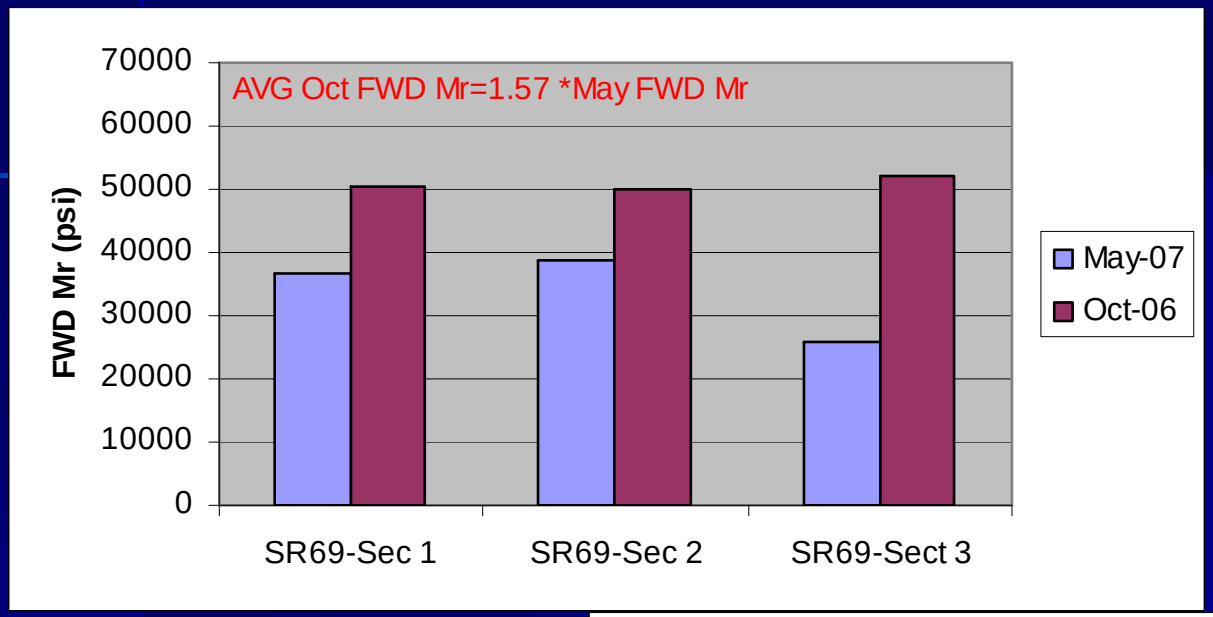

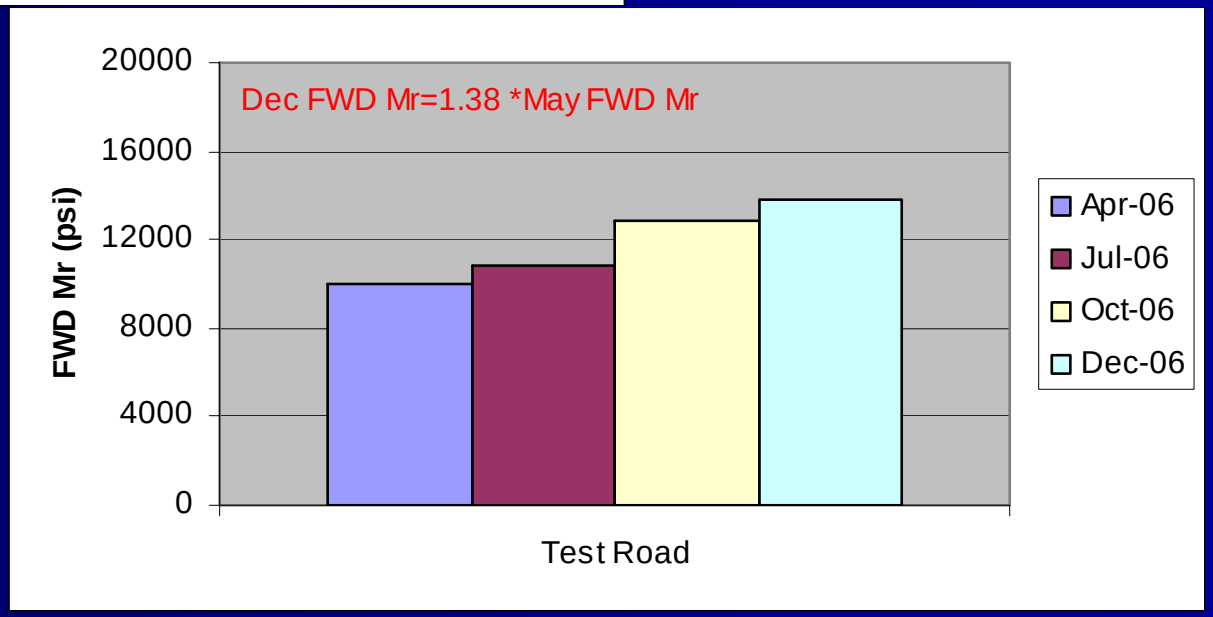

INDOT'S Practice

- In the past: CBR, Now: Resilient modulus
- Our practice: Geotechnical engineers evaluate resilient modulus of subgrade soils from the repeated triaxial test and give it to pavement engineers
- 2 resilient modulus test units (Research office and Geotechnical office)
- INDOT targets Level 1 Design for resilient modulus

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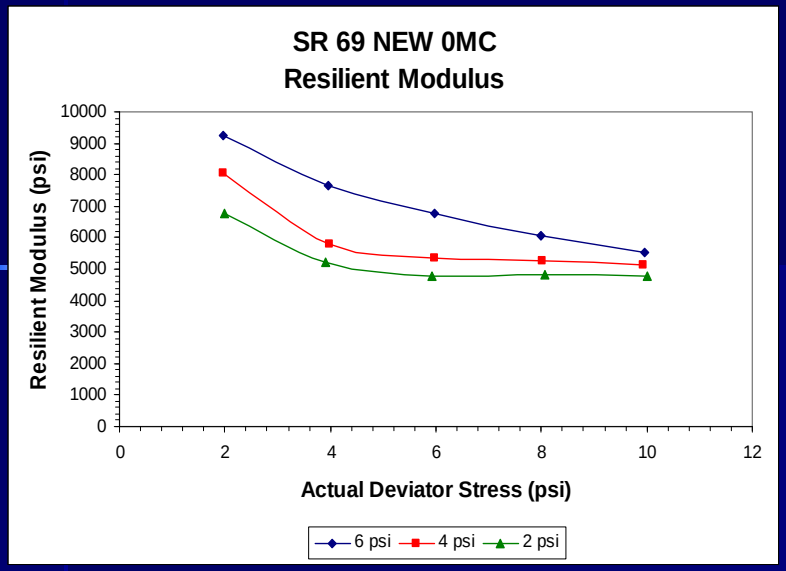

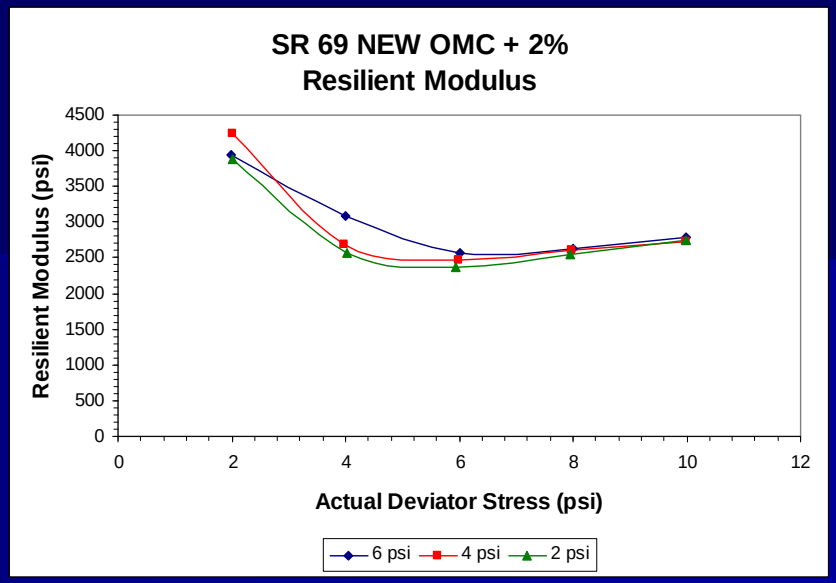

		K_1	K_2	K_3
SR69 New	OMC	254.57	0.397	-0.365
	OMC + 2%	142.58	0.123	-0.287

$$Mr = k_1 p_a \left(\frac{\theta}{p_a}\right)^{k_2} \left(\frac{\tau_{oct}}{p_a} + 1\right)^{k_3}$$

Construction of Database

RESILIENT MODULUS TEST RESULTS

General Description			Classification	Index Properties							Standard Proctor		Actual Dry Density & Moisture Content (After Test)				Resilient Modulus at σd =6 psi, σc= 2 psi		Regression Coefficient					
Des. #	Location	Boring No's.	Textural / AASHTO Classification	Gravel %	Sand %	Silt %	Clay & Coll. %	LL	PI	Specific Gravity	Mx.Dry Density lbs/ft3	OMC %	Actual Dry Density at OMC lbs/ft3	Actual Moisture Content at OMC %	Actual Dry Density at OMC +2 lbs/ft3	Actual Moisture Content at OMC + 2%	at OMC (psi)	at OMC + 2 (psi)	K1 at OMC	K2 at OMC	K3 at OMC	K1at OMC+2	K2 at OMC+2	K3 at OMC+2
100981	SR-57 Greene Co.	RB-16	Sandy Loam / A-4 (0)	6.3	50.1	34.4	9.2	NP	NP	2.625	111.5	14.4	N/A	N/A	N/A	N/A	4829	3666	319.63	-0.0296	-0.0704	236.74	0.195	-0.121
100981	SR-57 Greene Co.	RB-45	Silty Loam / A-4 (7)	0.5	6.5	75.7	17.3	31.3	7.3	2.667	105.7	16.9	N/A	N/A	N/A	N/A	6052	3098	412.21	0.114	-0.0846	202.58	0.645	-0.203
10072	US-50 Jackson Co.	RB-1	Silty Loam / A-4 (5)	3.1	5.6	73	18.3	30.7	5.8	2.762	113.6	15.3	113.282	14.82	113.745	17.31	5862.3	3077.5	411.53	0.13	-0.201	245.05	0.2	0.0504
10072	US-50 Jackson Co.	RB-3	Silty Clay Loam / A-6 (12)	0.2	1.3	72.2	26.3	33.7	12	2.696	112.4	16.8	112.279	17	107.538	19.36	2670.5	1836.5	141.08	0.417	-0.44	165.89	-0.251	0.207
1180	CR-300 S.	ST-9	Silty Loam / A-4 (5)	10.3	24.7	53	12	35.4	8.5	2.622	106.1	17.2	103.998	17.01	104.149	19.18	3359.7	1686.3	219.07	0.15	-0.151	124.04	0.32	0.0187
1180	CR-300 S.	RB-8	Silty Loam / A-4 (3)	7.3	20.6	59.5	12.6	30.3	5.5	2.648	105.6	16.8	107.608	16.77	105.66	18.19	2489.5	2929.4	168.96	0.034	-0.585	263.87	-0.0088	0.311
9900830	SR-39 Hendricks Co.	RB-13	Clay Loam / A-6 (11)	10.4	27.7	35.1	26.8	39.2	21.6	2.686	109.1	15.3	111.87	15.46	109.235	18.2	10013	4332.3	556.25	0.0745	-0.198	186.04	0.0802	-0.518
600323	SR-120 La Garange Co.	RB-13	Sandy Loam / A-4 (0)	3.2	58.2	29.1	9.5	NP	NP	2.575	106.5	17.2	105.545	17.34	102.545	19.67	2051.7	1261.3	126.84	0.384	-0.216	131.49	-0.12	0.007
600323	SR-120 La Garange Co.	RB-45	Sandy Loam / A-2-4 (0)	10.6	63.5	20.7	5.2	NP	NP	2.623	115.8	13.1	115.81	13.6	110.239	16.22	3233.2	2098.3	236.68	0.399	0.0147	243.16	0.0187	0.672
100750	SR-144 Morgan Co.	RB-2	Sandy Loam / A-4 (0)	14.8	38.9	32	14.3	20	6.6	2.749	129.9	9.1	130.427	9.16	126.852	11.03	6584.4	3154	445.89	0.175	-0.12	319.48	0.109	0.344
710189	SR-65 Gibson Co.	RB-9	Silty Loam / A-4 (0)	0.4	4.7	79.6	15.3	NP	NP	2.666	101.3	19.3	100.176	18.84	98.797	21.09	3930.5	2548.7	248.0	0.224	-0.185	154.39	0.704	-0.271
710291	SR-28 Tipton Co.	RB-4	Clay Loam / A-4 (3)	5.5	34.3	38.3	21.9	23.1	9.5	2.746	125.2	10.6	124.909	10.06	123.424	12.7	6955.6	2539.7	414.44	0.156	-0.2	178.16	0.0056	-0.136
100953	SR-67 Greene Co.	RB-2	Silty Clay Loam / A-6 (12)	4.2	9.5	63.1	23.2	34.8	14.4	2.679	111	15.3	113.142	15.53	110.123	18.01	5089.6	24.83.8	260.28	0.302	-0.413	144.54	0.0789	-0.299

Further Work

- More sensitivity analysis with the MEPDG software
- More work on coarse grained soils, stabilized soils using chemicals and geosynthetics
- Effect of drainage and freeze-thaw of unbound materials on the performance of pavement