WORK PLAN [Draft 03/07/2017]

2017 MnROAD Unbound Layer Evaluation Using Intelligent Compaction

Ingios Geotechnics, Inc.

Problem Statement

Re-construction of the 2017 MnROAD-NRRA low volume and mainline road test sections will involve several pavement and foundation materials (recycled materials and large aggregate bases) that will be evaluated and tested during construction and long-term (see Appendix).

Although the final evaluation details are currently being developed, key research objectives include:

- Developing and accessing methods to characterize the pavement foundation materials as part of the quality inspection process,
- Assessing pavement system performance properties over time (drainability, modulus of foundation layers, deformation under traffic loading, durability, and uniformity), and
- Determining best practices for how to incorporate the measured in situ properties and pavement system performance results into pavement design for future implementation.

Ingios Geotechnics, Inc. has expertise in pavement system characterization and assessment of pavement design input values using automated plate load testing (APLT), validated integrated compaction monitoring (VICM), and geospatial drainage assessment using in situ pavement permeameter test (PPT) measurements. Ingios has prepared the following work plan details are part of the proposed no-cost partnership agreement with MnDOT to provide testing and analysis for selected test sections.

Project Goals

The goal of this Ingios testing and analysis is to develop spatial coverage maps of calibrated mechanistic design input parameter values (e.g., resilient/elastic modulus, modulus of subgrade reaction) on finished unbound foundation layers for the test cells identified in Table 1.

Scope of Work

To achieve the project goal, the following scope of work and associated project tasks have been identified:

1. Mobilize Ingios vibratory compactor outfitted with the VICM and RTK-GPS system along with the APLT and PPT to MnROAD.
2. Conduct on-site safety briefing with all personnel involved with Ingios activates prior to initiating work tasks.
3. Using the VICM equipped roller (Figure 1), map the cell areas listed in Table 1 to produce various index and modulus map results.
4. Perform independent field calibration testing, involving 12 to 20 test locations using the APLT (Figure 2). This process with include testing areas of interest in the designated cells based on the VICM mapping results. APLTs will involve using a 12, 18, 24, or 30 in. diameter plate with a 2-layer sensor kit to obtain stress-dependent moduli values for

both the aggregate base and the underlying subgrade layer. The plate diameter and testing approach will be determined based on the VICM results.

5. Perform five PPTs (Figure 3) in each cell. Select an additional one to three cells to perform a spatial test point layout (20 to 40 test points) for drainage analysis.
6. Select up to three test locations for extended cycle APLT permanent deformation tests to characterize the permanent deformation response of the foundation layer system under cyclic loading with up to 10,000 loading cycles.
7. Produce data summary and calibration reports.
8. Provide raw data in formats requested by MnDOT.
9. Pending input from state DOT design engineers, provide recommendations for implementation of test results in term of each state design methodology.
10. Prepare a brief webinar to summarize all findings and deliver to NRRA groups as requested.

A review of the current pavement design procedures for the participating NRRA states was conducted and summarized in Table 2. The design input parameters are elastic modulus (E), resilient modulus (M_r), modulus of subgrade reaction (k), R-value, California bearing ratio (CBR), and structural layer coefficients which are correlated to resilient modulus. In the field calibration efforts with VICM, field testing will be conducted using stress-dependent M_r or E and k-value determined from APLT testing.

Successful completion of the proposed testing is contingent upon being provided timely updates as to construction schedules and access timeline for the cells/completed unbound layers. The partnership agreement outlines Ingios and MnDOT responsibilities to facility successful and safe completion of the proposed testing.

Table 1. Proposed MnROAD test cells and unbound layers for evaluation by Ingios research team

Roadway	2017 Study	Cell	Unbound Distances (Feet)	Unbound Materials to Compact (layers - bottom to top)
Low Volume Road	PCC Early Traffic Opening	124 - 424	507	Top of sand Subgrade 6" Class 6 Aggregate Base
	Large Subbase Aggregate [3.5 in. HMA Standard Mix]	127	282.5	Top of clay subgrade 18" large aggregate subbase (1 lift) 6" Class 6 Aggregate Base
		227	285	Top of clay subgrade 18" large aggregate subbase (2 lifts) 6" Class 6 Aggregate Base
		128	285	Top of clay subgrade 9" large aggregate subbase 6" Class 6 Aggregate Base
		228	285	Top of clay subgrade 9" large aggregate subbase 6" Class 5Q Aggregate Base
	Fiber Reinforced PCC	139	280	Top of clay Subgrade 4" common borrow 6" Class 5 Aggregate Base
		239	285	
Mainline	Fiber Reinforced PCC	506	134	Top of 3" existing Class 5 11" Class 5Q Aggregate Base
		606	135	
		706	135	
		806	135	

Table 2. Summary of pavement foundation layer inputs with existing pavement design procedures at the NRRA participating states.

STATE	PAVEMENT	DESIGN DESCRIPTION	SUBGRADE INPUTS	BASE/SUBBASE INPUTS
CA	Flexible	HMA and base/subbase layer thickness based on R-value of the subgrade and Traffic Index	R-Value[1]	R-Value[1]
	Rigid	PCC and base/subbase layer thickness based on R-value of the subgrade and Traffic Index	R-Value[1]	Resilient Modulus[2]
IL	Flexible	Modified AASHTO Design procedure. Thickness design based on traffic factor and estimated structural number.	IBR value	Structural layer coefficients (a_2, a_3)
	Rigid	Modified AASHTO Design procedure. Thickness design based on traffic factor and IBR or k-value.	IBR value or k-value[3]	N/A [only minimum thickness]
MI	Flexible	Pavement ME Design [Similar to AASHTOWare™] – Level 2 or 3 (Typical values)	Resilient Modulus[2]	Resilient Modulus[2]
	Rigid	Pavement ME Design [Similar to AASHTOWare™] – Level 2 or 3 (Typical values)	Resilient Modulus[2]	Resilient Modulus[2]
MO	Flexible	AASHTO Pavement ME Design	Resilient Modulus[6]	Resilient Modulus[6]
	Rigid	AASHTO Pavement ME Design	Resilient Modulus[6]	Resilient Modulus[6]

STATE	PAVEMENT	DESIGN DESCRIPTION	SUBGRADE INPUTS	BASE/SUBBASE INPUTS
MN	Flexible	MnPAVE-Flexible with basic, intermediate, and advanced level. Advanced level requires moduli of all layers, while basic and intermediate levels require typical values or DCP test results, R-value results.	R-value[4] (basic/int) or Resilient Modulus (advanced)	DCP index[4] (basic/int) or Resilient Modulus (advanced)
	Rigid[5]	MnPAVE-rigid uses MEPDG level 3 based design procedure.	Resilient modulus	Resilient Modulus
WI	Flexible	AASHTO 1972 design procedure. Thickness design based on design ESALs, soil support value, and estimated structural number.	Soil support value (correlated to CBR)	Structural layer coefficients (a_2, a_3)
	Rigid	AASHTO 1972 design procedure. Thickness design based on design ESALs, working stress, and modulus of subgrade reaction (k)	k-value	NA

[1] California R-value is a measure of resistance to deformation of the soils under saturated conditions and traffic loading as determined by the stabilometer test (CT301). Typical range between 5 (very soft) to 80 (treated base material). Typical values provided based on soil classification/ region.

[2] Typical resilient moduli vales are provided in the design guide based on the material type.

[3] Illinois bearing ratio (IBR) is a slight modification of CBR test run after 4-days of soaking. Typical values are provided based on soil classification (ranges between 2 and 20). Modulus of subgrade reaction (k) value vs. IBR is provided in the design nomographs.

[4] Minnesota R-value determined from modulus value (R = [0.41+0.873*(subgrade modulus/1000)]^1.28)

[5] MnPAVE-Rigid design procedure for PCC bonded overlay over HMA uses the ACPA procedure to determine composite k-value based on subgrade k-value and aggregate layer resilient modulus. http://apps.acpa.org/applibrary/KValue/

[6] personal communication, 03/02/2017, John P. Donahue, P.E., Construction and Materials Liaison Engineer, MoDOT

CalTrans Highway Design Manual - http://www.dot.ca.gov/hq/oppd/hdm/pdf/english/HDM_Complete_07Mar2014.pdf

ILDOT Pavement Design Manual - http://www.idot.illinois.gov/Assets/uploads/files/Doing-Business/Manuals-Split/Design-And-Environment/BDE-Manual/Chapter%2054%20Pavement%20Design.pdf

MDOT User Guide for ME Pavement Design:
https://www.michigan.gov/documents/mdot/MDOT_Mechanistic_Empirical_Pavement_Design_User_Guide_483676_7.pdf

MnDOT Pavement Design Manual: www.dot.state.mn.us/materials/pvmtdesign/manual.html

WIDOT Facilities Development Manual: http://wisconsindot.gov/rdwy/fdm/fd-14-10.pdf

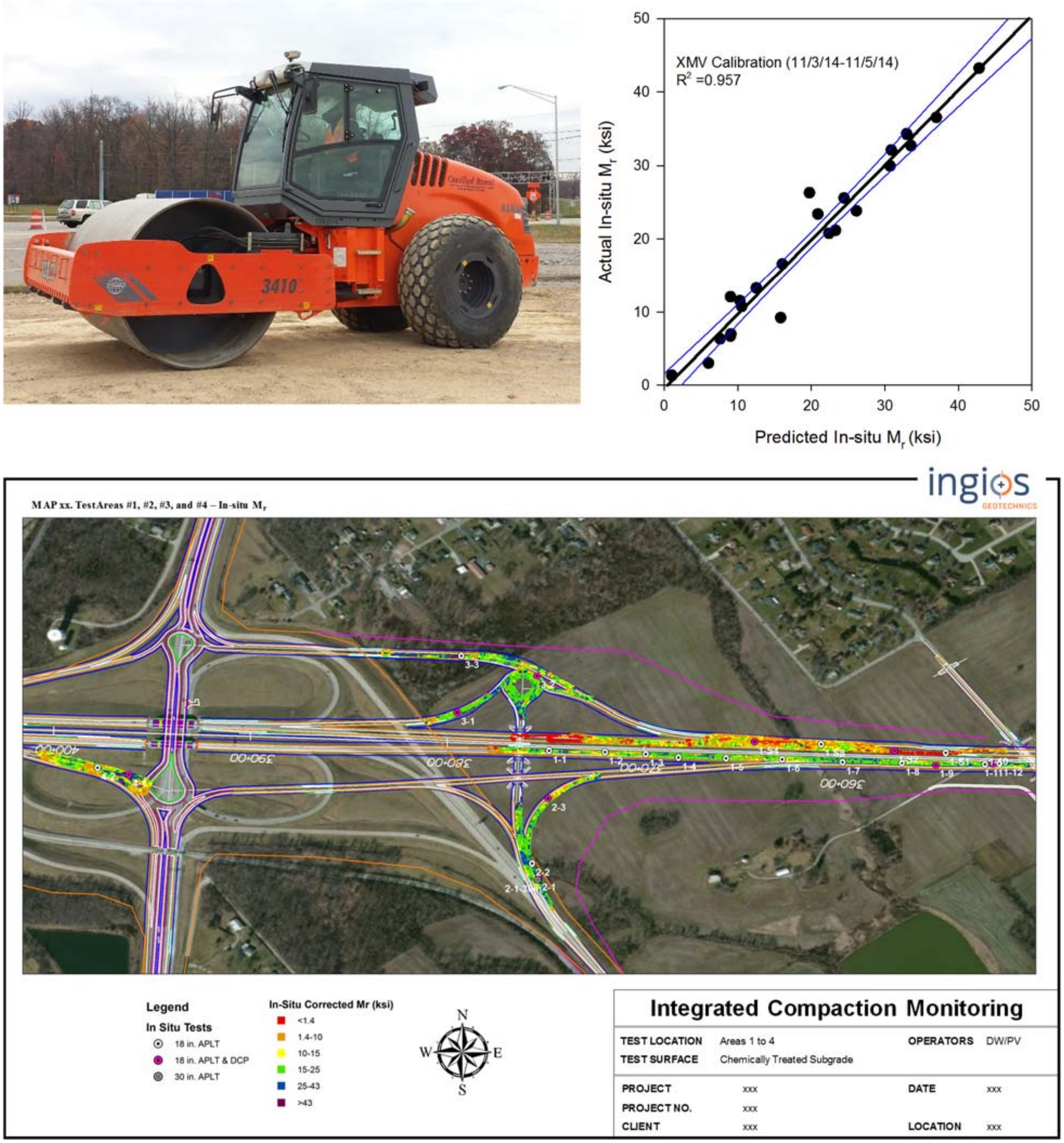
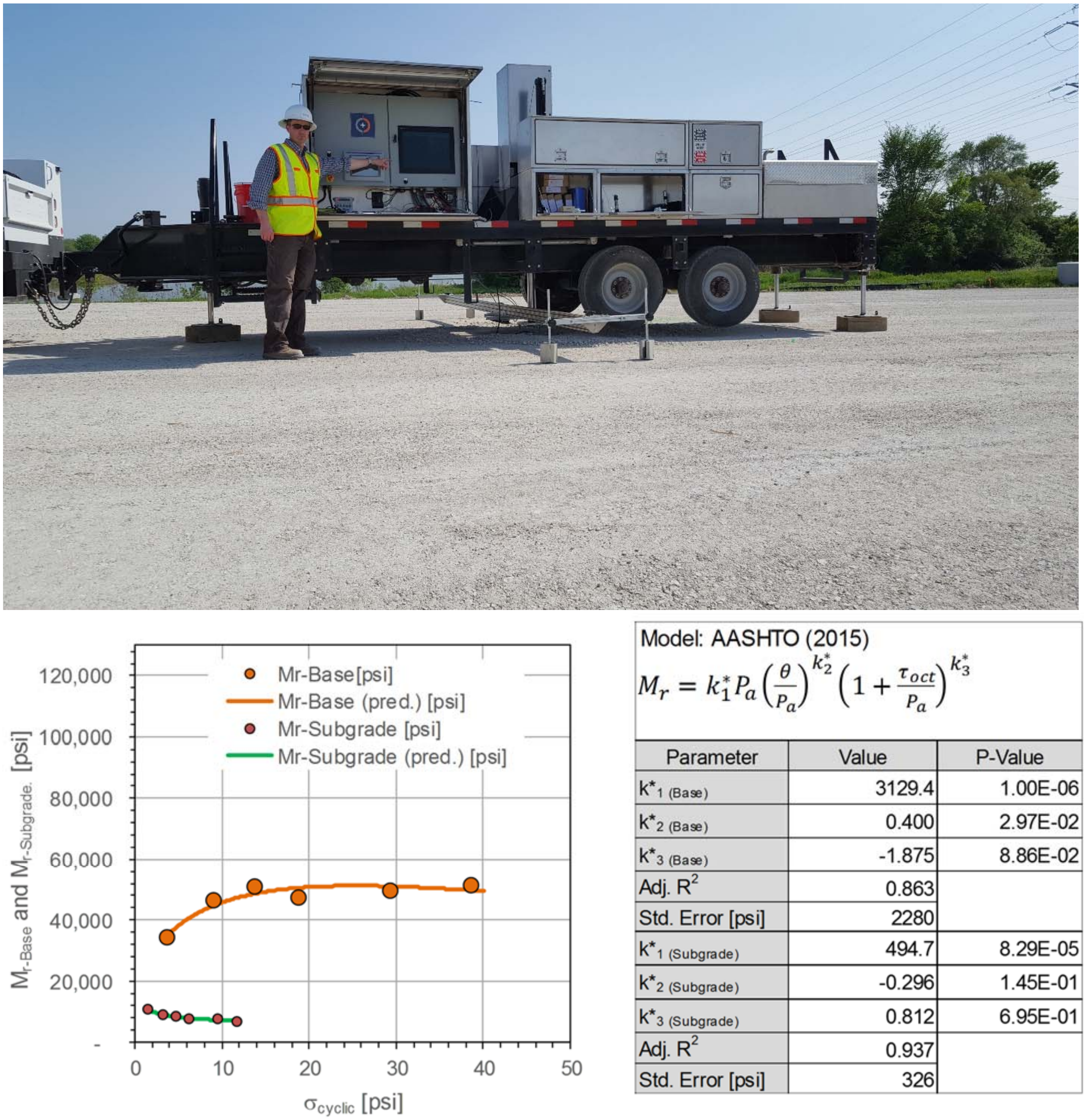


Figure 1. Ingios VICM equipped roller, calibration verification plot, and example output.

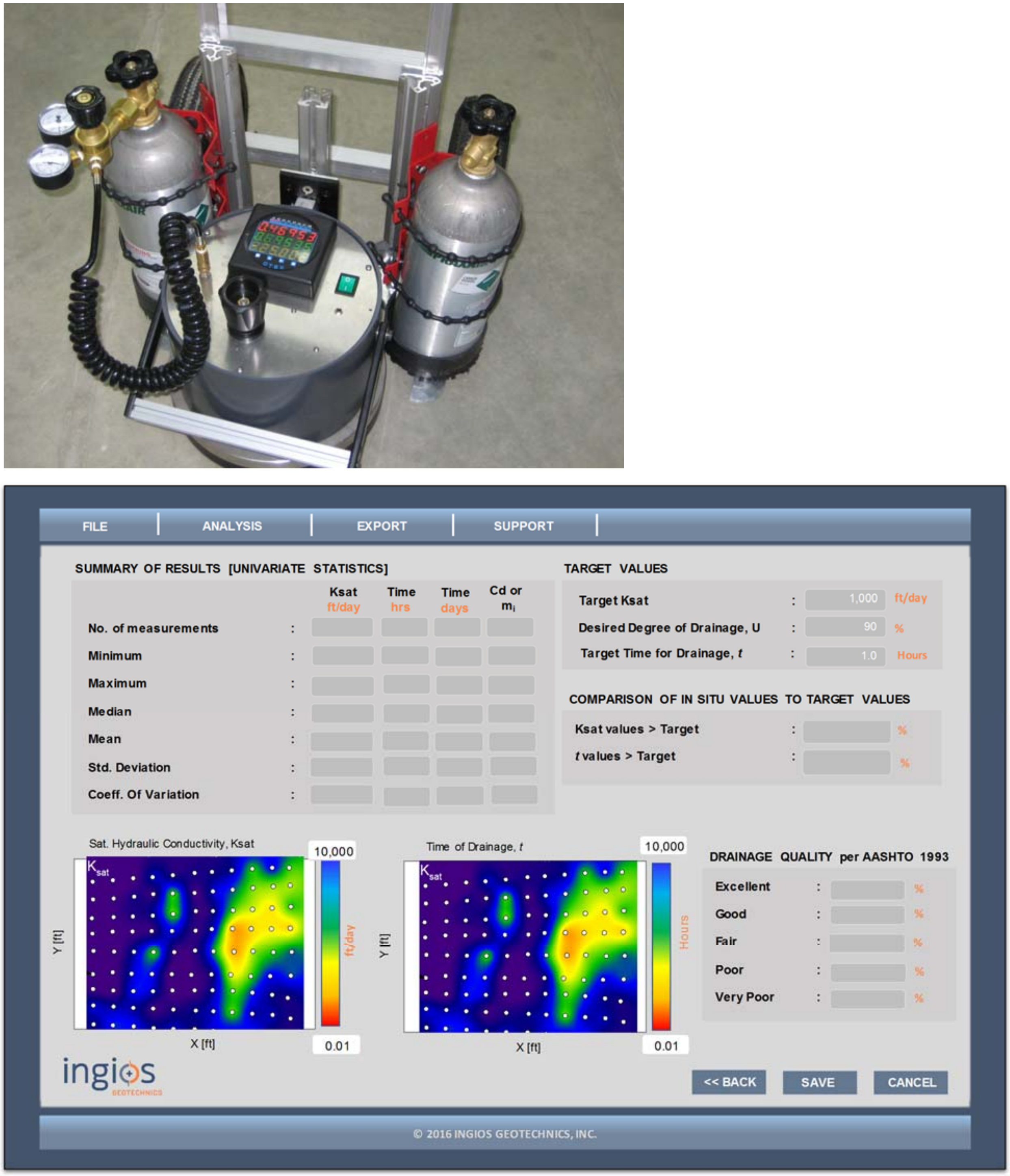


Model: AASHTO (2015)

$$M_r = k_1^* P_a \left(\frac{\theta}{P_a}\right)^{k_2^*}\left(1+\frac{\tau_{oct}}{P_a}\right)^{k_3^*}$$

Parameter	Value	P-Value
k*$_1$ (Base)	3129.4	1.00E-06
k*$_2$ (Base)	0.400	2.97E-02
k*$_3$ (Base)	-1.875	8.86E-02
Adj. R^2	0.863	
Std. Error [psi]	2280	
k*$_1$ (Subgrade)	494.7	8.29E-05
k*$_2$ (Subgrade)	-0.296	1.45E-01
k*$_3$ (Subgrade)	0.812	6.95E-01
Adj. R^2	0.937	
Std. Error [psi]	326	

Figure 2. Ingios APLT system with 2-layered sensor measurement kit for measurement of stress-dependent resilient modulus and AASHTO (2015) universal model parameters.



SUMMARY OF RESULTS [UNIVARIATE STATISTICS]

		Ksat ft/day	Time hrs	Time days	Cd or m_i
No. of measurements	:				
Minimum	:				
Maximum	:				
Median	:				
Mean	:				
Std. Deviation	:				
Coeff. Of Variation	:				

TARGET VALUES

Target Ksat	:	1,000	ft/day
Desired Degree of Drainage, U	:	90	%
Target Time for Drainage, *t*	:	1.0	Hours

COMPARISON OF IN SITU VALUES TO TARGET VALUES

Ksat values > Target	:		%
t values > Target	:		%

DRAINAGE QUALITY per AASHTO 1993

Excellent	:		%
Good	:		%
Fair	:		%
Poor	:		%
Very Poor	:		%

Figure 3. Ingios PPT equipment and geospatial drainage time analysis output.