In Situ Modulus Measurement Using Automated Plate Load Testing for Statewide Mechanistic-Empirical Design Calibration

Final Report
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16. Abstract

The Iowa Department of Transportation (DOT) selected the Automated Plate Load Testing (APLT) to conduct a state-wide field calibration study to develop the AASHTOWare Pavement ME Design™ input data needed for typical Iowa foundation layers. A total of 10 project sites were selected that covered common unbound foundation layer cross-sections used in Iowa highways. The goal at each site was to perform cyclic APLTs to determine stress-dependent composite and layered resilient modulus (Mr) using a 12 in. diameter loading plate and perform static APLTs to determine modulus of subgrade reaction k-value using a 30 in. diameter loading plate. The cyclic APLTs showed that the M_r values on the unbound layers are variable across the state and within each project site. The coefficient of variation (C_v) at each site varied between 7% and 70%. Sites with 2 ft of special backfill consisting of recycled asphalt material to improve subgrade, provided higher Mr values than other project sites. Results demonstrated that using the typical values provided in the AASHTOWare Pavement ME Design™ guide based on soil classification can significantly under or overestimate the Mr values. This emphasizes the importance of field verification testing of design input parameters. The modulus of subgrade reaction k-values obtained across the state varied between 35 pci to 300 pci. 11 out of the 14 tests performed across the state showed k values < 150 pci. Permanent deformation (δ_p) values at the end of static APLTs show the values varied between 0.05 and 0.4 in., with 11 out of the 14 tests performed across the state showed δ_p greater than the critical 0.05 in. limit considered in developing loss of support beneath the pavement. Finite element (FE) analysis conducted using the range of values obtained from APLTs indicated that the two most significant measures that can be taken to reduce the bending stresses developed in the pavement layer are increasing pavement thickness and reducing the δ_p in the unbound foundation layers. Simply changing the foundation stiffness/modulus value without accounting for LOS that can potentially occur due to δ_p under repeated loading, the calculated bending stresses in the pavement can be misleading.

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EXECUTIVE SUMMARY

Overview

To develop the AASHTOWare Pavement ME Design™ input data needed for typical Iowa foundation layers, the Iowa Department of Transportation selected the Automated Plate Load Testing (APLT) to conduct a state-wide field study. An experimental plan was developed in collaboration with the Iowa DOT pavement design and construction engineering teams. A total of 10 project sites were selected that covered common unbound foundation layer cross-sections used in Iowa highways. Projects consisted of different subbase types (granular subbase and modified subbase, per Iowa DOT standard specifications), different subbase materials (crushed limestone and recycled concrete aggregate), different subgrade types (select subgrade and embankment cut/fill subgrade). The goal at each site was to perform cyclic APLTs at 4 to 8 test locations using a 12 in. diameter loading plate and perform static APLTs to determine modulus of subgrade reaction *k*-value at 1 to 2 test locations using a 30 in. diameter loading plate.

Six of the ten projects (Projects 1 to 6) were tested in fall of 2017 and the remaining four (Projects 7 to 10) in spring of 2018, shortly after the spring-thaw. An additional site was selected for testing in fall 2018, but rain delays prevented project access. For each project site, an individual data report for each test location summarizing the composite resilient modulus ($M_{r\text{-}Comp}$), layered resilient modulus analysis results ($M_{r\text{-}Base}$ and $M_{r\text{-}SG}$), the "universal" model parameter values, modulus of subgrade reaction (*k*-values), penetration resisatnce profile from dynamic cone penetration (DCP) test and a picture were documented. Summary statistics of average (μ), standard deviation (σ), and coefficient of variation (C_v) of the different parameters are summarized separately for each project.

Key Findings

- Typical values provided in the AASHTOWare Pavement ME Design™ guide based on soil classification can significantly under or overestimate the M_r values. Therefore, it is important to perform field measurements for verification of design input parameters.
- The cyclic APLTs showed that the M_r values on the unbound layers are variable across the state and within a given project site. The C_v at each site varied from 7% to 70%. For reference, a C_v of about 20% is typically considered a relatively uniform condition. Results from six out of the ten projects yielded C_v > 20%.
- The use of 2 ft of special backfill to improve subgrade in one of the project sites (Projects 4 and 10), provided higher M_r values than other projects, and the special backfill material layer (contained of RAP material) increased its stiffness between test periods.
- The modulus of subgrade reaction *k*-values obtained across the state varied between 35 pci to 300 pci. 11 out of the 14 tests performed across the state showed *k* values < 150 pci – the typically assumed (conservative) design input target value by Iowa DOT for PCA (1984) design. At one site (Project 7), two tests performed on the compacted modified subbase layer about 420 feet apart, showed *k*-values of 39 and 284 pci.
- The k_{comp} values obtained over granular subbase/modified subbase layers were on average lower than the *k*-values obtained directly on the underlying subgrade layer. This finding

suggests that the subbase layers were relatively loose/uncompacted at the surface, which is also evidenced by the relatively high re-load to initial load *k-value* ratio (k_2/k_1). 6 out of 7 tests on subbase layers produced ratios > 3. For reference, Swedish specifications require the ratio of reload to initial moduli values to be < 2.8 for base/subbase layers within the top 0 to 10 inches as an indicator of compaction quality.

- Permanent or plastic deformations occurring from repeated traffic loading is a recognized cause of pavement distresses. δ_p was monitored and reported for the cyclic and static APLTs. The average δ_p from each site varied between 0.01 in. and 0.26 in., and the C_v at each site varied between 14% and 123%. δ_p values at the end of static APLTs show the values varied between 0.05 and 0.4 in. 11 out of the 14 static APLTs showed $\delta_p > 0.05$ in., which is considered the critical limit to develop LOS beneath pavement.

Mechanistic Analysis of In Situ Results

The APLT results were utilized to perform mechanistic analysis of a rigid pavement system and assess the pavement performance characteristics. A few example cases are demonstrated in this report using Kenslabs 2D FE analysis. The main objective of the FE analysis was to assess the influence of *k*-value, LOS condition, and pavement thickness on the bending stresses in the pavement layer. The stress ratio (SR) values were calculated for each case as the ratio of the maximum principal stress in the pavement layer and the modulus of rupture of the concrete (assumed as 660 psi).

FE analysis results showed that there were no significant differences in the bending stresses between the low and high *k-value* cases for LOS = 0 condition, but there are significant differences when LOS = 0 versus 1 cases are compared. For the LOS = 1 cases, the peak stresses occurred in a distribution corresponding to a typical corner break observed in distressed concrete pavements. For LOS = 0 condition, the SR values are < 0.45 for all three thicknesses evaluated and *k*-values evaluated. For LOS = 1 and 2 conditions, the SR values increased and the associated number of allowable load repetitions per PCA (1984) are decreased, with no significant differences between LOS 1 versus 2 conditions. The SR's were either similar or lower for LOS 3 compared to LOS 2 condition.

This analysis demonstrates that during pavement design, simply changing the *k*-value without accounting for LOS that can potentially occur due to plastic deformations under repeated loading, the calculated bending stresses can be misleading.

AASHTOWare Pavement ME State-Wide Calibration

The Iowa DOT is currently either performing or in the process of considering state-wide calibration for AASHTOWare Pavement ME Design™ input parameters. AASHTO (2010) provides guidance on how to perform this calibration work, with the primary objectives of reducing bias and increasing precision of the empirical models used in the design software for predicting performance indicators (i.e., distresses, ride quality). The end-result of this process is developing local calibration-based regression factors that can be updated in the design software.

The AASHTO guide document details an approach consisting of 10 steps for the local calibration process. Detailed procedures for developing an experimental plan, estimating the sample size, selecting the roadway segments, collecting the required field data, and assessing bias/standard error in the global calibration factors for local conditions, are discussed in the AASHTO (2010) guide document.

When considering future field test sites for local calibration, consideration should be given to the type of surface distress, pavement type and thickness, and subgrade soil type as primary factors. Secondary factors are climate, traffic, and other pavement type dependent design features that are unique to the Iowa. After selecting the different factors, a factorial matrix is developed and at least two replicate sites for each condition are selected (AASHTO, 2010). Iowa DOT maintains a database of state-wide FWD testing results tied with pavement performance data, which can be a useful resource in selecting the key project sites and specific locations on a given site. We recommend the Iowa DOT test sites with alternative foundation layers (e.g., various stabilization materials such as at Central Iowa Expo test sections in Boone, IA) during the site selection process. The Expo test sections include foundation layers with different mechanical and chemical stabilization methods.

This report highlights the importance of quantifying permanent deformations, which must be included as part of future calibration efforts. Virtually no field data exists from decades of pavement system monitoring in the U.S. to quantify permanent deformation – without which limited design improvements can be expected. Given the range of geomaterials used in pavement foundation layers (e.g., recycled materials, stabilized material, and geosynthetics), it is essential to characterize the in situ resilient modulus and permanent deformation behavior in terms of material index properties, moisture content, and stress-dependency.

Design Input Parameter Selection and Field Verification

This study showed that unbound layer material M_r values are highly variable across the state and often over a given project site. The reasons can be attributed to many factors including, but not limited to poor compaction control and natural variability in the underlying subgrade layers. Many of the test sites showed lower *k-values* than the assumed 150 pci in the rigid pavement design by Iowa DOT. This emphasizes the importance of better characterization procedures to select appropriate design input parameters and the importance of field verifying pavement design values during construction.

Selection of appropriate design input parameters should be based on project specific materials and conditions considering the variability and potential post-construction changes in saturation. For rehabilitation design projects, foundation layers can be tested directly to determine in situ *k* or M_r values. The variability aspect can be addressed by determining the mean (μ) and standard deviation (σ) of the data and calculating the target value as equivalent to $\mu - 2\sigma$. The moisture aspect must be addressed, especially if field tests are conducted when material is relatively dry. Moisture corrections can be performed via laboratory M_r testing on a given material type at different moisture contents and determining the correction factors for the design moisture content. Alternatively, empirical procedures established based on local historical data or some provided in the AASHTOWare ME design guide can be utilized.

Field verification of M_r values reduces risk of not meeting the design the pavement design performance criteria and increase quality, thus helping to insure long-term performance. A field quality assurance (QA) protocol and specifications that requires measurement and reporting of in situ M_r values is recommended. The specification should address the test frequency (1 every 500 to 1,000 feet, depending on in situ conditions) required for QA. Specification options with reduced QA testing frequency with implementation of intelligent compaction technologies should also be considered.

INTRODUCTION

In the new mechanistic empirical (ME) pavement design guide (AASHTOWare Pavement ME Design™), resilient modulus (M_r) values for the pavement foundation layers are used in both rigid and flexible pavement design (AASHTO 2015). Transitioning from primarily empirical design to mechanistic empirical (ME) pavement design has been identified as an engineering implementation recommendation to improve predictions of pavement life and serviceability in Iowa (Ceylan et al. 2008). Ceylan et al. (2009) noted that calibrating the ME design models with reliable data is required to advance the practice.

In situ foundation support values (i.e., resilient modulus (M_r), modulus of subgrade reaction (k-value), and permanent deformation(δ_p)) have not been directly measured as part the current statewide ME calibration practices in Iowa. The ME calibration process for foundation input parameters is primarily empirical or relies upon limited and often time-consuming laboratory testing and adopting conservative values (AASHTO 2010, Darter et al. 2014, Mallela et al. 2013). Even with modern laboratory testing of foundation materials, various challenges limit the understanding of in situ conditions as highlighted in Figure 1. In situ plate load testing overcomes many of those limitations.

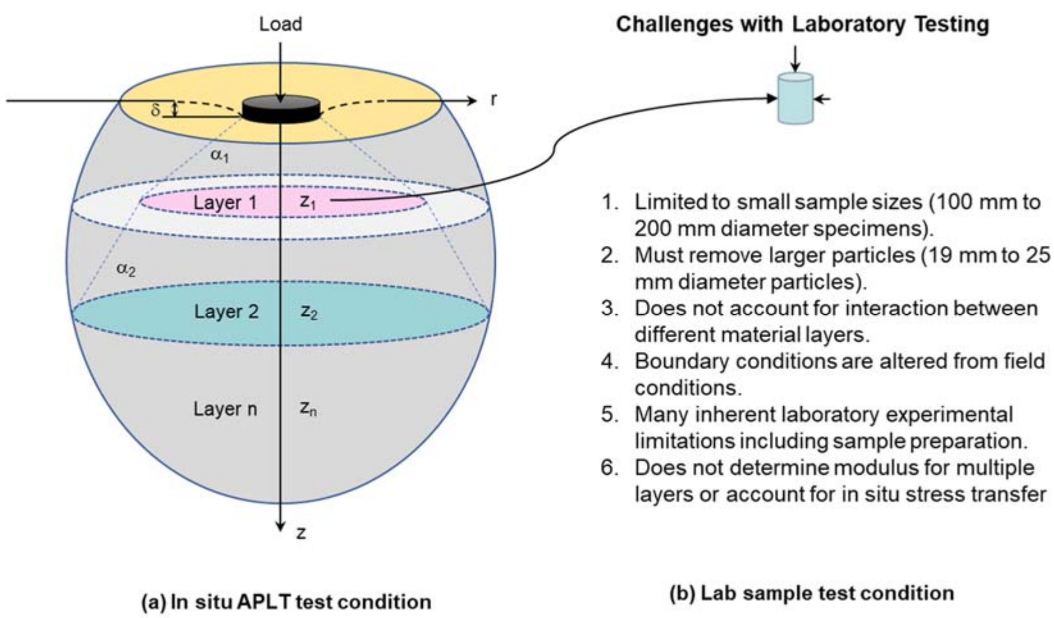


Figure 1. Automated plate load testing (APLT) in comparison to limitations of laboratory testing.

Plate load testing is considered the long standing "gold standard" for assessing in situ pavement foundation support conditions. From the 1930s to 1980s, the Bureau of Public Roads, the U.S. Corps of Engineers, AASHO, and several state agencies used plate load testing (Teller and Sutherland 1935, U.S. Corps of Engineers 1943, AASHTO 1962), to determine k-value for airfield and highway applications, investigate concrete pavement behavior, and verify/calibrate design equations. In the 1940's Bureau of Public Roads reported extensive field testing from the

Arlington Experiment Farm in Virginia, which involved repeated load-unload plate load tests (Teller and Sutherland 1943). The AASHTO Road Test also included repeated load-unload plate load testing for determination of k-values for rigid pavements and resilient modulus M_r (using k-M_r theoretical relationship) for flexible pavements. The pioneering efforts from the 1930s to 1980s established plate load testing to determine the load-displacement relationship of foundation layers and played a significant role in calibrating the pavement thickness design equations developed by the AASHTO, PCA, and Corps of Engineers. However, the *manual* methods were time consuming because of significant setup times with heavy reaction loads often creating unsafe conditions. Also, without automation, producing reproducible results from manual testing can be difficult because of operator bias, lack of control with maintaining and applying loads, etc., even for a static test. It is almost impractical to apply repeated loads at a controlled load pulse using manual methods.

Because of those limitations, the frequency at which plate load tests were conducted has diminished substantially. As a simplification, several agencies attempted to develop local empirical relationships between plate load test measurements and California bearing ratio, R-value, falling weight deflectometer (FWD) testing, and others. These empirical relationships, however, present significant uncertainties and often poorly match the field conditions.

Realizing the very important role of plate load testing for pavement foundation characterization, the limitations involved with the manual setups, and the uncertainties associated with using empirical relationships, the modern automated plate load testing (APLT) system was developed (Figure 2). With the APLT, it is now possible to obtain direct and rapid measurement of pavement foundation support values. The APLT technology although relatively new, has been used in recent years on several pavement projects (see White and Vennapusa 2017, Vennapusa et al. 2018) and was selected for deployment in Iowa to assist with the determination of foundation support values as part of the Iowa DOTs on-going statewide calibration efforts.

Figure 2. Automated plate load testing setup from Project 2 – US 20 (picture taken on 10/19/2017)

In Situ Automated Plate Load Testing (APLT)

The APLT is used to perform static plate load tests (per AASHTO T222 and other standards) which takes about 30 minutes to 4 hours depending on subgrade stiffness and deformation characteristics. Cyclic/repetitive plate load tests (per AASHTO T221 and other standards) can be also be performed using the APLT with up to 100 cycles (5 minutes), 1,000 cycles (20 minutes), and 10,000+ cycles test (2+ hours) per test location. The cyclic test process uses a controlled load pulse duration and dwell time (e.g., as required in the laboratory AASHTO T307 M_r test methods) for selected cycle times depending on the field conditions and measurement requirements. The advantage of cyclic tests is that the modulus measurements better represents the true field stiffness value because of the ability to apply a conditioning load sequence. This finding is well documented in the literature and is considered a major short-coming of other testing methods that only apply a few cycles/dynamic load pulses on the foundation materials.

APLT can be used to measure inputs to develop in situ confining and deviator stress-dependent constitutive models used in the AASHTOWare Pavement ME Design™. The result of this test is a direct field measure of the mechanistic response of the pavement foundation. This is the only such in situ test to directly measure the stress-deflection response with confinement control. Confinement control can be applied to precisely duplicate the pavement-induced stress conditions. Because the APLT test system is automated, the test methods are highly repeatable and reproducible (i.e., no operator bias). Operators only need to input the desired loading conditions (cyclic stress levels, load pulse duration and dwell time, and number of cycles) which are then tightly controlled by the machine. An advanced fluid-power control system was designed to perform the test operations and meets or exceeds the applicable testing standards.

Figure 3 provides an example of the automated load pulse and deflection output provided to the operator. The results of cyclic deformation, permanent deformation, elastic modulus, stiffness, resilient modulus, cyclic stresses, and number of cycles are calculated in real-time and are available for reporting immediately (see illustration of key parameters in Figure 4). The test locations are recorded with an integrated GPS measurement and the data is populated on an aerial image of the project.

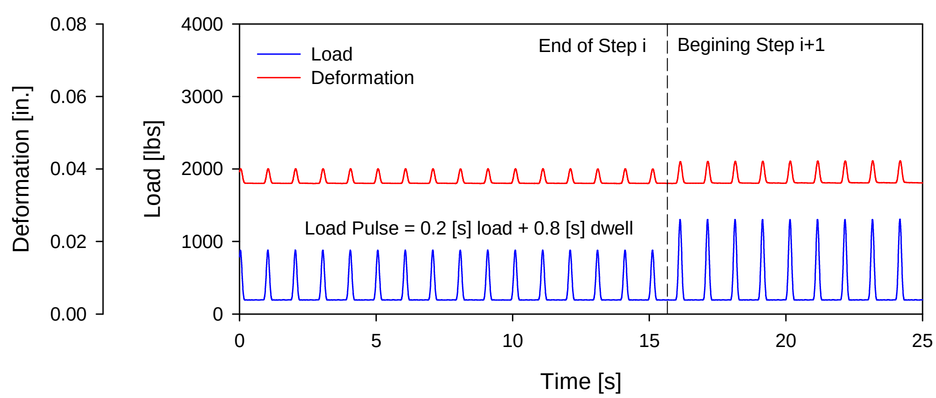


Figure 3. Automated load pulse and deformations during cyclic APLT.

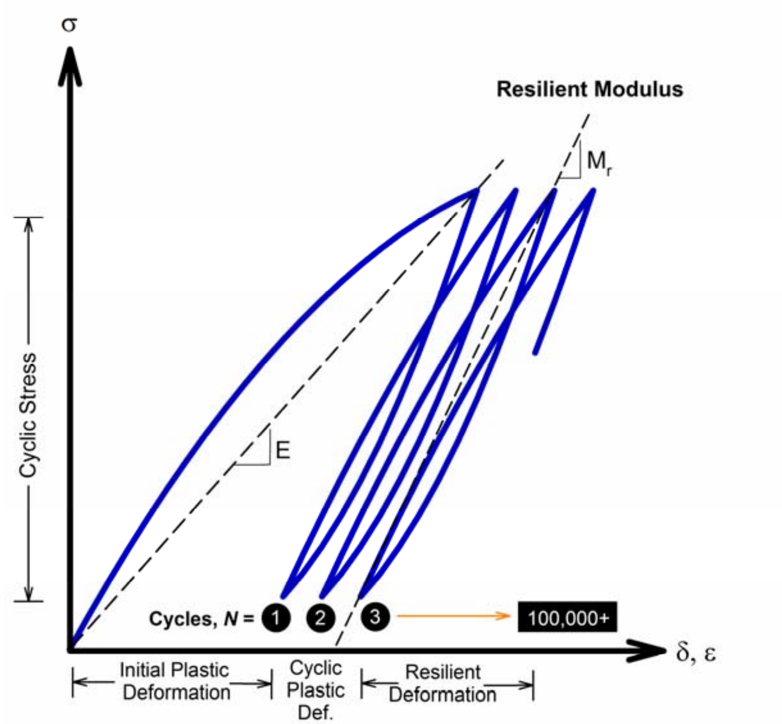
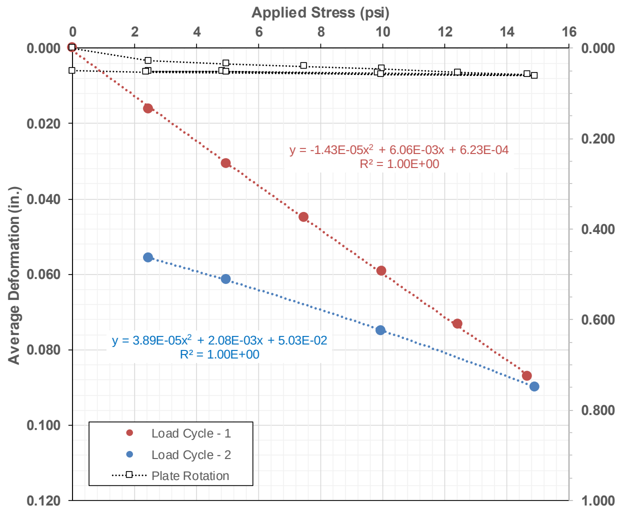


Figure 4. Illustration of the parameters measured from APLT cyclic plate load tests.

Modulus of Subgrade Reaction Testing using APLT

The APLT can be used to perform automated static plate load tests in accordance with the applicable AASTHO, ASTM, Corps of Engineers, State Agency, and European test standards (e.g., AASHTO T222, AASHTO T221, CRD-C 655-95, ASTM D1196, ASTM D1195, DIN 18134, Tex-125E, FM 55-527). APLT is configured with 6 in., 12 in., 18 in., 24 in., and 30 in. diameter loading plates.

An example of test results with a 30-in. diameter loading plate with two loading cycles is shown in Figure 5, with calculations shown to calculate *k* values (uncorrected and corrected for plate bending), per AASHTO T222. The graph shows stress versus deformation values for two loading cycles along with plate rotation measurements. The stress versus deformation readings shown in Figure 5 from each loading cycle are fit with a second order polynomial relationship, which shows a coefficient of determination (R^2) of close to 1, demonstrating the quality of the data produced from the automated test.



Calculations		
Deformations at target applied stress [4]		
δ_1 (in.)		0.0592
δ_2 (in.)		0.0247
Modulus at target applied stress [4]		
First Cycle		
E_1 (psi)		5,676
k'u1(30)_(pci)		169
$k'_{u1(30)}$ (pci)		169
$k_{u1(30)}$ (pci)		162
Second Cycle		
E_2 (psi)		11,683
k'u2(30)_(pci)		405
$k'_{u2(30)}$ (pci)		405
$k_{u1(30)}$ (pci)		333
E_2 / E_1 or k_2 / k_1 Ratio		2.1

Figure 5. Example results of 30 in. diameter static plate load test with two loading cycles, per AASHTO T222

Composite Resilient Modulus Testing

Cyclic APLT performed on a base layer underlain by a subgrade would provide a measure of the composite resilient modulus that represents the moduli values of both the top base layer as well as the subgrade layer within its measurement influence depth. The composite uncorrected resilient moduli values from APLT can be calculated using the modified Boussinesq's elastic half space solution equation shown in Eq. (1):

$$M_{r-comp} = \frac{(1-\nu^2)\sigma_0 a}{\delta_{r,0}} \times f \qquad (1)$$

where, $M_{r\text{-}comp}$ is in situ composite resilient modulus, δ_r is the resilient deflection of plate during the unloading portion of the cycle (determined as the average of three measurements along the plate edge, i.e., at a radial distance $r' = r$), ν is the Poisson ratio (often assumed as 0.40), σ_o is the applied cyclic stress, r is the radius of the plate, f is the shape factor selected based on the anticipated stress distribution beneath the plate (π/2 to 8/3).

Layered Analysis for Individual Layer Resilient Models

Ingios designed and developed a layered analysis sensor kit (as illustrated in Figure 6) that measures the resilient deflections at radii of 12 in. (2r), 18 in. (3r), and 24 in. (4r) away from the plate center. The sensor kit provides average resilient deflections measured over one-third of the circumference of a circle at the selected radii. This method was designed to improve upon practices that use point measurements, which are often variable from point-to-point for unbound aggregate materials. Like the loading plate representing an integrated response of the material under the plate, the deflection basin circumference bars were designed to represent an integrated deflection basis response over a length of one-third the circumference.

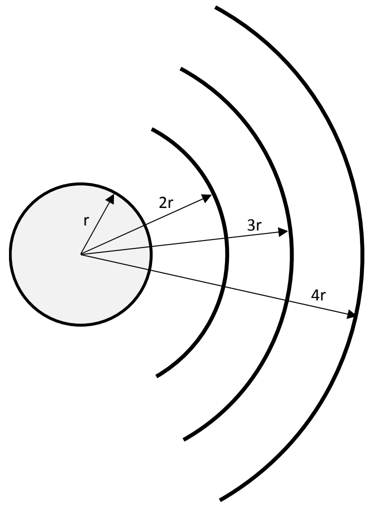


Figure 6. APLT plate setup with deformation measurements of plate and at 2r, 3r, and 4r from plate center axis.

Using the deflection basin measurements, two and three-layered analysis can be performed to develop stress-dependent M_r values. The two-layered analysis is performed using the Odemark method of equivalent layer thickness approach (AASHTO 1993), while the three-layered analysis is performed using a proprietary back calculation analysis recently developed by Ingios (APLT-BACK). The program was developed through a numerical algorithm to solve an extended formulation of the linear-elastic analysis theory. The pavement layers are idealized as multi-layered linear elastic half-space. The algorithm employs piecewise linear integration, and automatic integration step size, and gradation in performing the numerical inversion. The program uses an optimization method to match the measured deflection basin with a predicted deflection basin from a static model and iteratively modifying the layer moduli values. This procedure is referred to as the backcalculation method and the iterations are continued until a selected minimum root mean squared (RMS) value is obtained between the measured and calculated deflection values.

The most significant advantage of the APLT-BACK program over the many back calculation programs that are currently available is that the program allows modeling the analysis for different stress distributions beneath the loading plate (i.e., uniform, parabolic, and inverse parabolic). The different stress distributions can be easily accounted for in the $M_{r\text{-}Comp}$ calculations using the appropriate stress distribution factor (f) in Eq. 1, but most of the current backcalculation programs typically are only designed to solve a uniform stress distribution problem. The uniform stress distribution is true only for a flexible plate on cohesionless soil, but the assumption is not accurate because of the rigidity of the plate and the soil type can be either cohesive or cohesionless. This is accounted for in the APLT-BACK analysis program, by allowing the user to select an appropriate stress distribution.

Correction for Future Changes in Moisture Content/Saturation

Post-construction changes in saturation levels in the foundation layers are inevitable due to seasonal changes with wetting/drying or freezing/thawing. The level of variations depends on the geographic location, material type, layer boundary conditions, and the depth of the layer in the pavement structure. The AASHTOWare Pavement ME Design™ currently addresses the seasonal variations through the Enhanced Climatic Integrated Model (EICM), which incorporates regional databases of climatic changes and assumed moisture variations and its potential effects of moduli values through empirical equations. The older version of the AASHTO pavement design (i.e., AASHTO 1993) addresses the seasonal variations by assigning a modulus value for each month. Other pavement design procedures (e.g., FAA 2016, PCA 1984) assume moduli values of materials when in saturated state in the design.

Regardless of the design method chosen, it is well-known that modulus/stiffness properties are significantly influenced by the moisture content (or saturation) of the material. The modulus value assumed in the design is not a singular value but is a stress-dependent and moisture/saturation dependent value. Therefore, any field modulus/stiffness measurements taken at the time of construction at the in-place conditions, must be adjusted corresponding to the assumptions made in the design for the anticipated saturation levels.

Determination of "Universal" Model Regression Parameters

The "universal" model regression parameters required for the ME design can be obtained in situ using APLT at different cyclic stresses like the AASHTO T-307 lab testing. The applied cyclic and contact stresses and the number of loading cycles can be customized per project needs. Cyclic stresses can be varied between 2 psi and 150 psi using a 12-in. diameter loading plate. The data can then be analyzed to fit the model shown in Eq. (2), which is similar to the laboratory test based "universal" model that is being used in AASHTO (2015) ME design, expect that the regression parameters are identified with a * to differentiate with the regression parameters obtained from laboratory testing:

$$\textit{In situ}\ M_r = k_1^* P_a \left(\frac{\theta}{P_a}\right)^{k_2^*} \left(\frac{\tau_{oct}}{P_a} + 1\right)^{k_3^*} \qquad (2)$$

where, k_1^*, k_2^*, and k_3^*= regression coefficients represented by * to differentiate with the parameters described in Eq. (1) for laboratory test measurements. .

An example of universal model fit curves at three test locations obtained from the Illinois Tri-State Tollway project near O'Hare project are shown in Figure 7 and the model parameters are summarized in Table 1. Results showed that the in situ $M_{r\text{-}comp}$ values are sensitive to the applied cyclic stress and showed a "break-point stress ($\sigma_{cyclic\text{-}BP}$)" at which point further increase in stress showed a decrease in $M_{r\text{-}comp}$ values. Identification of this break-point stress is critical to pavement designers to model future pavement designs to limit permanent deformation and premature distress problems.

Using the deflection basin measurements and layered analysis calculations performed on APLT measurements obtained at different cyclic stress, universal model parameters can be obtained for both the top and bottom layers in a two-layered structure. Example test results of such a case with testing on a crushed aggregate base over natural subgrade is shown in Figure 8 along with the universal model parameters separately for each layer. Results showed a generally increasing trend with cyclic stress for the top base layer (granular material) and a generally decreasing trend with cyclic stress for the bottom subgrade layer (cohesive material).

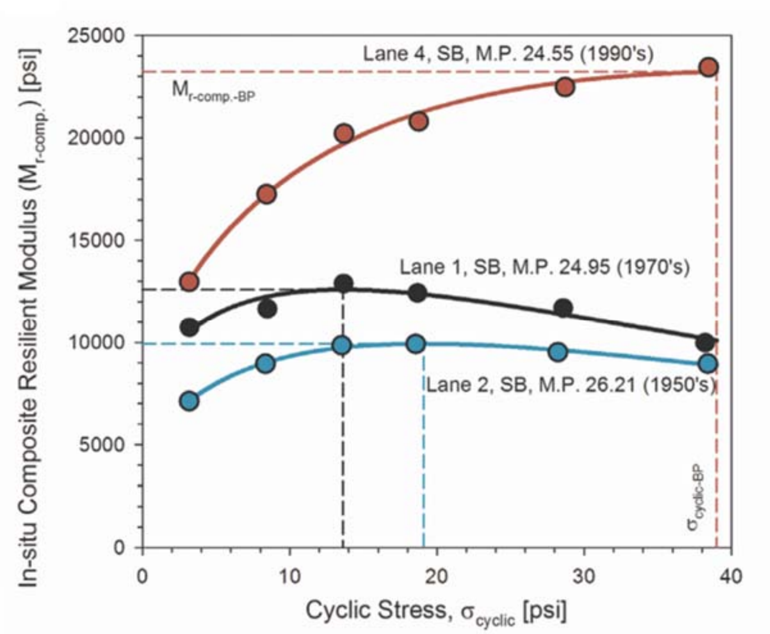
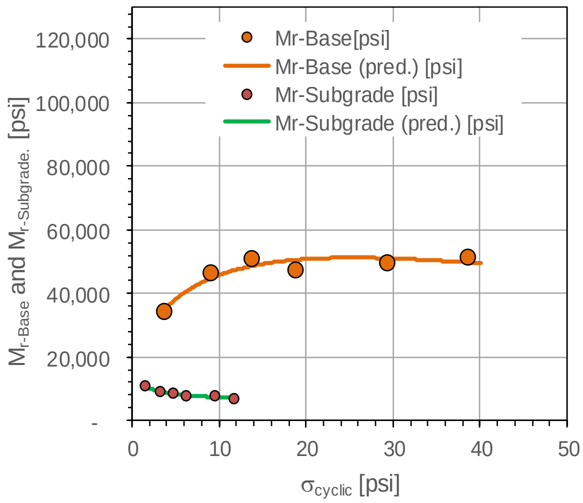


Figure 7. Cyclic stress versus in situ composite M_r and universal model fit curves.

Table 1. Summary of universal model regression parameters from IL Tri-State Tollway project

Test point	k^*_1	k^*_2	k^*_3	$M_{r\text{-comp-BP}}$ (psi)	□$_{cyclic\text{-BP}}$ (psi)
APLT_033, SB, Lane 1	926	0.444	-3.11	12,603	13.6
APLT_037, SB, Lane 2	638	0.561	-3.05	9,936	19.1
APLT_032, SB, Lane 4	1072	0.523	-1.62	23,239	39.0



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 8. Cyclic stress versus in situ M_r of base and subgrade layers, and universal model parameters separately for each layer.

Foundation Inputs for Mechanistic Pavement Design

For both rigid and flexible pavement design, the AASHTO (2015) guide provides three levels of design inputs. Level 1 includes selection of stress-dependent constitutive model parameters (k_1, k_2, and k_3) and determining M_r at the anticipated field stresses. Level 2 includes empirical correlations to estimate M_r from other test measurements such as California bearing ratio (CBR), dynamic cone penetrometer (DCP) measurements, and R-value measurements. Level 3 includes using default or recommended M_r values based on the soil AASHTO classification. For rigid pavement design, the software internally converts the M_r value to a modulus of subgrade reaction (*k*) value, which is representative of k-value measured using a 30 in. diameter loading plate.

In situ M_r is also estimated from non-destructive surrogate tests including the falling weight deflectometer (FWD) or light weight deflectometer (LWD). In practice, the elastic moduli values calculated from these test devices based on total deformations which are often confused with M_r values based on resilient (i.e., recoverable) deformations. Other limitations of these non-destructive surrogate tests are the lack of a conditioning stage prior to testing (such as the initial 500 to 1000 loading cycles performed in laboratory M_r testing) and limited ability to maintain a minimum contact stress during unloading. During pavement construction, pavement foundation materials are subjected to relatively high loads from construction traffic, compaction equipment, and wetting/drying cycles. In response to these loads, aggregate particles rearrange themselves. For this reason, it is important to apply conditioning load cycles prior to testing to determine in situ M_r, which is not possible with FWD/LWD testing and provide confinement with a minimum contact stress during unloading to simulate overlying pavement layers. The response of a pavement foundation to repeated traffic loading is both nonlinear and stress-dependent and therefore the effect of confinement is an important condition to consider in a field-based M_r test.

To overcome these limitations, an experimental test plan was developed and executed in this study to perform a state-wide in situ calibration of ME design input parameters for a range of Iowa pavement foundation layers. Field testing was performed on a range of typical materials and cross-sections used in Iowa on state and interstate highways. The results of the testing were analyzed to develop a database of in situ material-specific stress-dependent M_r values, M_r constitutive model parameters (k_1, k_2, and k_3) and *k* values.

Objectives and Scope of Project

To develop the AASHTOWare Pavement ME Design™ input data needed for Iowa foundation layers, the following testing program of in situ APLT testing was proposed for new pavements and reconstruction projects in six Iowa districts. The scope of work included:

- Reviewing pertinent project location information provided by the Iowa DOT to select two project sites from each Iowa district for up to10-12 project locations that cover a wide range of soil conditions.
- Mobilizing APLT to each project site to conduct field testing.
- Conducting cyclic and static APLTs at each project location to generate a statistically robust dataset.
- Conducting dynamic cone penetrometer (DCP) test at each APLT location to obtain the layer thickness profile for backcalculation analysis.
- Obtaining and conducting the necessary laboratory tests for soil characterization/ classification.
- Developing a data report for each project site with a summary memo for Iowa DOT review.
- Developing a final report and presentation to Iowa DOT on key findings.
- Developing a technical brief.

Benefits

The results of implementing AASHTOWare Pavement ME Design™ capability coupled with in situ measured/verified M_r values is anticipated to reduce risk of not meeting pavement design performance criteria, save money for optimizing selection of pavement foundation materials, provide efficiencies in design and construction, and increase quality, thus helping to insure long-term performance. The results and approach presented in this project report offers valuable information to practicing engineers and highway agencies on in situ ME calibration work for pavement foundation layers.

TESTING PLAN

Experimental Plan

An experimental plan was developed in collaboration with the Iowa DOT pavement design and construction engineering team to perform field testing to determine mechanistic properties on pavement foundation layers in situ at selected project sites across the State of Iowa. The goal at each site was to perform cyclic APLTs to determine composite and layered M_r properties (when subbase over subgrade conditions were present) at 4 to 8 test locations using a 12 in. diameter loading plate (Figure 9) and perform static APLTs to determine *k* value at 1 to 2 test locations with 30 in. diameter loading plate (Figure 10). A dynamic cone penetrometer (DCP) test was conducted at each test location (Figure 11a). Light weight deflectometer testing was also conducted on selected projects (Figure 11b).

The APLT testing plan summarizing the loading sequences for cyclic and static testing provided in Table 1. Cyclic APLTs involved performing a total of 1,500 loading cycles, which involved a 500 cycle conditioning sequence at 15 psi maximum stress followed by 100 to 250 cycles at 5 to 40 psi maximum stresses. Plate deformations and deflection basin measurements at 2x, 3x, and 4x, the plate radius were obtained for backcalculation of the two-layered M_r properties for each stress sequence. The average of the last 5 cycles was used for representation of M_r for each loading sequence. A 0.2 sec load time and a 0.8 sec dwell time was used. Static APLTs were performed following AASHTO T222 (2012), using two loading cycles.

Figure 9. 12 in. diameter loading plate setup for cyclic APLT on Project 3 – I-35/US30E Ramp (picture taken on 10/28/2017).

Figure 10. 30 in. diameter loading plate setup for static APLT on Project 2 - US 20 (picture taken on 10/19/2017).

(a) (b)

Figure 11. (a) Dynamic cone penetrometer testing on Project 2 - US 20 (picture taken on 10/19/2017), and (b) Light weight deflectometer testing on Project 4 – Hwy 330 near Hwy 65 (picture taken on 11/2/2017).

Table 2. Summary of plate load testing plan

Test Designation	Step	Number of cycles, N	Cyclic Stress, σ_{cyclic} [psi]	Minimum stress, σ_{min} [psi]	Maximum Stress, σ_{max}	Plate Configuration/Notes
A [1,100 cycle APLT]	Cond.	500	13	2	15.0	12 in. diameter flat plate with deflection readings at r, 2r, 3r, and 4r from plate center [r = plate radius]. 0.2 second load time and 0.8 second dwell time
	1	100	4	2	6.0	
	2	100	8	2	10.0	
	3	100	13	2	15.0	
	4	150	18	2	20.0	
	5	200	28	2	30.0	
	6	250	38	2	40.0	
B [Static APLT]	1	2	NA	NA	15.0	30 in. diameter stacked plate, load applied in 2.5 psi increments

A total of 10 project sites were selected that covered common cross-sections used in Iowa highways. The project location details, cross-section details, subbase and subgrade layer materials and notes on field testing are provided in Table 1. The cross-sections and materials from the different project sites are shown in Figure 12 and the project locations are shown on Google Earth aerial image in Figure 13. Projects were selected by the Iowa DOT with different subbase types (granular subbase and modified subbase, per Iowa DOT standard specifications), different subbase materials (crushed limestone and recycled concrete aggregate), different subgrade types (cohesive and granular select subgrade and embankment cut/fill subgrade). A summary of the gradation properties of the materials tested at each site are shown in Tables 3 to 5.

According to Iowa DOT standard specifications (Section 2010), the select subgrade cohesive materials should classify as A-6 or A-7-6 soils of glacial origin with plasticity index (PI) less than 10, 45% or less silt size fraction, and a standard Proctor maximum density of 110 pcf or greater. For select subgrade granular materials, the requirements are the material be classified as A-1, A-2, or A-3 with PI < 3, 15% or less silty + clay fraction, and standard Proctor maximum density of 110 pcf or greater. The subgrades at the field project sites were at or wet of optimum moisture at the time of field testing. Therefore, no moisture adjustments were made in this study for future changes in saturation levels, but those corrections can be applied (AASHTO T222, NCHRP 2000).

Six of the ten projects (Projects 1 to 6) were tested in fall of 2017 and the remaining four (Projects 7 to 10) in spring of 2018, shortly after the spring-thaw. In Project 10 (testing conducted in May 2018), tests were conducted at/near the same locations as in Project 4 (testing conducted in November 2017), but the tests were conducted on top of the 6 in. granular subbase that was placed over the previously placed 24 in. of special backfill. Only special backfill and the subgrade was tested in Project 4. In Project 9, the test locations showed relatively soft conditions to access with the truck and trailer and was therefore not tested with the APLT. Only DCP tests were conducted on Project 9 to document the conditions.

Table 3. Summary of Iowa DOT Projects used to develop database.

Project No.	Date	Location	Subbase	Subbase Type	Subbase Thickness (in.)	Subgrade Type	Field testing
1	10/12/2017	Hwy 20 EB, Early, Sac County, IA	Granular Subbase[1]	Crushed Limestone	8.4 to 10.9	24 in. Select Subgrade (Cohesive)[3]	8 cyclic APLTs and 1 static APLT on subbase. DCPs and LWDs at all locations.
2	10/19/2017	Hwy 20 EB, Early, Sac County, IA	Granular Subbase[1]	Recycled Concrete	9.7 to 11.0	24 in. Select Subgrade (Cohesive)[3]	5 cyclic APLTs on subbase and 2 static APLTs (1 on subbase and 1 on subgrade). DCPs and LWDs at all locations.
3	10/28/2017	I-35NB to US30EB Ramp, Ames, Story County, IA	Modified Subbase[2]	Recycled Concrete	10 to 11.1	24 in. Select Subgrade (Cohesive and Granular)[3]	6 cyclic APLTs on subbase and 2 static APLTs on subgrade. DCPs and LWDs at all locations.
4	11/2/2017	Hwy330 near Hwy65, Jasper County, IA	—	—	—	23 to 24 in. Special Backfill[4] over geogrid on embankment cut/fill	5 cyclic APLTs on special backfill and 3 cyclic APLTs on subgrade. DCPs and LWDs at all locations.
5	11/3/2017	Hwy100N, Linn County, IA	—	—	—	24 in. Select Subgrade (Cohesive)[3]	5 cyclic APLTs on subgrade. DCPs and LWDs at all locations.
6	11/15/2017	Hwy20, E. of Moville, Woodbury, IA	—	—	—	24 in. Select Subgrade (Cohesive)[3]	5 cyclic APLTs on subgrade. DCPs and LWDs at all locations.
7	4/25/2018	I-80/I-35 and 100th St. Ramp, Polk County, IA	Modified Subbase[2]	Crushed Limestone	12.0 to 12.0	24 in. Select Subgrade (Cohesive)[3]	7 cyclic APLTs and 2 static APLTs on subbase. DCPs at all locations.
8	5/8/2018	Hwy100 N., Linn County, IA	Modified Subbase[2]	Recycled Concrete + Crushed Limestone	7.5 to 9.6	24 in. Select Subgrade (Cohesive)[3]	4 cyclic APLTs and 3 static APLTs on subbase. DCPs at all locations.
9	5/16/2018	Hwy20, Woodbury County, IA	Granular Subbase[1]	Recycled Concrete	6 to 10.3	24 in. Select Subgrade (Cohesive)[3]	No APLTs due to soft support conditions. 12 DCPs on subbase.
10	5/29/2018	Hwy330 near Hwy65, Jasper County, IA	Granular Subbase[1]	Crushed Limestone	6 to 6	21 to 23 in. Special Backfill[4] over geogrid on embankment cut/fill	5 cyclic APLTs on subbase. DCPs at all locations.

[1]Iowa DOT aggregate gradation No. 4121
[2]Iowa DOT aggregate gradation No. 4123
[3]Iowa DOT Standard Specifications Section 2010.
[4]Iowa DOT aggregate gradation No. 4132.02 – consisting of reclaimed asphalt material.

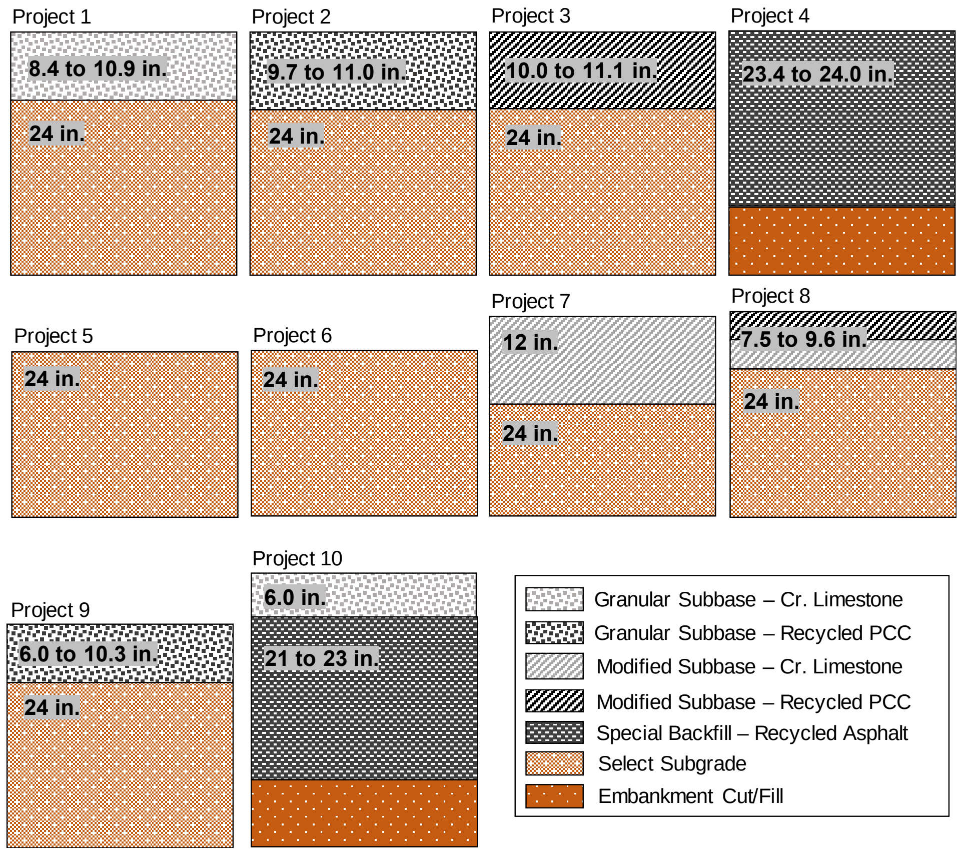


Figure 12. Idealized cross-sections of foundation layers at different projects.

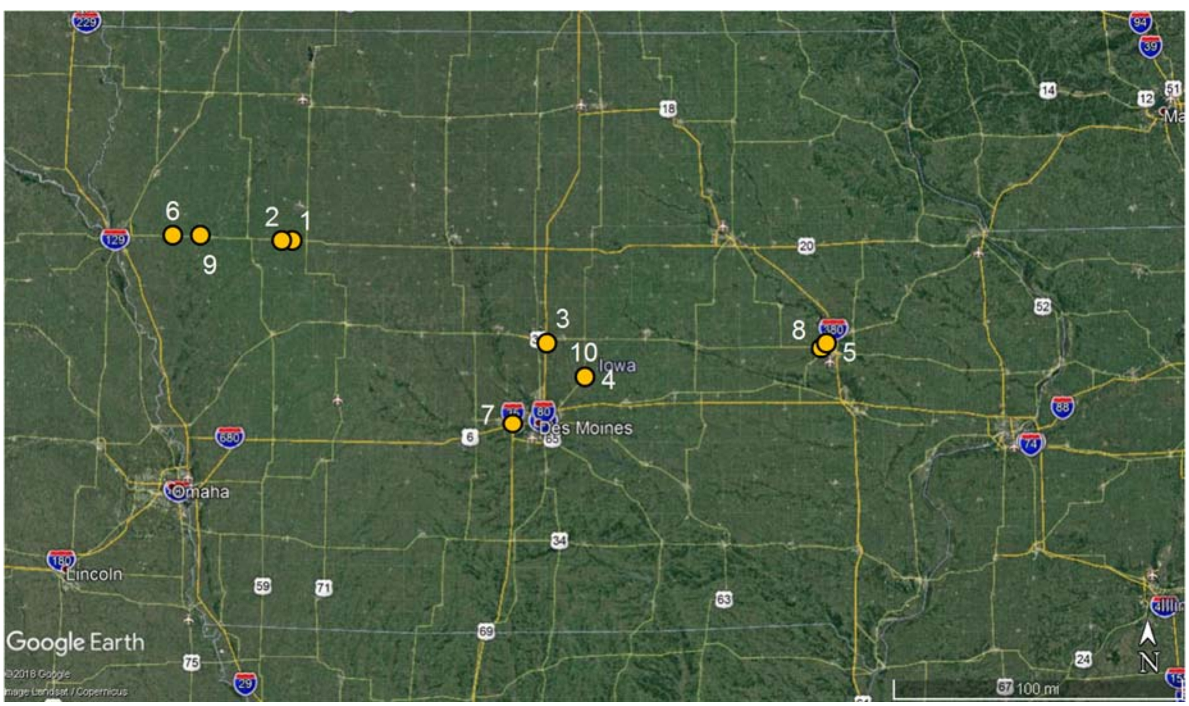


Figure 13. Google earth image showing the different project locations 1 to 10.

Table 4. Summary of particle-size analysis results (subbase material)

Parameter	Project #1	Project #2	Project #3	
Location	Hwy20, near Early, IA	Hwy20, near Early, IA	I35/US30 near Ames, IA	
Description	Granular Subbase (Iowa DOT 4121)	Granular Subbase (Iowa DOT 4121)	Modified Subbase (Iowa DOT 4123)	
	Crushed Limestone [Untrimmed]	Recycled Material [Untrimmed]	Recycled Material [Untrimmed]	Recycled Material [Trimmed]
% Gravel	82.9	88.4	66.3	36.6
% Sand	12.4	9.9	28.4	52.6
% Fines	4.8	1.6	5.3	10.9
D_{10} (mm)	1.8	4.0	0.25	0.06
D_{30} (mm)	8.1	9.9	3.6	0.5
D_{50} (mm)	13.5	16.0	11.6	2.2
D_{60} (mm)	15.5	19.1	15.5	4.1
D_{85} (mm)	21.7	28.4	25.8	13.4
D_{100} (mm)	37.5	37.5	37.5	37.5
C_u	8.6	4.8	62.7	72.0
C_c	2.3	1.3	3.4	1.1
AASHTO Classification	A-1-a	A-1-a	A-1-a	A-1-a
USCS	GW	GW	GP	SW
Gradation Specification Iowa DOT 4121 / 4123 [Percent passing for different sieve sizes]				
1.5 in. – 100 (4121) 1.5 in –- 100 (4121	100	100	100	100
3/8 in. – 40 to 80 (4121) 3/4 in. – 70 to 90 (4123)	35.2	28.6	69.4	91.4
#8 – 5 to 25[a] (4121) #8 – 10 to 40 (4123)	11.1	6.4	26.0	51.3
#200 – 0 to 6 (4121) #200 – 3 to 10 (4123)	4.8	1.6	5.3	10.9

NOTES:
Highlighted in gray indicates outside the gradation specification limits.
[a]5 to 20% for recycled materials.

Table 5. Summary of particle-size analysis results (subbase material) [Contd.]

Parameter	Project #7	Project #8	Project #9	Project #10
Location	I-80/35 and 100th St. Ramps, Polk County, IA	Hwy 100, North of E Ave., Linn County	Hwy 20, Woodbury County, IA	Hwy330, NE of Des Moines, IA
Description	Modified Subbase (Iowa DOT 4123)	Modified Subbase (Iowa DOT 4123)	Granular Subbase (Iowa DOT 4121)	Granular Subbase (Iowa DOT 4121)
	Crushed Limestone	Recycled Material	Recycled Material	Recycled Material [Trimmed]
% Gravel	66.1	70.9	87.1	61.5
% Sand	22.8	24.4	10.6	32.4
% Fines	11.1	4.7	2.2	6.1
D_{10} (mm)	NA	0.6	3.1	0.5
D_{30} (mm)	3.9	5.0	11.5	3.5
D_{50} (mm)	8.9	10.1	18.3	8.3
D_{60} (mm)	11.6	13.8	21.5	12.0
D_{85} (mm)	18.5	24.5	30.9	22.0
D_{100} (mm)	37.5	37.5	37.5	37.5
C_u	NA	23.7	6.9	23.8
C_c	NA	3.1	2.0	2.1
AASHTO Classification	A-1-a	A-1-a	A-1-a	A-1-a
USCS	GP-GM	GP	GW	GW
Gradation Specification Iowa DOT 4121 / 4123 [Percent passing for different sieve sizes]				
1.5 in. – 100 (4121) 1.5 in -– 100 (4121	100	100	100	100
3/8 in. – 40 to 80 (4121) 3/4 in. – 70 to 90 (4123)	86.8	72.8	24.6	54.0
#8 – 5 to 25[a] (4121) #8 – 10 to 40 (4123)	23.5	20.0	8.5	22.0
#200 – 0 to 6 (4121) #200 – 3 to 10 (4123)	11.1	4.7	2.2	6.1

NOTES:
Highlighted in gray indicates outside the gradation specification limits.
[a]5 to 20% for recycled materials.

Table 6. Summary of particle-size analysis results (special backfill/select subgrade)

Parameter	Project #4		Project #5	Project #6
Location	Hwy330, NE of Des Moines, IA		Hwy 100, Linn County	Hwy 20, E. of Moville
Description	Special Backfill (Iowa DOT 4132.02)	Select Subgrade	Select Subgrade	Select Subgrade
	Recycled Material	Sandy Lean Clay	Sandy Lean Clay	Sandy Lean Clay
% Gravel	37.2	2.3	12.0	1.8
% Sand	59.6	40.6	38.3	33.3
% Silt	3.2	44.7	38.4	64.9
% Clay		12.5	11.2	
D_{10} (mm)	0.29	0.008	0.002	0.014
D_{30} (mm)	0.97	0.015	0.022	0.023
D_{50} (mm)	2.8	0.05	0.079	0.048
D_{60} (mm)	4.3	0.10	0.20	0.066
D_{85} (mm)	11.1	0.44	1.8	0.38
D_{100} (mm)	37.5	19.0	25.0	19.0
C_u	15.0	13.3	127.4	4.8
C_c	0.8	0.3	1.6	0.6
AASHTO Classification	A-1-a	A-6[a]	A-6[a]	A-4[a]
USCS	SP	CL[a]	CL[a]	ML[a]
Gradation Specification Iowa DOT 4132.02 [Percent passing for different sieve sizes]				
1.5 in. – 100	100	Not applicable		
#8 – 10 to 40	46.9			
#200 – 0 to 10	3.2			

NOTES:
Highlighted in gray indicates it did not meet the specifications.
[a]Atterberg limits tests not performed – classifications based on visual identification of the material and gradation test results.

Measurement Parameters

The cyclic APLTs were performed to determine stress-dependent composite M_r ($M_{r\text{-}Comp}$) and individual layered M_r values for subgrade ($M_{r\text{-}SG}$) and base/subbase ($M_{r\text{-}Base}$) layers. The M_r constitutive model parameters (k_1, k_2, and k_3) were then determined for both composite and individual layers and are presented herein as k^*_1, k^*_2, k^*_3, where "*" is used to differentiate with regression coefficients traditionally developed for laboratory M_r test measurements. A subscript 'Comp' or 'SG' or 'Base' are added to the model coefficients (e.g., $k^*_{1(Comp)}$) to differentiate between composite or subgrade or base layer values, respectively. Additional details on the methods and analysis procedures are provided in Appendix A. The cyclic APLT test procedure is provided in Appendix B.

The static APLTs were used to determine the modulus of subgrade reaction *k*-value. The *k*-value is presented herein as k'_u which represents the *k* value after plate bending correction and with no moisture correction applied, per AASHTO T222 (2012). Two loading/unloading cycles were performed in this study and the results are therefore presented as $k'_{u(1)}$, and $k'_{u(2)}$ representing values for each loading cycle. If the measurement was performed on top of the granular subbase layer, the k'_u values are presented as $k'_{u(Comp)}$. The results are presented for a given target stress level of 10 psi, per AASHTO T222 and as well as at deformations (δ) = 0.05 in, per PCA (1984). Additional details on the test methods and analysis procedures are provided in Appendix A.

LWD tests were used to determine the elastic moduli values using peak deformations. Tests were performed following manufacturer recommendations (Zorn 2003). The assumptions for Poisson's ratio and shape factor for calculating moduli values were same as in case of APLTs. Additional details are provided in Appendix A.

DCP tests were performed in accordance with ASTM D6951 to determine the penetration resistance (inches or mm per blow) profile with depth and calculate the California bearing ratio (CBR) values. The average values of the top and bottom layer were calculated using the penetration resistance values. Additional details are provided in Appendix A.

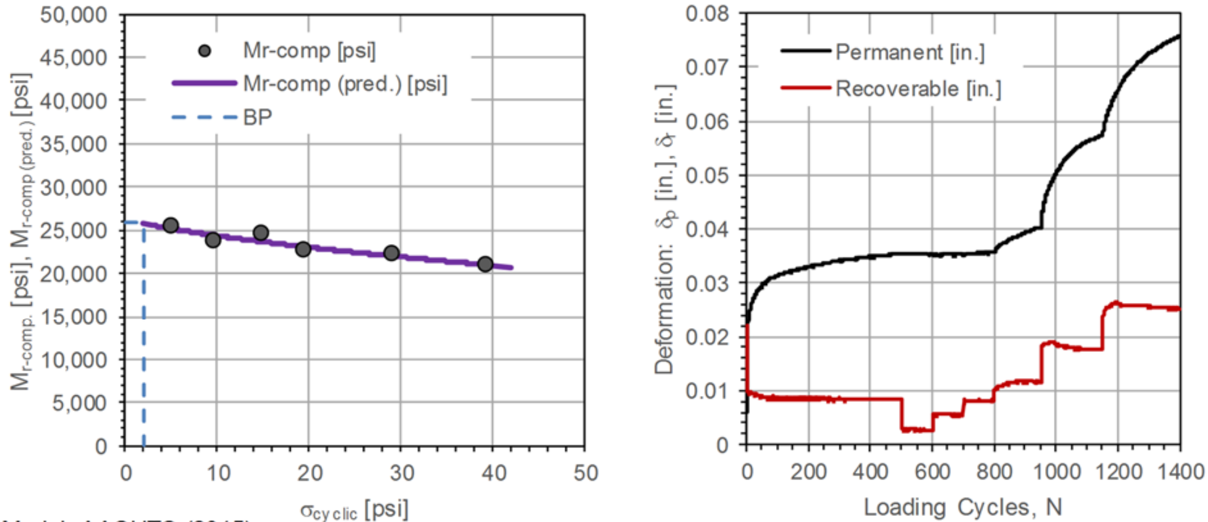
FIELD TEST RESULTS

For each project site, an individual data report for each test location summarizing the $M_{r\text{-Comp}}$ and layered analysis results, the "universal" model parameter values, *k*-values from selected interpretation methods, and a picture are documented in Appendix C. In addition, summary statistics of average (μ), standard deviation (σ), and coefficient of variation (C_v) of the different parameters are summarized separately for each project.

In Situ Stress-Dependent Resilient Modulus (M_r)

Example cyclic APLT results for $M_{r\text{-comp}}$ are shown in Figure 14 from Project 3 with 11 in. of modified subbase over select subgrade. The results show a plot of σ_{cyclic} versus $M_{r\text{-comp}}$ measured and predicted from Eq. 4, a plot of rebound (δ_r) and permanent (δ_p) deformations versus loading cycles, a picture of the test location, and a summary of the "universal" model parameters k^*_1, k^*_2, k^*_3, and the associated statistics of the regression fit (i.e., R^2 value, p-value, standard error of the fit). The $M_{r\text{-comp}}$ test results at that test location exhibited a decrease in modulus with increasing cyclic stress up to about 40 psi. Decreasing modulus with increasing stress is a characteristic of composite aggregate subbase over softer fine-grained subgrade.

Results from layered analysis for the test location are presented in Figure 15. The figure includes a plot showing σ_{cyclic} versus $M_{r\text{-Base}}$ and $M_{r\text{-SG}}$ measured and predicted from Eq. 4, a graph of DCP-CBR and cumulative blows versus penetration depth, a graph of the deflection basin for each loading step sequence, and a summary of the "universal" model parameters k^*_1, k^*_2, k^*_3, and the associated statistics of the regression fit separately for the subbase and subgrade layers. The $M_{r\text{-Base}}$ test results at that test location exhibited an increase in modulus with increasing cyclic stress up to about 40 psi, while the $M_{r\text{-SG}}$ exhibited an opposite trend. Increasing modulus with increasing stress observed for $M_{r\text{-Base}}$ is typically a characteristic of granular materials that exhibit strain hardening effect while the opposite observed for $M_{r\text{-SG}}$ is a characteristic of non-granular materials that exhibit stress-softening behavior.

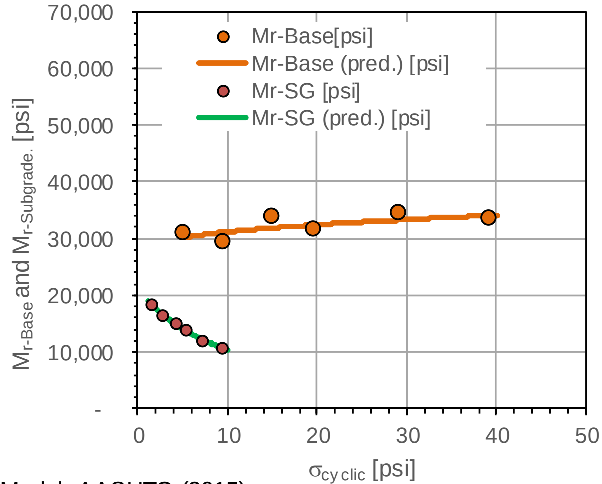


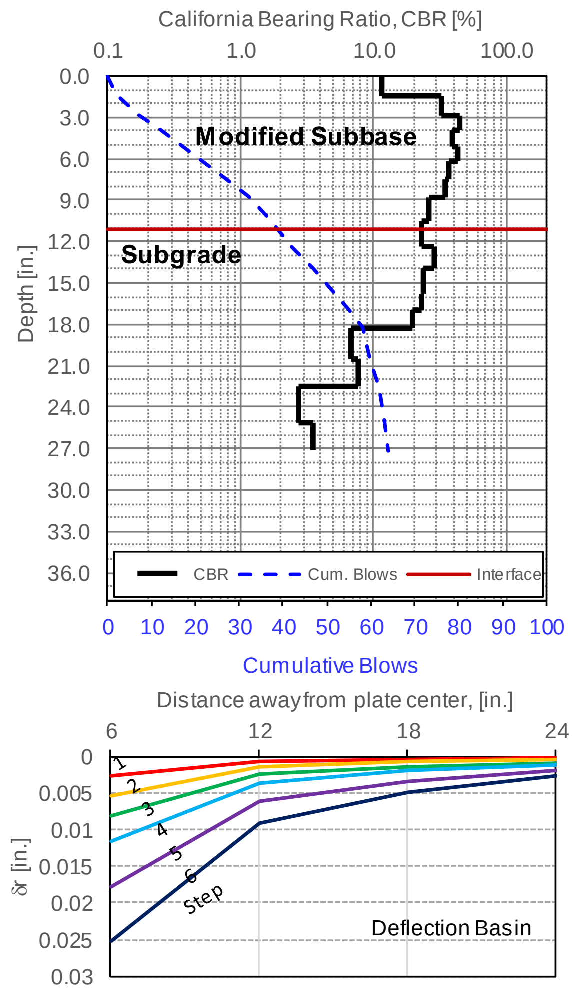
Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	1,759.7	2.29E-07
k^*_2	-0.008	9.21E-01
k^*_3	-0.551	3.66E-01
Adj. R^2	0.835	
Std. Error [psi]	626	
$M_{r\text{-comp (pred.)-BP}}$ [psi]		25,812
	$\sigma_{cyclic\text{-BP}}$ [psi]	2.0

Figure 14. Example test results from cyclic APLT performed at different stress levels showing Mr-Comp versus cyclic stress, permanent and rebound deformations for each loading cycle, AASHTO (2015) model parameters, and a picture of the test location (Project 3 – 11 in. modified subbase over select subgrade).





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
$k^*_{1\ (Base)}$	2053.0	1.02E-06
$k^*_{2\ (Base)}$	0.037	7.91E-01
$k^*_{3\ (Base)}$	0.151	8.74E-01
Adj. R^2	0.405	
Std. Error [psi]	1095	
$k^*_{1\ (SG)}$	1298.3	3.89E-06
$k^*_{2\ (SG)}$	-0.094	2.23E-01
$k^*_{3\ (SG)}$	-3.858	1.86E-02
Adj. R^2	0.997	
Std. Error [psi]	155	

Figure 15. Example test results from cyclic APLT performed at different stress levels showing layered Mr results ($M_{r\text{-}Base}$ and $M_{r\text{-}SG}$) versus cyclic stress on each layer, DCP-CBR and cumulative blows profile, AASHTO (2015) model parameters for each layer, and deflection basin for each load step (Project 3 – 11 in. modified subbase over select subgrade).

Table 7 provides a summary of statistics for M_r test results at a selected cyclic stress (13 psi) along with the "universal" model parameters. A box plot of M_r values ($M_{r\text{-}Comp}$, $M_{r\text{-}Base}$, and $M_{r\text{-}SG}$) at one selected cyclic stress level (nominal 13 psi) are presented for each project in Figure 16. The box plots show a box with the boundary of the box closest to zero indicating the 25th percentile, a line within the box marking the median, a dashed line within the box marking the mean, and the boundary of the box farthest from zero indicating the 75th percentile. The bars above and below the box indicate the 90th and 10th percentiles.

The M_r data is grouped with projects having similar material types and are presented as box plots in Figure 17.

Table 7. Summary statistics of M_r test results for each project site (composite, base, and subgrade layers along with "universal" model parameters).

Project No.	$M_{r\text{-}Comp}$ at σ_{cyclic} = 13 psi at surface			In situ "Universal" Model Parameters					
				$k_1^*{}_{(Comp)}$		$k_2^*{}_{(Comp)}$		$k_3^*{}_{(Comp)}$	
	n	μ (psi)	C_v (%)	μ	C_v (%)	μ	C_v (%)	μ	C_v (%)
1	8	20,283	14	1,334.1	14	0.185	60	-0.994	-48
2	5	23,215	13	1,491.2	11	0.166	79	-0.837	-98
3	6	22,327	35	1,676.1	32	-0.147	116	0.080	-185
4	5	22,980	70	1,532.1	70	-0.125	-93	0.636	103
4[a]	3	11,778	26	1,057.0	32	-0.130	-132	-1.235	-103
5[a]	5	21,388	39	1,957.7	55	0.376	36	-2.708	-5
6[a]	5	8,277	5	622.1	16	-0.104	-36	-0.342	-132
7	7	18,436	29	1,411.1	24	0.260	34	-2.699	-30
8	4	15,507	26	1,329.0	25	0.017	207	-2.137	-11
10	5	49,662	7	3,186.3	8	0.282	43	-1.278	-53

Project No.	$M_{r\text{-}Base}$ at σ_{cyclic} = 13 psi at surface			$k_1^*{}_{(Base)}$		$k_2^*{}_{(Base)}$		$k_3^*{}_{(Base)}$	
	n	μ (psi)	C_v (%)	μ	C_v (%)	μ	C_v (%)	μ	C_v (%)
1	8	23,254	16	1,433.6	21	0.232	67	-0.931	-75
2	5	20,115	12	1,247.2	12	0.181	105	-0.823	-136
3	6	29,998	25	2,146.2	31	-0.242	118	0.967	186
4	5	25,654	66	1,652.2	66	-0.142	-91	0.920	61
7	7	25,904	17	1,869.3	11	0.346	50	-2.805	-45
8	4	27,517	22	2,481.9	25	0.070	146	-2.973	-28
10	5	54,141	13	3,391.6	15	0.334	46	-1.432	-62

Project No.	$M_{r\text{-}SG}$ at σ_{cyclic} = 13 psi at surface			$k_1^*{}_{(SG)}$		$k_2^*{}_{(SG)}$		$k_3^*{}_{(SG)}$	
	n	μ (psi)	C_v (%)	μ	C_v (%)	μ	C_v (%)	μ	C_v (%)
1	8	17,278	25	1,453.0	23	0.166	53	–2.238	-29
2	5	30,062	20	2,490.3	21	0.204	50	–1.845	-79
3	6	15,708	50	1,306.4	36	0.011	94	-5.196	-108
4	5	14,807	82	1,904.3	161	0.176	412	-11.539	-76
7	7	12,251	59	1,345.0	36	0.238	66	-8.350	-64
8	4	8,977	26	678.7	21	0.075	-87	-1.997	-67
10	5	33,636	23	15,134.4	120	0.768	87	-17.753	-67

NOTES:

[a] Tests performed directly on top of subgrade.

n = number of tests, μ = mean, and C_v = coefficient of variation.

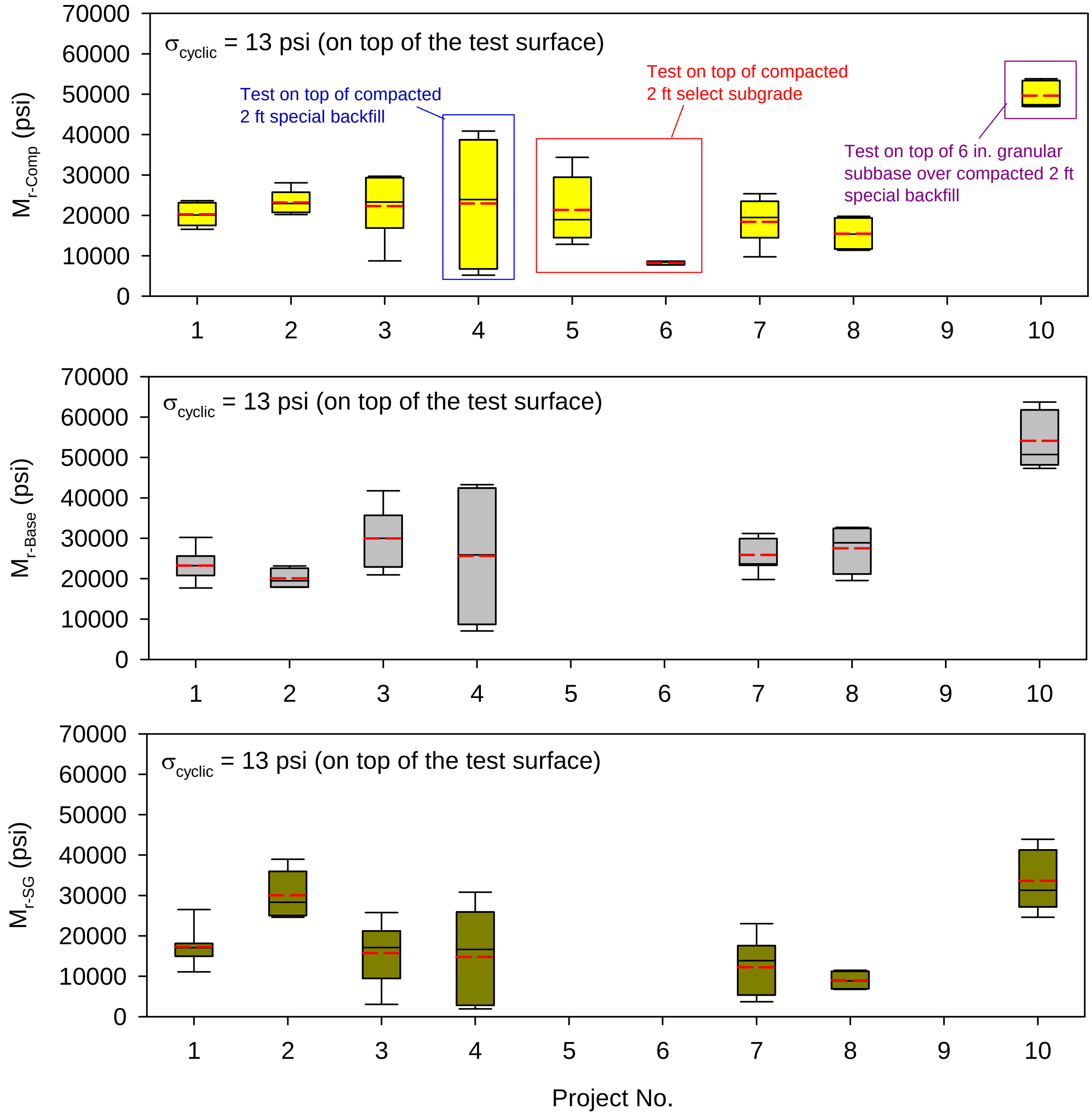


Figure 16. Box plots of $M_{r\text{-}Comp}$, $M_{r\text{-}Base}$, and $M_{r\text{-}SG}$ results from each project location.

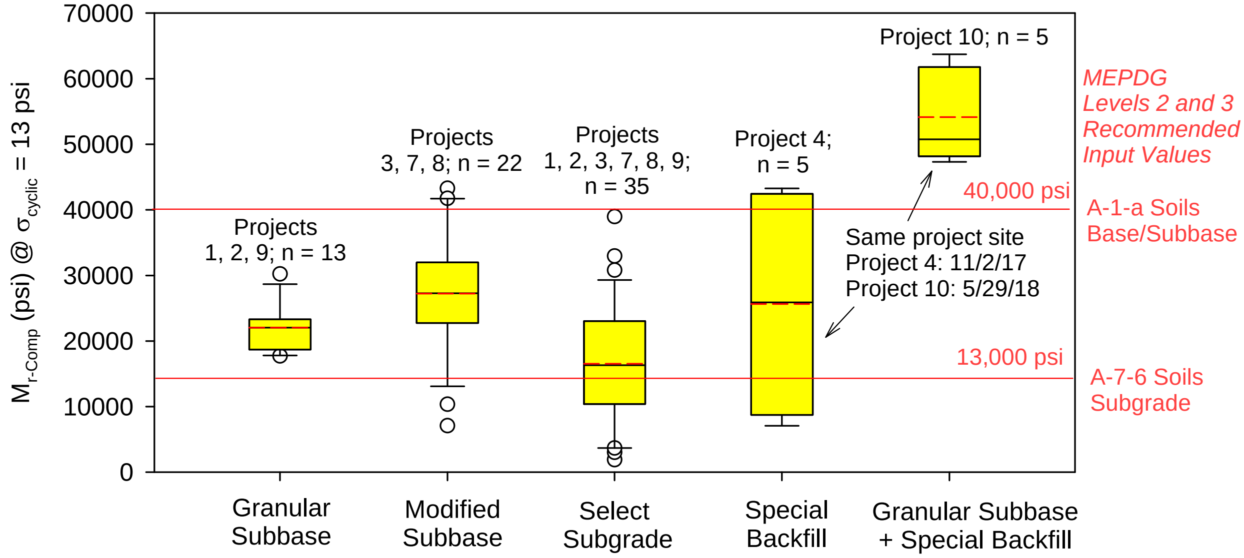


Figure 17. Box plots of $M_{r\text{-}Comp}$ for different material types.

The M_r test results presented as box plots and the summary statistics show that the measurement values are variable at each site. The C_v from each site varied between 7% and 70%. For reference, a C_v of about 20% over a given area/site is typically considered a relatively uniform condition. Results from six out of the ten projects yielded $C_v > 20\%$ for $M_{r\text{-}Comp}$ values summarized in Table 7.

Two reference lines are shown in Figure 17, which represent the typical recommended values for M_r inputs for AASHTOWare Pavement ME Design™ Levels 2 and 3 (AASHTO 2015) for two soil types that represent the select subgrade (cohesive) and the subbase materials tested at this site. Comparison of these reference values with the actual measured values indicate that the actual in situ M_r were several times lower to higher than the recommended input values for these soil types. This finding emphasizes the importance of in situ characterization of these values for selection in design as well as field verification of the input parameters during construction.

Field testing on Projects 4 and 10 were performed at similar test locations (matched using GPS measurements). However, as explained earlier for Project 10 conducted in May 2018, a nominal 6 in. of granular subbase was placed over the 2 ft of special backfill originally tested in Project 4 (November 2017). Results indicated a two-fold increase in $M_{r\text{-}Comp}$ values on average. DCP test results from November 2017 and May 2018 tests (at two selected locations) are compared in Figure 18, which show that the special backfill layer increased in stiffness from 6 in. to 24 in. depths. The special backfill material consisted of reclaimed asphalt pavement (RAP) material. The increase in the $M_{r\text{-}Comp}$ from November 2017 to May 2018 is attributed to strength-gain from curing of RAP material and construction trafficking after November 2017 testing.

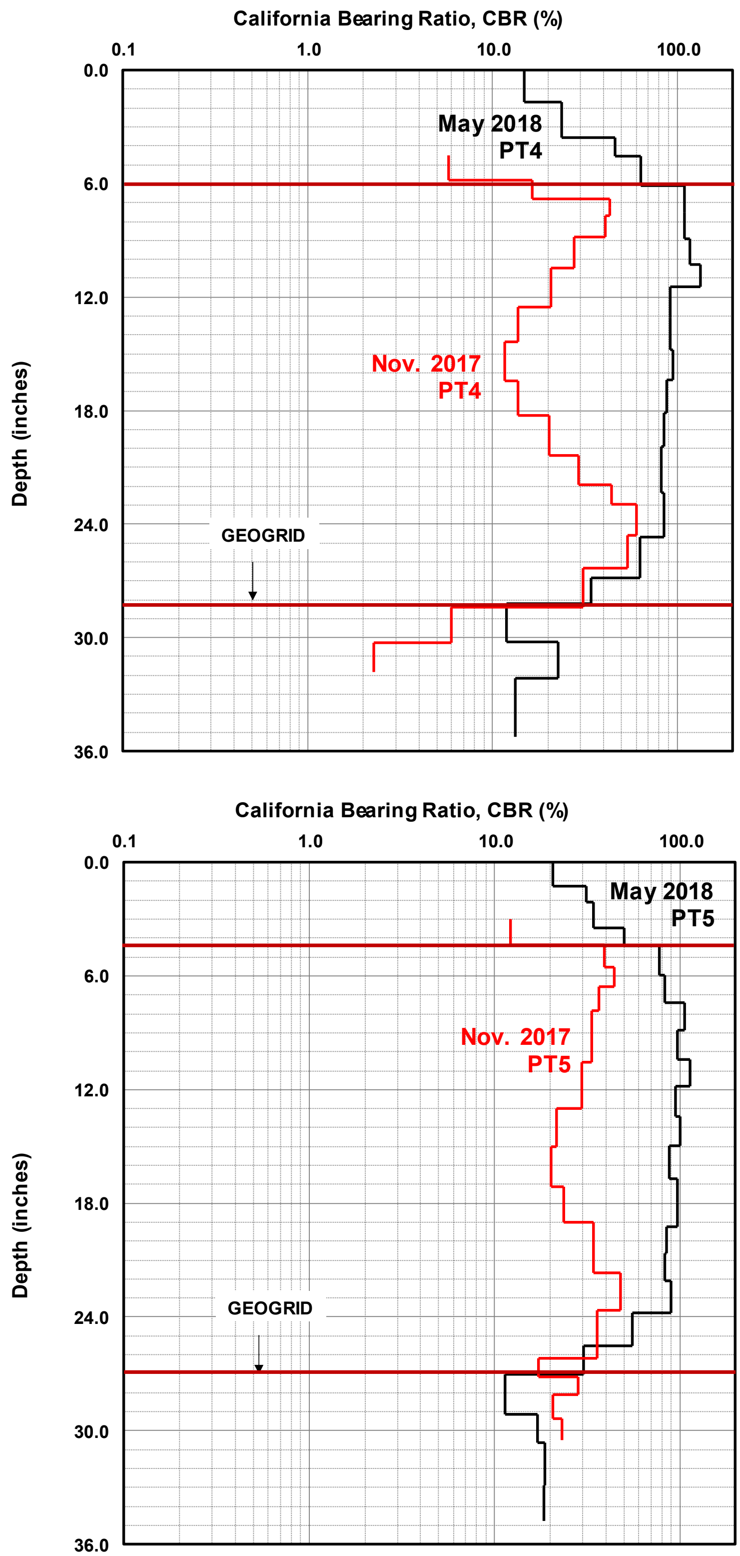


Figure 18. DCP-CBR plots at two selected locations (Points 4 and 5) from November 2017 (Project 4) and May 2018 (Project 10).

Modulus of Subgrade Reaction (k-values)

Example results from static PLT at two test points at a project site along with the interpreted k'_u values are shown in Figure 19. *k*-value results from all project sites are summarized in Table 8.

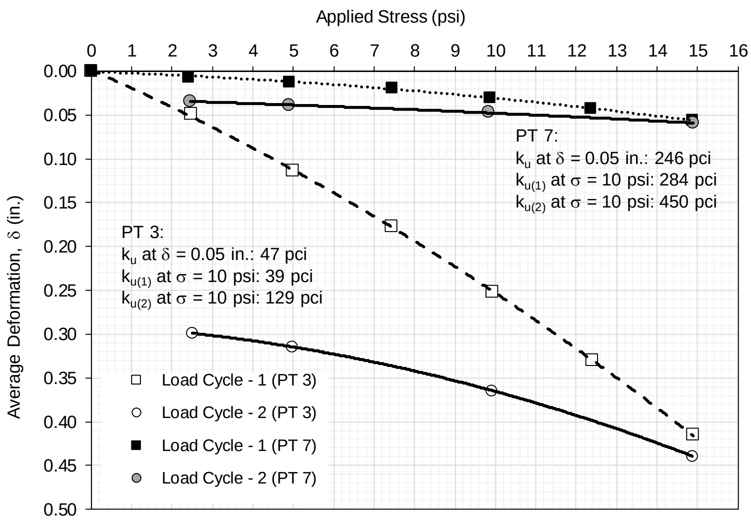


Figure 19. Example test results from static APLTs at two test locations (Project 7 – 12 in. modified subbase over compacted select subgrade).

Table 8. Summary of static PLT test results from all test sites.

Project No.	Test Surface	30 in. diameter plate static PLT				
		k_u (pci) at δ = 0.05 in[a]	k_{u1} (pci) at 10 psi	k_{u2} (pci) at 10 psi	δ_p at end of test (in.)	Ratio of k_{u2}/k_{u1}
1	Granular Subbase	58	70	639	0.165	9.1
2	Granular Subbase	76	91	504	0.122	5.5
	Subgrade[b]	89	98	394	0.096	4.0
3	Subgrade	37	36	213	0.346	5.9
	Subgrade	43	36	195	0.392	5.5
5	Subgrade	246	239	780	0.039	3.3
	Subgrade	266	245	690	0.035	2.8
6	Subgrade	85	92	216	0.077	2.4
	Subgrade	145	145	272	0.046	1.9
7	Modified Subbase	47	39	129	0.298	3.3
	Modified Subbase	246	284	450	0.028	1.6
8	Modified Subbase	104	106	351	0.094	3.3
8	Modified Subbase	52	52	224	0.205	4.3
8	Modified Subbase	58	62	275	0.169	4.5

[a]per PCA (1984) pavement design input requirement.
[b]Test performed on subgrade by excavating a 36 in. x 36 in. hole on the granular subbase layer.

Box plots of *k*-values obtained from static APLTs from all the project sites are provided in Figure 20. The results are grouped for tests performed on granular/modified subbase layers over subgrade and for tests performed directly on subgrade. The results showed significant variability across the state, with *k* values varying between 35 pci to 300 pci. 11 out of the 14 tests performed across the state showed *k* values < the typically assumed 150 pci design input target value by the Iowa DOT for PCA (1984) design. At one site (Project 7), two tests performed on the compacted modified subbase layer about 420 feet apart, showed $k_{u(1)}$ of 39 and 284 pci.

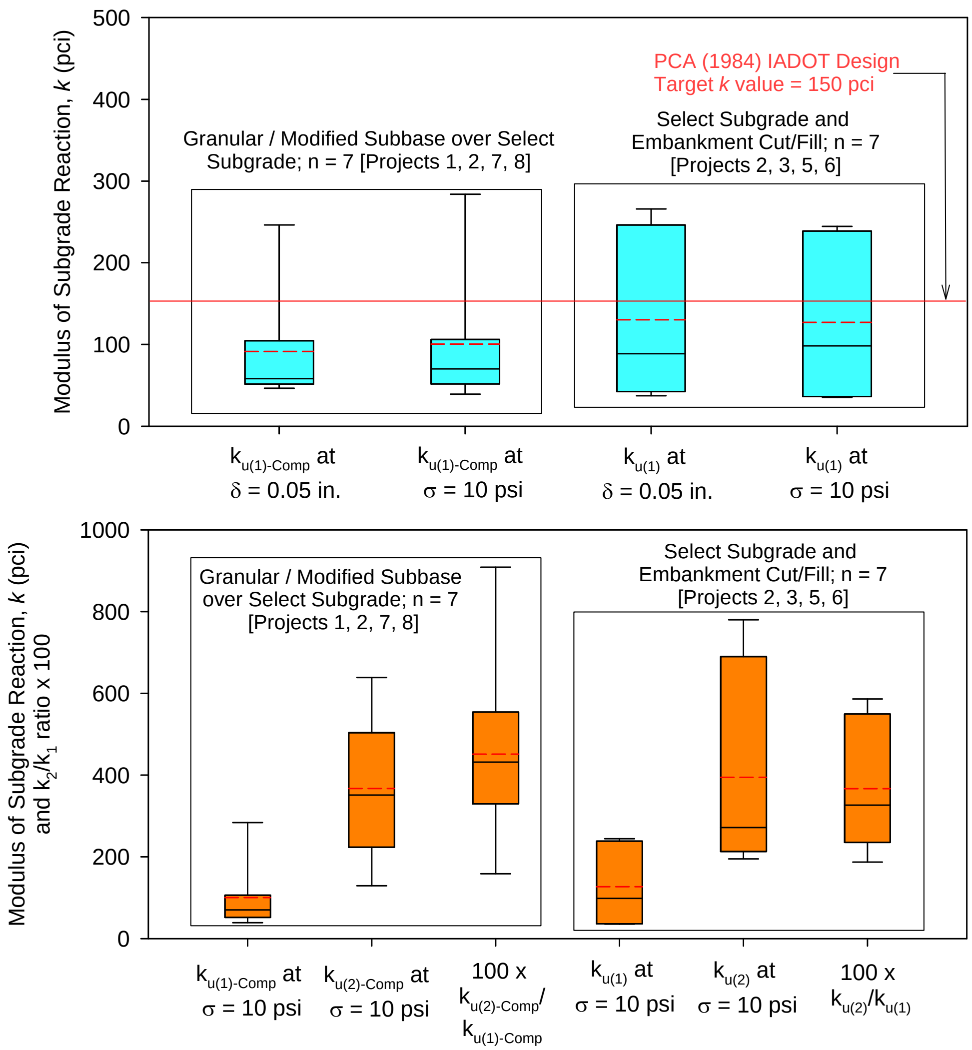


Figure 20. Box plots of *k*-values for different material types.

Comparing *k*-values across the sites, results showed that the k_{comp} values obtained over granular subbase/modified subbase layers were on average lower than the *k* values obtained directly on the underlying subgrade layer. This was because the subbase layers were in many cases were relatively loose/uncompacted at the surface, which is also evidenced by the relatively high k_2/k_1 ratio values (>3 at 6 out of 7 tests on subbase layers) (see Table 8 and Figure 20). For reference, Swedish specifications (ATB Vag 2005) require the ratio of reload to initial moduli values to be < 2.8 for base/subbase layers within the top 0 to 10 inches.

Permanent deformation (δ_p)

Permanent or plastic deformation occurring from repeated traffic loading is a recognized cause of pavement distresses. For rigid pavements, increases in total permanent deformation in the unbound layers contribute to increased faulting, roughness, and transverse cracking and reduced load-transfer efficient (LTE). In a study conducted by Birkhoff and McCullough (1979), a void gap of about 0.05 in. can load to loss of support, thereby increasing the bending stresses in the pavement leading to fatigue failure. For flexible pavements, as total permanent deformation within unbound and subgrade layers increases, surface rutting, roughness, and cracking increase. It is therefore essential that permanent deformation be measured, and mechanistic-empirical models be developed to predict permanent deformation performance.

Permanent deformations (δ_p) were monitored during cyclic and static APLTs conducted for this project. Summary statistics of δ_p values at the end of last stress sequence during cyclic APLTs are provided in Table 9. Results showed that average δ_p from each site varied between 0.01 in. and 0.26 in., and the C_v at each site varied between 14% and 123%. δ_p values at the end of static APLTs are summarized in Table 8, which show the values varied between 0.046 in and 0.398 in. 11 out of the 14 static APLTs showed δ_p > the critical 0.05 in. as identified by Birkhoff and McCullough (1979).

Figure 21 provides a graph of $k_{u(1)}$ versus δ_p from static APLT results at all project sites, which shows a strong power relationship between the two parameters. Based on this relationship, to limit δ_p to a critical 0.05 in., a minimum $k_{u(1)}$ = 170 pci must be achieved.

Table 9. Summary statistics of δ_p value at the end of last stress sequence (σ_{cyclic} = 38 psi) from cyclic APLT.

Project No.	Test Surface	$\Delta\delta_p$ at the end of last stress sequence at σ_{cyclic} = 38 psi		
		n	μ (in.)	C_v (%)
1	Granular Subbase	8	0.264	14%
2	Granular Subbase	5	0.125	16%
3	Modified Subbase	6	0.089	123%
4	Special Backfill	5	0.106	114%
4[a]	Subgrade	3	0.036	32%
5[a]	Subgrade	5	0.010	53%
6[a]	Subgrade	5	0.024	62%
7	Modified Subbase	7	0.059	49%
8	Modified Subbase	4	0.095	24%
10	Granular Subbase	5	0.015	20%

NOTES:
[a] Tests performed directly on top of subgrade.
n = number of tests, μ = mean, and C_v = coefficient of variation.

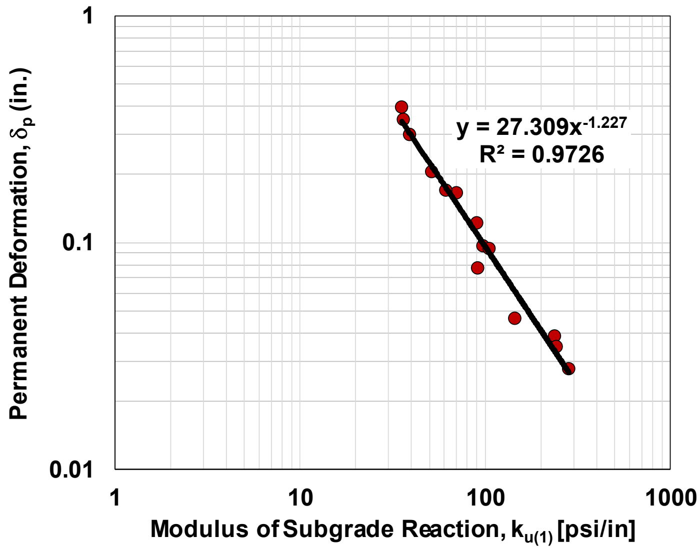


Figure 21. Relationship between modulus of subgrade reaction *k*-value for 1st load cycle at 10 psi stress and permanent deformation δ_p at the end of 2nd load cycle

DCP-CBR Measurements

Summary statistics (n, μ, C_v) for DCP-CBR test results along with the thickness of the subbase layers for each project are provided in Table 10. The DCP-CBR results also show high variability, as evidenced in the APLT measurements.

Table 10. Summary of DCP test results.

Project No.	Top Layer[a]					Bottom Layer[b]		Ratio of top/bottom layer CBR	
	n	Avg. H (in.)	C_v (%)	Avg. CBR (%)	C_v (%)	Avg. CBR (%)	C_v (%)	Avg. Ratio	C_v (%)
1	9	9.3	10	5.7	25	5.2	61	1.3	54
2	6	10.3	5	6.4	27	12	12	0.6	45
3	6	10.8	5	26	33	19	64	1.8	50
4	5	23.9	1	43	30	15	60	4.1	73
5	5	12.0	0	25	20	16	15	1.7	30
6	5	12.0	0	19	17	2.1	18	9.3	26
7	7	12.0	0	28	25	12	41	2.6	35
8	5	8.6	9	26	16	5.3	36	5.2	31
9	12	7.9	19	8.2	144	2.1	25	3.9	135
10	5	28.0	3	71	7	11	65	11.0	83

[a]Top layer represents granular/modified subbase layer for Projects 1, 2, 3, 7, 8, and 9; special backfill layer for Project 4; top 12 in. of select subgrade for Projects 5 and 6; and granular subbase + special backfill for Project 10.
[b]Bottom layer represents select subgrade or embankment cut/fil subgrade.
BLUE shaded projects with granular/modified subbase at the surface.
GREY shaded project with special backfill at the surface.
PINK shaded projects with select subgrade at the surface.

APPLICATION OF APLT RESULTS FOR MECHANISTIC ANALYSIS

The APLT results can be utilized to perform mechanistic analysis of a rigid pavement system and assess the pavement performance characteristics. A few example cases are demonstrated herein using finite-element (FE) analysis method. The Kenslabs 2D FE software developed based on thin plate theory is used herein. In this software, the pavement slab is divided into rectangular finite elements and stresses at each connecting node are determined (Huang 2004). The foundation can be modeled as liquid or solid or layered systems. The liquid model involves using a modulus of subgrade reaction (*k*-value), the solid model involves using a composite single layer resilient modulus values (i.e., $M_{r\text{-}Comp}$), and the layered model involves using individual layer moduli values and their corresponding layer thicknesses. In this study, the 'liquid' model using the *k*-values obtained from static APLTs were utilized.

The Kenslabs software was selected over other pavement analysis software programs because of its unique ability to model loss of support (LOS) with a defined magnitude of "gap" (i.e., δ_p) at each node. The different LOS areas were modeled using the LOS factors defined in AASHTO (1986, 1993). The LOS factor = 1 corresponds to a void area of 1.59%; LOS factor = 2 corresponds to a void area of 4.59%; and LOS factor = 3 corresponds to a void area of 8.16%, of the area of the slab (AASHTO 1986).

The FE model setup is illustrated in Figure 22. Two jointed square slabs of size 10 ft x 10 ft were modeled by loading near the joint/corner. The AASHTO standard 18-kip single axle dual wheel set highway loading was used for the corner loading.

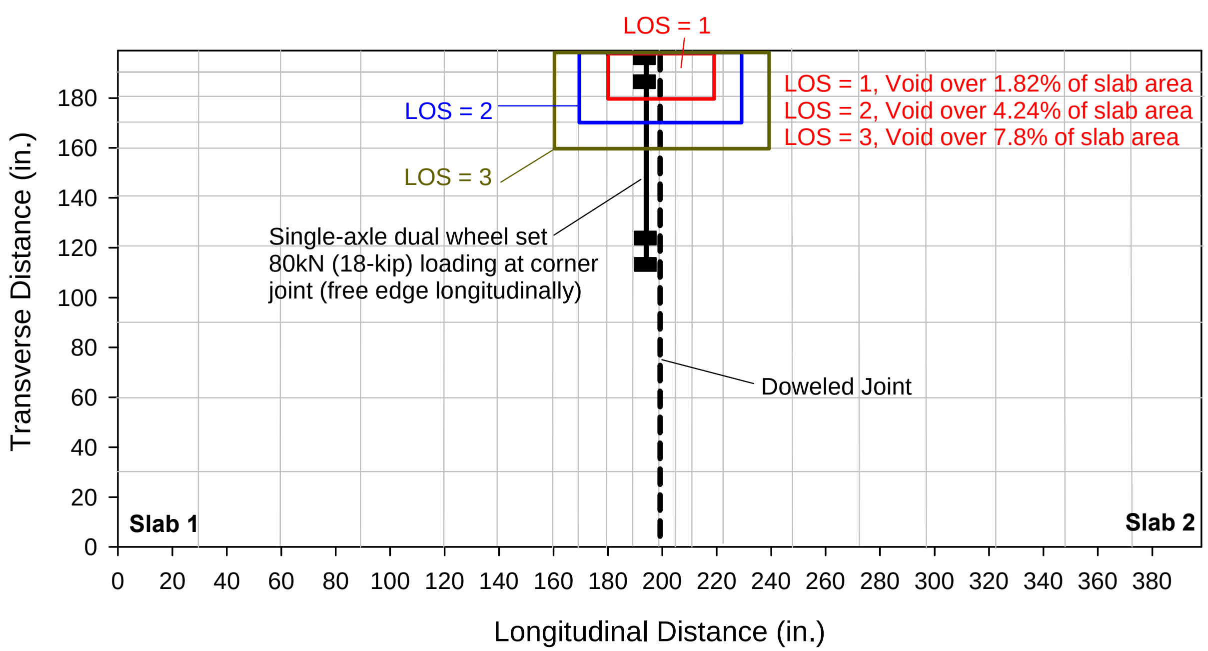


Figure 22. Illustration of FE model setup with two jointed slabs and 18-kip standard single axle loading (with dual wheel sets) near joint/corner and area of "void" beneath slab for different LOS conditions.

The FE model setup parameters are summarized in Table 11. Low, medium, and high *k* values were selected based on the field test results along with the corresponding δ_p values from those test locations. Three different pavement thickness cases were evaluated (6 in., 8 in., and 10 in.). The main objective of the FE analysis was to assess the influence of *k*-value, LOS condition, and pavement thickness on the bending stresses in the pavement layer. The stress ratio (SR) values were calculated for each case as the ratio of the maximum principal stress in the pavement layer and the modulus of rupture of the concrete (assumed as 660 psi). Based on the SR values, the number of load repetitions for fatigue failure (*N*) were calculated using the PCA (1984) fatigue model. For reference, SR < 0.45 results in *N* that is >100,000,000 cycles ("unlimited").

Table 11. FE model setup parameters.

Parameter	Value/Description
Pavement Slab	Two jointed square slabs (16.6 ft x 16.6 ft)
Pavement Thicknesses Evaluated:	6 in., 8 in., and 10 in. PCC
Foundation Layer Properties	Modeled as slab resting on 'liquid' foundation with a defined *k*-value. Low *k*: 39 pci (from Project 7) or equivalent M_r = 760 psi Medium *k*: 145 pci (from Project 6) or equivalent M_r = 2,810 psi High *k:* 284 pci (from Project 7) or equivalent M_r = 5,510 psi
Loss of Support (LOS) Modeling	LOS area modeled as gaps between pavement slab and foundation layer with thickness of gaps equal to average δ_p at the end of static PLT. High δ_p = 0.298 in. (from Project 7 corresponding to *k* = 39 pci) Medium δ_p = 0.046 in. (from Project 7 corresponding to *k* = 39 pci) Low δ_p = 0.028 in. (from Project 7 corresponding to *k* = 284 pci)
Joint Parameters	Modulus of dowel support: 300,000 psi Dowel bar diameter: 1.0 in. Joint width: 0.5 in.
Loading	*AASHTO Standard Highway Loading* • Axle weight: 18 kips • Single axle 2 dual tire sets • Tire contact area: 45 in^2 • Center-center spacing between tires in a dual set: 13.4 in. • Center-center spacing between tire sets: 70 in. • Tire contact stress: 100 psi

Spatial color-coded contour plots of bending stresses calculated in the pavement layer for 8 in. thick rigid pavement layer with LOS of 0 and 1, for low and high *k*-value cases are compared in Figure 23. Visually, it can be seen that there are no significant differences in the bending stresses between the low and high *k* value cases for LOS = 0 condition, but there are significant differences when LOS = 0 versus 1 cases are compared. For the LOS = 1 cases, the peak stresses occurred in a distribution corresponding to a typical corner break observed in distressed concrete pavements.

The SR values calculated from the peak stresses for of the cases evaluated are presented as bar charts Figure 24. For LOS = 0 condition, the SR values are < 0.45 for all three thicknesses evaluated and k-values evaluated. For LOS = 1 and 2 conditions, the SR values increased and the associated number of load repetitions decreased, with no significant differences between LOS 1 versus 2 conditions. The SR's were either similar or lower for LOS 3 compared to LOS 2 condition.

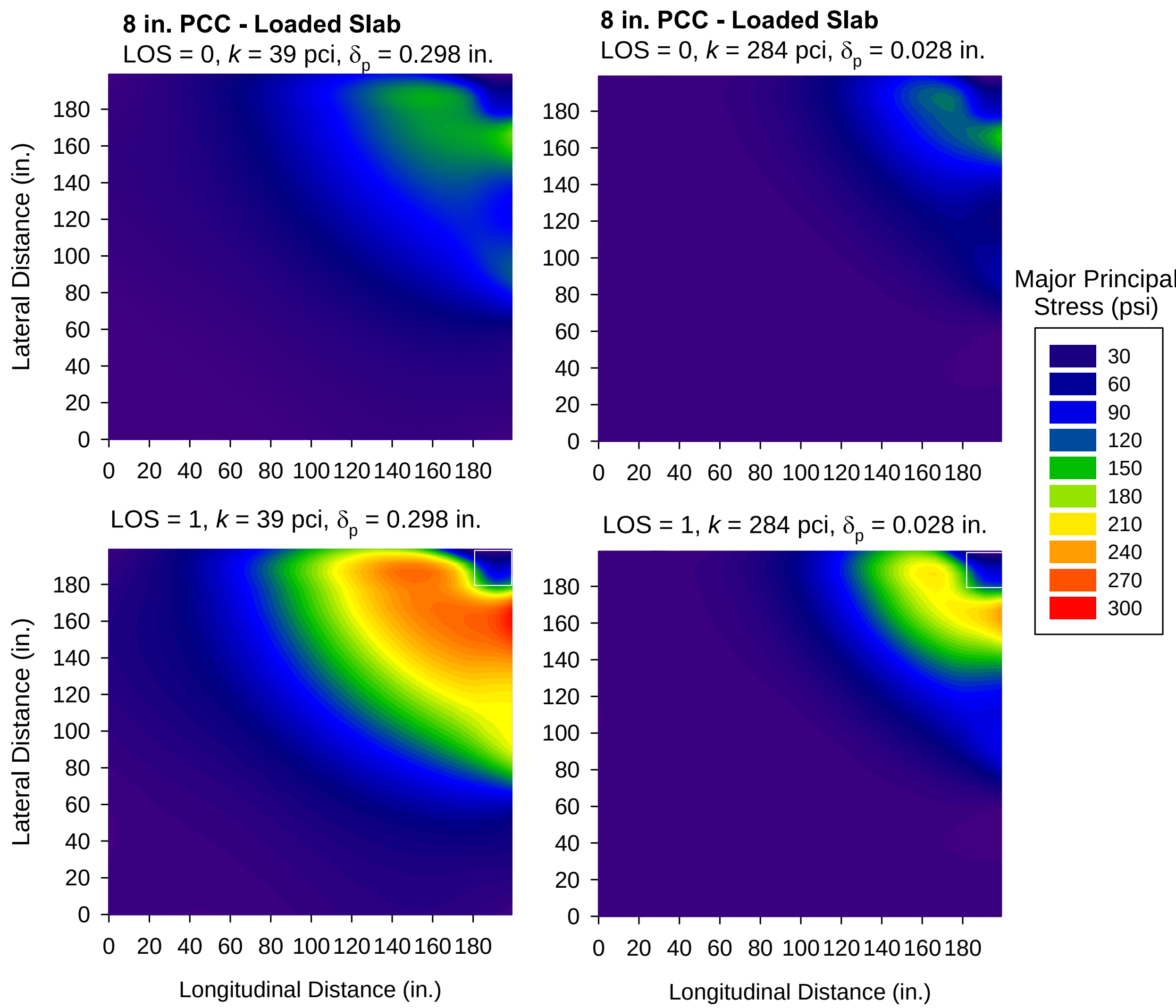


Figure 23. Spatial contour plots of major principal stresses in the pavement layer for k = 39 pci and δ_p = 0.298 in. (left) versus for k = 284 pci and δ_p = 0.028 in., for LOS = 0 and 1 cases.

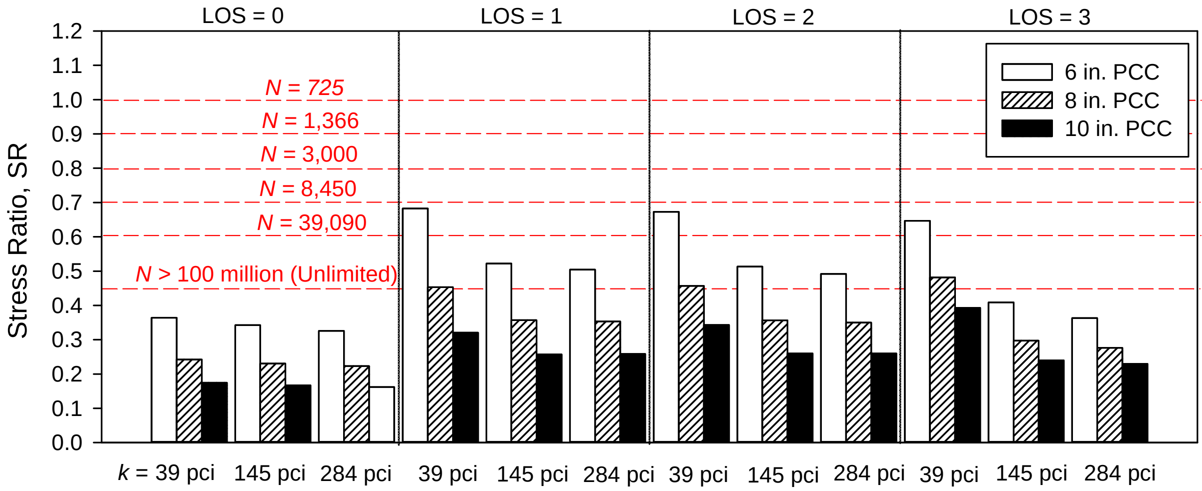


Figure 24. Bar charts of stress ratios for different support conditions (*k* and LOS) at three different pavement layer thicknesses.

The SR values calculated for 3 *k*-value and δ_p cases, 3 pavement thicknesses, and 4 LOS conditions (total 36 combinations) were analyzed using multivariate regression modelling. The objective was to assess the relatively influence of the four variables (*k*-value, δ_p, thickness, and LOS) on the calculated SR. The results of the multivariate analysis are summarized in Table 12 and the *k*-value and LOS variables were not found to be statistically significant, so they were removed from the model. The low significance of LOS here simply suggests there is no significant difference in LOS 1 versus 2 versus 3 for the cases evaluated, as can be seen in the bar charts in Figure 24. There is certainly a significant difference between LOS = 0 ($\delta_p = 0$) versus 1 ($\delta_p > 0$). The multivariate model with δ_p and thickness as statistically significant independent variables to predict SR yielded a strong relationship with R^2 of 0.86.

Table 12. Multivariate analysis to predict stress ratio (SR).

Parameter	Estimate	95% Confidence Interval	Standard Error	t-value	p-value	Fit Statistics
Constant	0.7584	0.6678 to 0.8490	0.0445	17.03	<0.0001	$R^2 = 0.860$ $R^2_{(Adj.)} = 0.851$ RMSE = 0.053
Pavement Thickness (in.)	-0.05777	-0.06873 to -0.04681	5.394E-03	-10.72	<0.0001	
d_p (in.)	0.6892	0.5390 to 0.8394	0.0738	9.34	<0.0001	
SR = 0.7584 – 0.0578 * Thickness + 0.6892 * δ_p						

Shapley value regression was conducted to determine the relative contribution of each statistically significant predictor/independent variable (δ_p and pavement thickness) on the predicted SR. The *Shapley value regression* procedure involves running a series of regressions in all possible combinations of the predictors against the dependent variable (including each predictor by itself, and each with pairs of others). Then the average contribution of the R^2 of the model of each predictor (all combinations) is computed (Lipovetsky and Conklin, 2001). The averaged contribution becomes the importance measure for each of the predictors.

Results of *Shapley value* regression showed that δ_p and thickness contribute to about 43% and 57%, respectively in predicting the SR value.

This analysis reveals that the two most significant measures that can be taken to reduce the bending stresses developed in the pavement layer are increasing pavement thickness and reducing the δ_p in the unbound foundation layers. Based on the results presented earlier in Figure 21, δ_p can potentially be reduced by increasing the stiffness of the unbound layers.

SUMMARY OF KEY FINDINGS

Summary

This report presents APLT field test results to develop mechanistic inputs (e.g., inputs to AASHTOWare Pavement ME Design) needed for selected Iowa pavement foundation layers. The experimental testing plan was developed in collaboration with the Iowa DOT pavement design and construction engineering team. A total of 10 project sites were selected that covered common unbound foundation layer cross-sections used in Iowa highways. Projects consisted of different subbase types (granular subbase and modified subbase, per Iowa DOT standard specifications), different subbase materials (crushed limestone and recycled concrete aggregate), and different subgrade types (select subgrade and embankment cut/fill subgrade). The goal at each site was to perform cyclic APLTs at 4 to 8 test locations using the 12 in. diameter loading plate and perform static APLTs to determine *k*-value at 1 to 2 test locations using the 30 in. diameter loading plate. A DCP test was conducted at each test location. LWD testing was also conducted on selected projects. Samples were collected for material characterization.

Cyclic APLTs were performed to determine stress-dependent composite M_r ($M_{r\text{-Comp}}$) and individual layered M_r values for subgrade ($M_{r\text{-SG}}$) and base/subbase ($M_{r\text{-Base}}$) layers. The M_r constitutive model parameters (k_1, k_2, and k_3) were then determined for both composite and individual layers and are presented herein as k^*_1, k^*_2, k^*_3, where "*" is used to indicate in situ and differentiate with regression coefficients traditionally developed from laboratory M_r test measurements.

Six of the ten projects (Projects 1 to 6) were tested in fall of 2017 and the remaining four (Projects 7 to 10) in spring of 2018, shortly after the spring-thaw. For Project 10 (testing conducted in May 2018), tests were conducted at/near the same locations as in Project 4 (testing conducted in November 2017), but the tests were conducted on top of the 6 in. granular subbase that was placed over the previously placed 2 ft of special backfill. Only special backfill and the subgrade was tested at Project 4. At Project 9, the test locations were too soft to access with the truck and trailer and therefore no tests performed with the APLT. Only DCP tests were conducted on Project 9 to document the conditions.

For each project site, an individual data report for each test location summarizing the $M_{r\text{-Comp}}$ and layered analysis results, the "universal" model parameter values, *k*-values from selected interpretation methods, and pictures are documented in Appendix C. In addition, summary statistics of average (μ), standard deviation (σ), and coefficient of variation (C_v) of the different parameters are summarized separately for each project.

Key Findings/Observations from In Situ Testing

- Typical values provided in the AASHTOWare Pavement ME Design™ guide based on soil classification can significantly under or overestimate the M_r values. Therefore, it is important to perform field measurements for verification of design input parameters.

- The cyclic APLTs showed that the M_r values on the unbound layers are variable across the state and within a given project site. The C_v at each site varied from 7% to 70%. For reference, a C_v of about 20% is typically considered a relatively uniform condition. Results from six out of the ten projects yielded C_v > 20%.
- The use of 2 ft of special backfill to improve subgrade in one of the project sites (Projects 4 and 10), provided higher M_r values than other projects, and the special backfill material layer (contained of RAP material) increased its stiffness between test periods.
- The modulus of subgrade reaction *k*-values obtained across the state varied between 35 pci to 300 pci. 11 out of the 14 tests performed across the state showed *k* values < 150 pci – the typically assumed (conservative) design input target value by Iowa DOT for PCA (1984) design. At one site (Project 7), two tests performed on the compacted modified subbase layer about 420 feet apart, showed *k*-values of 39 and 284 pci.
- The k_{comp} values obtained over granular subbase/modified subbase layers were on average lower than the *k*-values obtained directly on the underlying subgrade layer. This finding suggests that the subbase layers were relatively loose/uncompacted at the surface, which is also evidenced by the relatively high re-load to initial load *k-value* ratio (k_2/k_1). 6 out of 7 tests on subbase layers produced ratios > 3. For reference, Swedish specifications require the ratio of reload to initial moduli values to be < 2.8 for base/subbase layers within the top 0 to 10 inches as an indicator of compaction quality.
- Permanent or plastic deformations occurring from repeated traffic loading is a recognized cause of pavement distresses. δ_p was monitored and reported for the cyclic and static APLTs. The average δ_p from each site varied between 0.01 in. and 0.26 in., and the C_v at each site varied between 14% and 123%. δ_p values at the end of static APLTs show the values varied between 0.05 and 0.4 in. 11 out of the 14 static APLTs showed δ_p > 0.05 in., which is considered the critical limit to develop LOS beneath pavement.

Mechanistic Analysis of In Situ Results

The APLT results were utilized to perform mechanistic analysis of a rigid pavement system and assess the pavement performance characteristics. A few example cases are demonstrated in this report using Kenslabs 2D FE analysis. The main objective of the FE analysis was to assess the influence of *k*-value, LOS condition, and pavement thickness on the bending stresses in the pavement layer. The stress ratio (SR) values were calculated for each case as the ratio of the maximum principal stress in the pavement layer and the modulus of rupture of the concrete (assumed as 660 psi).

In the FE analysis, the foundation was modeled as a 'liquid' foundation using the *k*-values obtained from the static APLTs, and the δ_p measured at the end of the test was used to define a gap/void beneath near a jointed corner of the slab. The area of the gap/void was defined by the LOS factors defined in AASHTO (1986). The LOS factor = 1 corresponds to a void area of 1.59%; LOS factor = 2 corresponds to a void area of 4.59%; and LOS factor = 3 corresponds to a void area of 8.16%, of the area of the slab. The AASHTO standard 18-kip single axle dual wheel set highway loading at the jointed corner was used in the analysis. Low, medium, and high *k* values were selected based on the field test results along with the corresponding δ_p values from those test locations. Three different pavement thickness cases were evaluated (6 in., 8 in., and 10 in.).

FE analysis results showed that there were no significant differences in the bending stresses between the low and high *k-value* cases for LOS = 0 condition, but there are significant differences when LOS = 0 versus 1 cases are compared. For the LOS = 1 cases, the peak stresses occurred in a distribution corresponding to a typical corner break observed in distressed concrete pavements. For LOS = 0 condition, the SR values are < 0.45 for all three thicknesses evaluated and *k*-values evaluated. For LOS = 1 and 2 conditions, the SR values increased and the associated number of allowable load repetitions per PCA (1984) are decreased, with no significant differences between LOS 1 versus 2 conditions. The SR's were either similar or lower for LOS 3 compared to LOS 2 condition.

Statistical regression analysis of SR results from FE analysis revealed that the two most significant measures that can be taken to reduce the bending stresses developed in the pavement layer are increasing pavement thickness and reducing the δ_p in the unbound foundation layers. *k*-value was not a statistically significant parameter in estimating SR value. Field test results showed that δ_p is strongly correlated to *k*-value and increasing stiffness reduces δ_p.

This analysis demonstrates that during pavement design, simply changing the *k*-value without accounting for LOS that can potentially occur due to plastic deformations under repeated loading, the calculated bending stresses can be misleading.

RECOMMENDATIONS

AASHTOWare Pavement ME State-Wide Calibration

The Iowa DOT is currently either performing or in the process of considering state-wide calibration for AASHTOWare Pavement ME Design™ input parameters. AASHTO (2010) provides guidance on how to perform this calibration work, with the primary objectives of reducing bias and increasing precision of the empirical models used in the design software for predicting performance indicators (i.e., distresses, ride quality). The end-result of this process is developing local calibration-based regression factors that can be updated in the design software. The AASHTO guide document details an approach consisting of 10 steps for the local calibration process. Detailed procedures for developing an experimental plan, estimating the sample size, selecting the roadway segments, collecting the required field data, and assessing bias/standard error in the global calibration factors for local conditions, are discussed in the AASHTO (2010) guide document.

"Step 6" of the calibration procedure involves conducting field and forensic investigations to confirm or obtain any missing key input parameter values for the roadway segment selected. As a part of this step, foundation layer properties are typically either characterized by obtaining laboratory test measurements on reconstituted samples or use surrogate field-testing methods such as DCP or FWD testing. Laboratory testing on reconstituted samples has significant limitations as discussed earlier in the report. Although surrogate tests are convenient and can be useful in assessing relative differences between sites, they present significant uncertainty with the estimated values. Field APLTs overcome the limitations of laboratory and surrogate field-testing methods and provide an accurate measure of the foundation layer mechanistic properties.

When considering future field test sites for local calibration, consideration should be given to the type of surface distress, pavement type and thickness, and subgrade soil type as primary factors. Secondary factors are climate, traffic, and other pavement type dependent design features that are unique to the Iowa. After selecting the different factors, a factorial matrix is developed and at least two replicate sites for each condition are selected (AASHTO, 2010). Iowa DOT maintains a database of state-wide FWD testing results tied with pavement performance data, which can be a useful resource in selecting the key project sites and specific locations on a given site. We recommend the Iowa DOT test sites with alternative foundation layers (e.g., various stabilization materials such as at Central Iowa Expo test sections in Boone, IA) during the site selection process. The Expo test sections include foundation layers with different mechanical and chemical stabilization methods.

Results from the field project sites documented in this report represent the as-constructed mechanistic properties of the unbound foundation layers that are geo-referenced with GPS measurements along with a measure of variability at each site. Based on tests performed on top of the subbase layer, the M_r values varied between 16 ksi and 50 ksi with a coefficient of variation of 7% to 70% at each site, and the composite *k* values varied between 39 pci and 284 pci. Such an invaluable dataset of foundation properties does not currently exist at any of the long-term pavement performance (LTPP) sites across the United States. This presents a unique opportunity for the Iowa DOT to consider these sites (specifically the georeferenced areas that have been tested) for long-term performance monitoring. Tying the as-constructed foundation layer mechanistic properties and the long-term performance measurements will refine the local calibration factors used in pavement design (e.g., AASHTOWare software).

This report also highlights the importance of quantifying permanent deformations, which must be included as part of future calibration efforts. Virtually no field data exists from decades of pavement system monitoring in the U.S. to quantify permanent deformation – without which limited design improvements can be expected. Given the range of geomaterials used in pavement foundation layers (e.g., recycled materials, stabilized material, and geosynthetics), it is essential to characterize the in situ resilient modulus and permanent deformation behavior in terms of material index properties, moisture content, and stress-dependency.

Design Input Parameter Selection and Field Verification

This study revealed that unbound layer material M_r values are highly variable across the state and often over a given project site. The reasons can be attributed to many factors including, but not limited to poor compaction control and natural variability in the underlying subgrade layers. Many of the test sites showed lower *k-values* than the assumed 150 pci in the rigid pavement design by Iowa DOT. This emphasizes the importance of better characterization procedures to select appropriate design input parameters and the importance of field verifying pavement design values during construction.

Selection of appropriate design input parameters should be based on project specific materials and conditions considering the variability and potential post-construction changes in saturation. For rehabilitation design projects, foundation layers can be tested directly to determine in situ *k* or M_r values. The variability aspect can be addressed by determining the mean (μ) and standard deviation (σ) of the data and calculating the target value as equivalent to $\mu - 2\sigma$. The moisture aspect must be addressed, especially if field tests are conducted when material is relatively dry. Moisture corrections can be performed via laboratory M_r testing on a given material type at different moisture contents and determining the correction factors for the design moisture content. Alternatively, empirical procedures established based on local historical data or some provided in the AASHTOWare ME design guide can be utilized.

Field verification of M_r values reduces risk of not meeting the design the pavement design performance criteria and increase quality, thus helping to insure long-term performance. A field quality assurance (QA) protocol and specifications that requires measurement and reporting of in situ M_r values is recommended. The specification should address the test frequency (1 every 500 to 1,000 feet, depending on in situ conditions) required for QA. Specification options with reduced QA testing frequency with implementation of intelligent compaction technologies should also be considered.

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APPENDIX A: FIELD TESTING AND DATA ANALYSIS METHODS

Dynamic Cone Penetrometer (DCP)

DCP tests were performed in accordance with ASTM D6951-03 (2007). The tests involved dropping a 17.6 lb. hammer from a height of 22.6 in. and measuring the resulting penetration depth. A 30-in. penetrating rod was used. California bearing ratio (CBR) values were determined using Eqs. (1) and (2), whichever is appropriate, where the dynamic penetration index (DPI) is in units of mm/blow.

$$CBR(\%) = \frac{292}{DPI^{1.12}} \text{ for all materials except CL soils with CBR <10} \tag{1}$$

$$CBR(\%) = 1/(0.017019 \times DPI)^2 \text{ for CL soils with CBR <10} \tag{2}$$

The DCP test results were used to determine an average CBR of a given layer or for a given depth. The average values of the top and bottom layer were reported by calculating the DPI value based on the total number of blows taken from the top of the layer to the bottom of the layer or to a desired depth within the layer.

Automated Plate Load Testing (APLT)

Cyclic and static APLTs were conducted for this project. Static APLTs were conducted in general accordance with AASHTO T222 (2012) and some deviations from the test standard are provided below. Cyclic APLTs were conducted following a test procedure included in Appendix C.

In Situ Composite Resilient Modulus

Cyclic APLT using a 12-in. diameter loading plate was conducted to determine in situ composite resilient modulus ($M_{r\text{-}Comp}$) at six different stress levels. The $M_{r\text{-}Comp}$ was calculated as the ratio of the cyclic stress divided by the resilient deflection (during unloading) using the Boussinesq's half-space equation:

$$M_{r-Comp} = \frac{(1-\eta^2)\Delta\sigma_{cyclic} r}{\delta_r} \times F \tag{3}$$

where: $M_{r\text{-}Comp}$ = in situ composite resilient modulus (psi), δ_r = the resilient deflection of plate during the unloading portion of the cycle (determined as the average of three measurements along the plate edge), η = Poisson's ratio (assumed as 0.4), $\Delta\sigma_{cyclic}$ = cyclic applied stress (psi), r = radius of the plate (in.), F = shape factor depending on stress distribution (assumed as 8/3 for granular materials and π/2 for cohesive materials). Using the criteria of 1 to 1.5 times the plate diameter for measurement influence depth, the $M_{r\text{-}Comp}$ values have an influence depth of about 1 to 1.5 ft.

The M_r parameter is a stress-dependent parameter, and most soils exhibit the effects of increasing stiffness with increasing bulk stress and decreasing stiffness with increasing shear stress. The APLT testing program was designed to assess the in situ composite resilient modulus at six different stress levels. The results were used to model the behavior using the "universal" model (1) shown in Eq. (4):

$$M_r = k_1^* P_a \left(\frac{\theta}{P_a}\right)^{k_2^*} \left(\frac{\tau_{oct}}{P_a} + 1\right)^{k_3^*} \tag{4}$$

where, M_r = in situ resilient modulus (psi); P_a = atmospheric pressure (psi); θ = bulk stress (psi) = $\sigma_1 + \sigma_2 + \sigma_3$; σ_1 = applied cyclic stress ($\Delta\sigma_{cyclic}$) used in $M_{r\text{-}comp}$ calculations because there is no confining stress at the surface; $\sigma_2 = K_o\,\sigma_1$; $\sigma_3 = \sigma_2$, K_o = coefficient of lateral earth pressure at rest = $\eta/(1\text{-}\eta)$; η = Poisson's ratio assumed as 0.4; τ_{oct} = octahedral shear stress (psi) = $\sqrt{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2}\;/3$; and k_1^*, k_2^*, and k_3^*= regression coefficients determined from in situ testing (these coefficients are presented herein with a * to differentiate with the regression coefficients traditionally developed using laboratory test results).

Layered Resilient Modulus

Individual subbase and subgrade layer resilient modulus values ($M_{r\text{-}Base}$ and $M_{r\text{-}SG}$) were determined based on deflection basin measurements. Two-layered analysis was performed on the data using Odemark's method of equivalent thickness (MET) concept and the deflection basin results, as described in Ullidtz (*8*). The deflection basin measurement method and the data analysis is explained in detail in White et al. (*5*). The $M_{r\text{-}SG}$ and $M_{r\text{-}Base}$ values were calculated at different applied stress levels from layered analysis to assess the stress-dependent behavior independently for each layer. Similar to $M_{r\text{-}Comp}$ values, the calculated $M_{r\text{-}SG}$ and $M_{r\text{-}Base}$ values were used to model the behavior using the "universal" model (*1*) shown in Eq. (2). In modeling $M_{r\text{-}Base}$ behavior, the bulk stress (θ) values are the same as the σ_{cyclic} stress applied at the surface. In case of $M_{r\text{-}SG}$, the θ values were calculated using the following steps:

1. The applied cyclic stress at the base/subgrade interface was calculated using the KENLAYER layered elastic analysis program. The interface stresses are a function $M_{r\text{-}Base}/M_{r\text{-}SG}$ ratio, thickness of the base layer, radius of the plate, and the applied cyclic stress at the surface (*9*). The stresses were calculated at the plate center.
2. The applied vertical stress (σ_1) is calculated by adding the calculated cyclic stress at the interface and confining stress due to the aggregate layer over the subgrade (~0.5 psi).
3. The horizontal stresses (σ_2 and σ_3) were calculated as $\sigma_3 = \sigma_2 = K_o\,\sigma_1$, where $K_o = v/(1\text{-}v)$ and v = 0.35 for subgrade.

4. The bulk stress (θ) values were calculated as the sum of σ_1, σ_2, and σ_3.

The analysis approach described above assumes a flexible loading plate with uniform stress distribution at the surface and the assumption that both subgrade and subbase layers are linear elastic with homogenous conditions. The calculated stress values at the interface should therefore be considered approximate.

Modulus of Subgrade Reaction

Static plate load tests were conducted in general accordance with the AASHTO standard for nonrepetitive loading using static plate load test (AASHTO T222, 2012) to determine *k* value using a 30-in. diameter loading plate setup. A thin layer of fine silica sand was used as a bedding material for all tests. Using the criteria of 1 to 1.5 times the plate diameter for measurement influence depth, the *k* values determined using the 30-in. diameter loading plate have an influence depth of about 2.5 to 3.8 ft.

The test standard requires increasing applied stresses up to 30 psi in 5 psi increments. In this study, applied stresses were increased up to a maximum of at least 15 psi in 2.5 psi increments. The test was performed for two loading cycles. Plate deformations were measured at three locations along the edge of the plate. The uncorrected *k* value was determined using Eq. 5.

$$k_u^{'} = \frac{10 psi}{\delta} \quad (5)$$

where, k'_u = uncorrected modulus of subgrade reaction (pci), δ = deformation corresponding to the 10-psi loading increment (inches). In this study, a plot of applied stress on x-axis and average plate deflection on y-axis is prepared for the two loading cycles. Then a second order polynomial curve is fit separately for both first and second loading cycles, using model shown in Eq. 6:

$$y = a_1 x^2 + a_2 x + a_3 \quad (6)$$

where, y = deflection in inches; x = applied stress in psi; a_1, a_2, and a_3 = regression coefficients. To assess the quality of the regression fit, the coefficient of determination (R^2) value is determined. A minimum R^2 value of 0.98 has been established as required to achieve acceptable results.

Using the second order polynomial fit parameters the average plate deflections corresponding to a target applied stress (σ) are computed using Eqs. (7) and (8) for the first and second load cycles, respectively:

$$\delta_i = a_1 \sigma^2 + a_2 \sigma \quad \text{for 1st loading cycle} \quad (7)$$

$$\delta_r = a_1\sigma^2 + a_2\sigma \quad \text{for 2nd loading cycle} \tag{8}$$

In this study a target applied stress of σ = 10 psi has been used. The k'_u values calculated for 1st and 2nd loading cycles are reported as $k'_{u(1)}$ and $k'_{u(2)}$, respectively. The k'_u values were then corrected for plate bending to determine k_u following the procedure described in AASHTO T222 and Eq. 9 for $k'_u \geq 100$ pci and ≤ 1000 pci.

$$k_u = -39.9178 + 5.5076 \times \left[k'_u\right]^{0.7019} \tag{9}$$

The k_u values calculated for 1st and 2nd loading cycles are reported as $k_{u(1)}$ and $k_{u(2)}$, respectively. The k values were also calculated per PCA (1984) design method, which requires determining the k value using applied stresses at 0.05 in. deformation (Eq. 10):

$$k'_u = \frac{\sigma_{\delta=0.05in.}}{0.05} \tag{10}$$

These values were also corrected for plate bending using Eq. (9) and are presented herein as k_u at δ = 0.05 in.

Light Weight Deflectometer (LWD) Test

LWD tests were conducted using Zorn LWD setup with 11.8 in. diameter plate and 28 in. drop height. The tests were performed following manufacturer recommendations (Zorn 2003) and the elastic modulus values were determined using Equation 11:

$$\mathrm{E} = \frac{(1-\eta^2)\sigma_0 \mathrm{r}}{\mathrm{D}_0} \times \mathrm{F} \tag{11}$$

where E or E_{LWD} = elastic modulus (psi), D_0 = peak plate deformation under loading (in.), η = Poisson's ratio (0.4), σ_0 = applied stress (psi), r = radius of the plate (in.), F = shape factor depending on stress distribution (assumed as 8/3 for granular materials and $\pi/2$ for cohesive materials).

APPENDIX B: CYCLIC AUTOMATED PLATE LOAD TESTING METHOD

Standard Method of Test for

In Situ Determination of Resilient Modulus and Permanent Deformation from Cyclic Plate Load Testing for Pavement Foundations

1 SCOPE

1.1 This test method covers a procedure for performing cyclic plate load tests in situ to determine resilient modulus (Mr) of pavement base, subbase, and subgrade layers, in either the compacted condition or the natural state, and is to provide data for use in the evaluation and design of rigid and flexible-type airport and highway pavements.

1.2 The value of resilient modulus determined from this procedure is a measure of the elastic modulus of base, subbase, and subgrade soils recognizing certain nonlinear characteristics.

1.3 Resilient modulus values can be used with structural response analysis models to calculate the pavement structural response to vertical stresses imposed from wheel loads, and with pavement design procedures to design pavement structures.

1.4 The values given in Customary Units are to be regarded as the standard. The values given in parentheses (SI Units if provided) are not standard and may not be exact mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard.

2 REFERENCED DOCUMENTS

2.1 *AASHTO Standards:*

- T 307-99, Determining the Resilient Modulus of Soils and Aggregate Materials
- T 221-90, Repetitive Static Plate Load Tests of Soils and Flexible Pavement Components for Use in Evaluation and Design of Airport and Highway Pavements
- T 222-81, Nonrepetitive Static Plate Load Test of Soils and Flexible Pavement Components for Use in Evaluation and Design of Airport and Highway Pavements

2.2 *ASTM Standards:*

- D4602-93, Nondestructive Testing of Pavements Using Cyclic-Loading Dynamic Deflection Equipment.
- D4695-03, General Pavement Deflection Measurements.
- D5858-96, Calculating In Situ Equivalent Elastic Moduli of Pavement Materials Using Layered Elastic Theory.

2.3 *Other:*

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3 DEFINITIONS

3.1 *Rebound/Resilient deformation*—the amount of vertical rebound of a material surface that occurs when an external load is removed (unloaded) from the material surface.

3.2 *Permanent deformation*—the amount of irrecoverable or plastic deformation of the material surface that occurs when an external load is removed (unloaded) from the material surface.

3.3 *Resilient modulus*—is the measure of materials' modulus of elasticity determined using the applied cyclic stress on the loading plate and the corresponding resilient/rebound deflections.

3.4 *Haversine-shaped load form*—the required load pulse form.

3.5 *Maximum applied axial load* (P_{max})—The total axial load applied on the loading plate including the contact load and the cyclic loads.

3.6 *Cyclic load* (P_{cyclic})—Cyclic applied axial load.

3.7 *Contact load* ($P_{contact}$)—vertical load applied on the loading plate to maintain a positive contact between the loading plate and the testing material surface.

3.8 *Maximum applied axial stress* (σ_{max})—The total axial stress applied on the loading plate including the contact stress and the cyclic stress, calculated as the ratio of P_{max} and contact area of the loading plate (A).

3.9 *Cyclic stress* ($\Delta\sigma_{cyclic}$)—Cyclic applied axial stress, calculated as the ratio of P_{cyclic} and contact area of the loading plate (A).

3.10 *Contact Stress* ($\sigma_{contact}$)—Axial stress on the test surface to maintain a positive contact between the loading plate and the test surface, calculated as the ratio of $P_{contact}$ and contact area of the loading plate (A).

3.11 *Deflection basin*— The bowl shape of the deformed surface due to a specified load as depicted from the rebound/resilient deflection measurements of a series of deflection sensors placed at radial offsets from the center of the load plate.

3.12 *Deflection sensor*— Electronic device(s) capable of measuring the relative vertical movement of a loading plate surface and mounted in such a manner to a reference beam as to minimize angular rotation with respect to its measuring plane at the expected movement.

3.13 *Load cell*— Capable of accurately measuring the load that is applied perpendicular to load plate.

3.14 Load duration is the time interval the specimen is subjected to cyclic stress.

3.15 Cycle duration is the time interval between the successive applications of a cyclic stress.

4 APPARATUS

4.1 Loading device, such as a truck, trailer, tractor-trailer, an anchored frame, or other structure loaded with the minimum reaction load to produce the desired reaction on the surface under test. The supporting points (wheels, in the case of a truck or trailer or outriggers in case of other construction vehicles) should be at least 8 ft. (2.4 m) from the circumference of the largest diameter bearing plate being used.

4.2 *Bearing plates*—Set of circular steel bearing plates, not less than 1 in. (25.4 mm) in thickness, machined so they can be arranged in pyramid fashion to ensure rigidity, with diameters ranging from 6–30 in. (152–762 mm).

Note 1— Plate size selection will be dependent on the pavement design, materials, and layer thicknesses.

4.3 *Loading device*:

4.3.1 The loading device shall be a top-loading, closed loop, electrohydraulic or electropneumatic testing machine with a function generator which is capable of applying repeated cycles of haversine-type load pulse with a minimum load duration of 0.2 sec and minimum rest period of 0.8 sec.

4.3.2 The haversine load pulse shall confirm to Section 3.4. All preconditioning and testing shall be conducted using a haversine-shaped load pulse. The system-generated haversine waveform and the response waveform shall be displayed to allow the operator to adjust he gains to ensure that they coincide during preconditioning and testing.

4.3.3 The axial load measuring device should be an electronic load cell located between the loading actuator and the loading plate.

4.3.4 The load measurements shall be displayed and stored with a resolution of 50lbf (200 N) or less.

4.3.5 The load cell readings shall be read and reviewed during the test to confirm haversine waveform.

4.4 *Deflection Measurements*:

4.4.1 Axial deflection measurements shall be obtained at three locations on the plate at equidistance apart in a triangular pattern near the edge of the plate. The deflection measurement devices shall be capable of measuring the full deflection response of the plate during haversine loading such that the peak, resilient, and permanent deformations can be determined for each load cycle.

4.4.2 For tests where layered backcalculation analysis is required, a deflection basin should be obtained at pre-determined distances away from the center of the loading plate. At a minimum, deflection measurements should be obtained at three locations away from the plate center (e.g., 2r, 3r, and 4r (where r is the radius of the loading plate)).

4.4.3 The axial deflection measurements for plate and deflection basin shall be displayed and stored with a resolution of 0.08 mils (2 μm) or less.

4.4.4 All axial deflection sensors shall be wired such that each sensor readings can be read and reviewed independently, and the results averaged (for plate deformation) for calculation purposes.

4.4.5 Deflection reference beam for mounting the displacement devices. The assembly can be constructed from a 2.5 in. (63.5 mm) diameter standard metal pipe, a 3 × 3 × 1/4 in. (76 × 76 × 6 mm) steel angle, or equivalent that rest upon supports set away from the edge of the bearing plate per the requirements of Table 1. The reference beam should provide sufficient weight so that wind does not disturb the displacement measurement.

Table 1. Recommended minimum reference beam lengths for support

Plate Diameter	Distance for reference beam support away from edge of plate
18 in. (457 mm)	5 ft. (1.5 m)
12 in. (305 mm)	4 ft. (1.2 m)

4.5 Suitable signal excitation, conditioning, and recording equipment are required for simultaneous recording of axial load and deformations. The signal shall be clean and free of noise. Use shielded cables for connections. If a filter is used, it shall have a frequency that cannot attenuate the signal. Each of the deflection sensor shall be wired separately so that the signal of each sensor can be monitored independently. A minimum of 1,000 data points from each sensor shall be recorded per load cycle.

4.6 Data Acquisition System and Storage:

4.6.1 The load and deflection data obtained for each loading cycle shall be recorded and saved on personal computer.

4.6.2 The data acquisition system shall be capable of determining and displaying the resilient and permanent deflections for each sensor, and the maximum and cyclic load, separately for each loading cycle, in real-time.

4.6.3 The data acquisition system shall be capable of determining and displaying the M_r value for each loading cycle in real-time.

4.6.4 The testing will involve performing cyclic tests at different cyclic stress levels in sequences. The data acquisition system shall be capable of determining and displaying the average M_r value of the last 5 cycles for each loading sequence, representing the average M_r value for that loading sequence.

4.7 Calibration and Periodic Checks:

4.7.1 The load cell readings should be checked once every two weeks, or after every 50 tests, whichever comes first, using a calibrated proving ring or a calibrated load cell to assure that the load cell is operating properly.

4.7.2 The response of the deflection sensors shall be checked once every two weeks, or after every 50 tests, whichever comes first, using a set of machined gauge blocks or using a micrometer with compatible resolution.

4.8 *Data Quality Control*:

4.8.1 *Plate Rotation:* Due to the non-homogeneity of material in situ, the plate deformation may not always be uniform across the contact area. Excessive non-uniform deformation of the plate could result in erroneous results, and therefore should be checked and controlled during testing. This can be done by measuring the angle of rotation of the plate using Eq. 1:

$$\theta = cos^{-1}\left[\frac{\frac{3}{2}r}{\sqrt{\delta_1^2+\delta_2^2+\delta_3^2-\delta_1\delta_2-\delta_1\delta_3-\delta_2\delta_3+\frac{9}{4}r^2}}\right] \qquad (1)$$

where, r = plate radius in inches (mm), δ_i= resilient deformation of i[th] sensor (i = 1, 2, and 3) in inches (mm), θ = angle of rotation in degrees. If the angle is greater than 0.3 degrees, the test results should be examined for the influence of non-uniform plate displacement by plotting the individual displacement device results to determine if the results are valid. The ground conditions should also then be examined and excavated under the plate area to determine if non-uniform support conditions (e.g., buried rock) exist and require re-testing at a new location.

4.8.2 *Signal-to-Noise Ratio (SNR):* Noise from measurement devices, such as load and deflection sensors, affects data quality, especially when the measured values are small. SNR is used to control noise effects on the results. SNR is calculated from time history data of each load and displacement measurement using Eq. 2:

$$SNR = \frac{Peak}{3\times SDev(Baseline)} \qquad (2)$$

where, *Peak* = peak values of load or deflection from time history data, and *SDev(Baseline)* = standard deviation of the baseline values calculated using Eq. 3:

$$SDev = \sqrt{\frac{\sum_0^N(Y(n)-\mu^2)}{N-1}} \qquad (3)$$

where, μ = mean of the baseline values, Y(n) = value at point n, and N = total data points. The SNR for each deflection sensor should be ≥ 3 and load cell should be ≥ 10.

4.9 Miscellaneous tools, including a carpenter's square, a level to check grade, jacking column, and plate, and trowel for preparing bedding material for the plate placement.

5 PROCEDURE

5.1 Close off the entire testing area from vehicular or construction equipment for the entire testing period. Coordinate any other safety issues that would impact the testing procedure and safety of the testers.

5.2 Follow the procedure described below for surface preparation for confined and unconfined tests.

5.3 For confined plate load tests on existing pavement structures, the diameter of the excavated/ cored circular area shall be just sufficient to accommodate the selected bearing plate.

5.4 For unconfined plate load tests on existing pavement structures, remove the surrounding material to provide a clearance equal to at least twice the bearing plate diameter from the edge of the bearing plate to eliminate surcharge effects.

5.5 Carefully center a bearing plate of the selected diameter under the loading actuator assembly, so the center loading plate is in line with center of the actuator.

Note 2-- The selected plate diameter should ideally be based on what may be considered as the most critical combination of conditions of wheel load and tire pressure. A 12 in. (305 mm) or an 18 in. (457 mm) diameter plate should be sufficient for flexible pavement applications. For testing foundation layers under rigid pavement, a larger plate size such as 30 in. (762 mm) diameter plate is needed. As an alternative to using 30 in. diameter plate, a procedure with 12 in. or 18 in. diameter plate along with deflection basin measurements is provided in this standard to obtain backcalucated layered elastic moduli values.

5.5.1 Set the bearing plate parallel to the testing surface on a thin layer of fine sand, using the least quantity of materials required for uniform bearing (not to exceed ¼ in. thickness). Turning or working the plate back and forth will help to provide uniform seating of the plate.

5.5.2 Set the remaining plates of smaller diameter concentric with and on top of the bearing plate. Ensure that all plates are in complete contact with the adjacent plates.

5.6 Place the load cell between the actuator and the loading plate, near the center of the loading plate.

5.7 Setup the reference beam so that the deflection sensors are positioned equidistant apart in a triangular pattern, and are measuring the deflection near the edge of the loading plate. Ensure that the deflection measurement sensors are positioned to allow measurement of at least 0.5 in. (12.5 mm) of vertical movement.

5.8 If deflection basin measurements are required, the deflection sensors at the pre-determined radial distance away from the load center should be positioned so that they are in good contact with the testing surface and is independent of the loading device. The deflection sensors can be connected to the reference beam. Ensure that the deflection measurement sensors used for deflection basin away from the plate center are positioned to allow measurement of at least 0.2 in. (5 mm) of vertical movement.

5.9 Apply loading in accordance with the testing sequence shown in Table 2.

Note 3-- The load values corresponding to the contact stress to be maintained must include the self-weight of the loading plate. For e.g., if the plate assembly weights about 50 lbf (220 N) which equals to a stress of about 0.44 psi (3 kPa), the additional stress to be applied to maintain the 2 psi (13.8 kPa) contact stress is 1.56 psi (10.8 kPa).

Table 2. Testing sequence for base/subbase layer at surface

Sequence	Cycles	Load Time (sec)	Dwell Time (sec)	Cyclic Stress [$\Delta\sigma_{cyclic}$]		Contact Stress [$\sigma_{contact}$] (psi)		Maximum Axial Stress [σ_{Max}] (psi)	
				psi	kPa	psi	kPa	psi	kPa
Conditioning	500-1000	0.2	0.8	13.0	89.6	2.0	13.8	15	103.4
1	100	0.2	0.8	4.0	27.6	2.0	13.8	6	41.4
2	100	0.2	0.8	8.0	55.2	2.0	13.8	10	69.0
3	100	0.2	0.8	13.0	89.6	2.0	13.8	15	103.4
4	100-150	0.2	0.8	18.0	124.1	2.0	13.8	20	137.9
5	100-200	0.2	0.8	28.0	193.1	2.0	13.8	30	206.9
6	100-250	0.2	0.8	38.0	262.0	2.0	13.8	40	275.8

5.9.1 *Conditioning* – Begin the test by applying a minimum 500 repetitions of load equivalent to a maximum axial stress of 15 psi (103.4 kPa) and corresponding cyclic stress of 13 psi (89.6 kPa) using a haversine-shaped load pulse with a load duration time of 0.2 sec and a dwell time of 0.8 sec. The conditioning sequence aids in minimizing the effects of any initial imperfect contacts between the loading plate and the testing surface. If the M_r values are not relatively constant (i.e., increasing or decreasing with loading cycles) or if the permanent deformations are continuing to increase at the end of 500 cycles, then the number of conditioning cycles may be increased to 1,000 cycles.

5.9.2 *Loading Sequences* – The are six loading sequences are shown in Table 2 which include a maximum axial stress increased from about 6 psi to 40 psi and a cyclic stress increased from about 4 psi to 48 psi. A minimum 100 repetitions are recommended for each loading sequence. At higher stress levels (≥20 psi), it is not uncommon to see that permanent deformations continue to increase at the end of 100 loading cycles. In such cases, higher than 100 repetitions are suggested.

5.9.3 Record and report the average rebound/resilient deflections and permanent deformations from the three deflection sensors on the loading plate and rebound/resilient deflections at each radial location away from the loading plate, for each loading cycle.

6 DATA ANALYSIS

6.1 *Determination of Composite Resilient Modulus:*

6.1.1 The in situ composite M_r is calculated as the ratio of the cyclic axial stress divided by the resilient deflection using the Boussinesq's half-space equation:

$$M_{r-Comp} = \frac{(1-\upsilon^2)\cdot\Delta\sigma_{cyclic}\cdot r}{\delta_r} \times f \tag{3}$$

where, $M_{r\text{-}Comp}$ = in situ composite resilient modulus (uncorrected) in psi (kPa); δ_r = the resilient deflection of plate during the unloading portion of the cycle (determined as the average of three measurements along the plate edge, i.e., at a radial distance *r* from plate center) in inches (mm); ν = Poisson ratio; $\Delta\sigma_{cyclic}$ = cyclic stress in psi (kPa); *r* = radius of the loading plate in inches (mm); and *f* = shape factor.

Note 4--The *f* value depends on the anticipated stress distribution beneath the plate and is a function of the rigidity of the loading plate and the material that is in contact with the plate. The stress distributions beneath the loading plate can vary from uniform (f = 2) to parabolic (f = 8/3) to inverse parabolic ($f = \pi/2$). A rigid plate resting on cohesive clayey material produces an inverse parabolic shaped stress distribution and on cohesionless material produces a parabolic distribution. A rigid plate resting on an intermediate plate produces a stress distribution that is in between inverse parabolic and uniform ($f = \pi/2$ to 2).

6.1.2 The average $\Delta\sigma_{cyclic}$ and δ_r of the last five cycles of each loading sequence are used in $M_{r\text{-}Comp}$ calculation.

6.1.3 There is certain amount of bending in the bearing plates, even when a nest of plates is used. The bending effect can be reduced using stiffened plates.

6.1.4 The in situ $M_{r\text{-}Comp}$ obtained from the procedure above will be representative of the moisture conditions at the time of testing. If the material gets saturated in the future, particularly the underling subgrade material, $M_{r\text{-}Comp}$ value will be decreased. It is not feasible to saturate the soil in the field prior to the field test. Therefore, if a value representative of saturated condition is desired in the design, the $M_{r\text{-}Comp}$ value determined from Eq. (3) must be corrected. Saturation correction is not normally required when evaluating pavements older than three years. Cohesionless soils are insensitive to saturation, and when the field test is performed on such soils, the correction for saturation is not necessary. The most applicable method for correcting for saturation is through an adaptation of the consolidation test on undisturbed samples obtained from the subgrade layer. The procedure for this correction is explained in AASHTO T222-81.

6.2 *Layered Backcalculation Analysis:*

6.2.1 Individual subgrade and base layer resilient modulus values were determined using the deflection basin measurements. The following simple backcalculation procedure based on the Odemark's method of equivalent thickness (MET) is suggested. The method idealizes the structure into a two layered structure with a relatively stiff base/subbase layer over a relatively weaker subgrade layer.

6.2.2 First, determine the underlying subgrade layer resilient modulus (M_{r2}) using Eq. 4:

$$M_{r2} = \frac{(1-\upsilon_2^2)\cdot P_{cyclic}}{\pi \cdot r' \cdot \delta_{r,r'}} \tag{4}$$

where, P_{cylic} = cyclic load in lbf (kN); $\delta_{r,r'}$ is the resilient deflection in inches (mm) during the unloading portion of the cycle at $r' = 2r$ or $3r$ or $4r$ away from plate center; and v_2 = Poisson's ratio of the underlying subgrade layer. The r' must be far enough away that it provides a good estimate of the subgrade modulus, independent of the effects of any layers above, but also close enough that it does not result in a too small value. If the moduli values are plotted against radial distance r', in linear elastic materials such as sands and gravels, the modulus values decrease with increasing distance and then level off after a certain distance. The distance at which the modulus values level off can be used as r' in Eq. 4. In some cases the modulus values decrease and then increase with distance. Such conditions represent either soils with moderate to high moduli with poor drainage at the top of the subgrade or soft soils with low moduli. In those cases, the distance where the modulus is low can be used as r' in Eq. 4.

6.2.3 The formulation for using the MET method to determine the top layer resilient moduli (M_{r1}) is shown in Eq. 5, which can be iteratively solved by changing M_{r1} by minimizing the difference between the left and right hand sides of the equation:

$$\delta_r = (1-\upsilon_1^2)\cdot \Delta\sigma_{\text{cyclic}} \cdot r \cdot f \left[\frac{1}{M_{r1}\sqrt{1+\left(\frac{h}{r}\times\sqrt[3]{\frac{M_{r1}(1-\upsilon_1^2)}{M_{r2}(1-\upsilon_2^2)}}\right)^2}} + \frac{\left(1-\frac{1}{\sqrt{1+\left(\frac{h}{r}\right)^2}}\right)}{M_{r2}} \right] \tag{5}$$

where, v_1 = Poisson's ratio of the top layer; and h = top layer thickness in inches (mm).

6.3 *Stress-dependency modeling of resilient modulus:*

6.3.1 The M_r parameter is a stress-dependent parameter. In general, most soils exhibit the effects of increasing stiffness with increasing bulk stress and decreasing stiffness with increasing shear stress.

6.3.2 *Composite Resilient Modulus:* The loading sequence in Table 2 provides data to calculate in situ $M_{r\text{-}Comp}$ at six different stress levels. The results can be used to model the stress-dependency behavior using Eq. 6:

$$M_r = k_1^* P_a \left[\frac{\theta}{P_a}\right]^{k_2^*} \left[\frac{\tau_{oct}}{P_a}+1\right]^{k_3^*} \tag{6}$$

where, P_a = atmospheric pressure in psi (kPa); θ = bulk stress in psi (kPa) = $\sigma_1 + \sigma_2 + \sigma_3$; σ_1 = applied cyclic stress ($\Delta\sigma_{cyclic}$) in psi (kPa) used in $M_{r\text{-}comp}$ calculations when tests are not performed in an excavated hole (when tests are performed on material beneath an existing pavement, a confining stress equivalent to the overburden stress due to the weight of the pavement should be added to the cyclic stress); $\sigma_2 = K_o\,\sigma_1$ in psi (kPa); $\sigma_3 = \sigma_2$; K_o = coefficient of lateral earth pressure at rest = $v/(1-v)$; v = Poisson's ratio; τ_{oct} = octahedral shear stress in psi (kPa) = $\sqrt{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}$; and k_1^*, k_2^*, and k_3^*= regression coefficients determined from in situ testing (these coefficients are presented herein with a * to differentiate with the regression coefficients traditionally developed using laboratory test results).

6.4 *Layered Resilient Modulus:*

The M_{r1} and M_{r2} values calculated at different applied cyclic stresses at the surface from layered analysis in Section 6.2 can be used to assess the stress-dependent behavior of each layer, similar to in situ composite M_r values using Eq. (6).

In modeling M_{r1} behavior, the bulk stress (θ) values in Eq. (6) are the same as for $M_{r\text{-Comp}}$. In case of Mr-SG, the θ values can be calculated using the following steps:

- Calculate the applied cyclic stress at the interface of the top and bottom layer based on layered elastic analysis theory. The stresses shall be calculated at the center of the plate.
- The applied vertical stress (σ_1) is calculated by adding the calculated cyclic stress at the interface and confining stress due to the aggregate layer over the subgrade (overburden stress).
- The horizontal stresses (σ_2 and σ_3) shall be calculated using the same procedure as described under Section 6.3.2.
- The bulk stress (θ) values shall be calculated as the sum of σ_1, σ_2, and σ_3.

6.4.1 Any established elastic layer analysis programs (e.g., Kenlayer, Julea, Illislab, etc) can be used for to calculate the stresses at the interface of the top and bottom layers. The interface stresses are a function of the ratio of the top and bottom layer moduli values, thickness of the top layer, radius of the plate, and the applied cyclic stress at the surface.

6.4.2 The analysis approach descried above assumes a flexible loading plate with uniform stress distribution at the surface and the assumption that both subgrade and base layers are linear elastic with homogenous conditions within each layer. The calculated stress values at the interface should therefore be considered approximate.

6.5 Determine the coefficient of determination (R^2) value comparing the measured and predicted M_r values (from Eq. 6) along with standard error (SE) of the estimate, separately for $M_{r\text{-Comp}}$, M_{r1}, and M_{r2}. The R^2 and SE values provide a measure of the goodness of the fit between the measured and predicted values.

7 REPORT

7.1 Prepare a data report that consist the following information at each test location:

- Date of test.
- Initials of person performing the test.
- Project location.
- Test location (station, global positioning system coordinates).
- General weather conditions at the time of test.
- Time of beginning and completion of test.
- Any irregularity in routine procedure.

- Any unusual observations made during the test.
- Any unusual conditions observed at the test site.
- Layer tested and base layer thickness.
- Plot of $M_{r\text{-}Comp}$ versus loading cycles.
- Plot of permanent deformation versus loading cycles.
- Plot of resilient deflection versus loading cycles.
- Plot of $M_{r\text{-}Comp}$ versus $\Delta\sigma_{cyclic}$ along with predicted curve using Eq. 6, along with a summary of R^2 and the SE value of the estimate.
- Plot of M_{r1} versus $\Delta\sigma_{cyclic}$ along with predicted curve using Eq. 6, along with a summary of R^2 and the SE value of the estimate.
- Plot of M_{r2} versus $\Delta\sigma_{cyclic}$ along with predicted curve using Eq. 6, along with a summary of R^2 and the SE value of the estimate.
- A picture of the test location/test setup.
- Results of moisture correction test results (if applicable) – in situ moisture and dry density of the material, moisture content of the material when saturated, and correction factor for saturation.

8 PRECISION AND BIAS

8.1 The precision and bias of this test method for making cyclic plate load tests on pavement components has not been determined. Soils and aggregate materials within a few feet apart can exhibit significantly different load-deflection relationships. Data to quantify the precision of the test method does not exist currently.

APPENDIX C: FIELD PROJECT TEST RESULTS

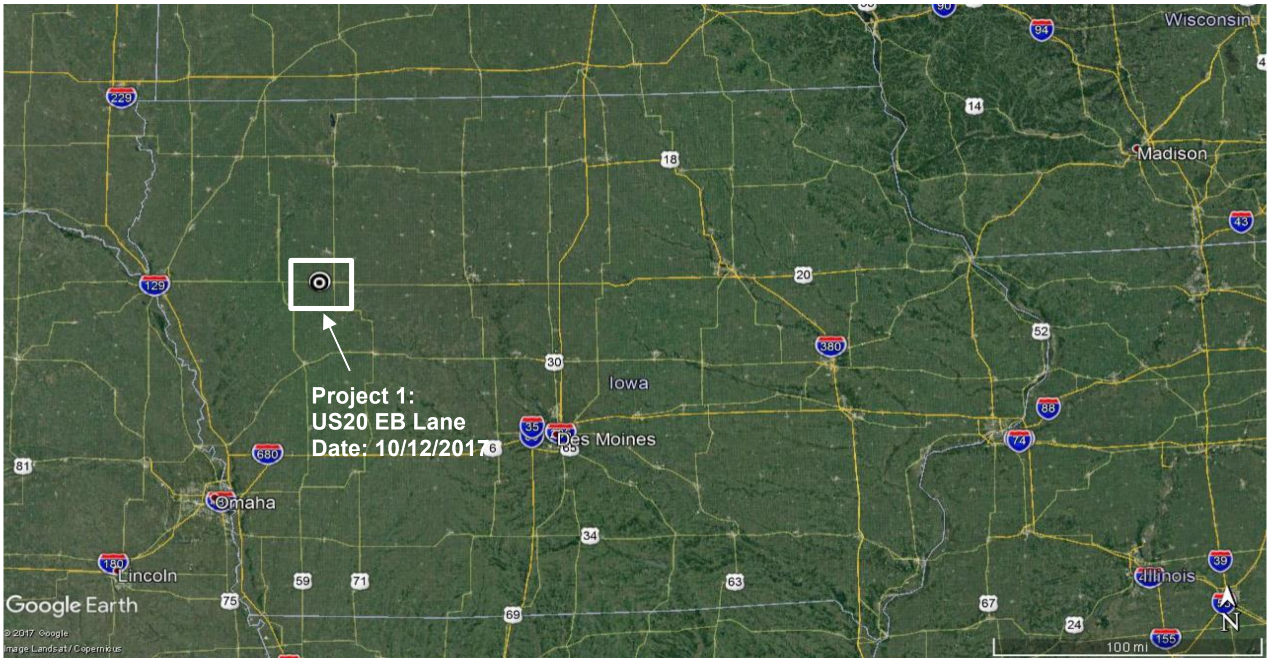
Field Project # 1

Hwy 20 EB, Early, Sac County, IA

10/12/2017

Granular subbase (crushed limestone) over select subgrade

Project Location and Test Locations



Test Locations	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Eastbound near Early, IA (Project #1)

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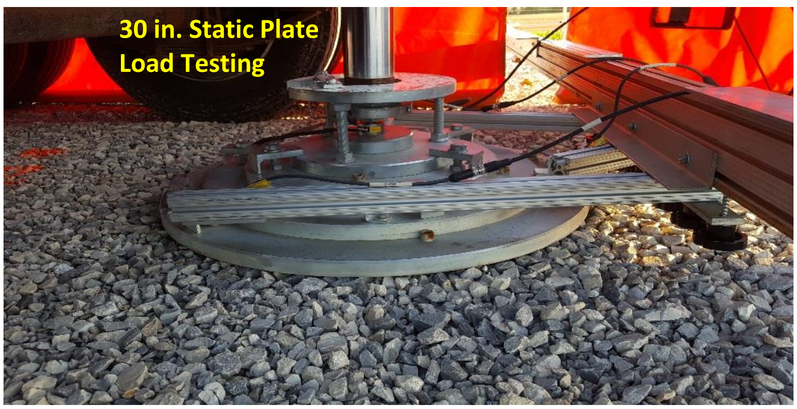
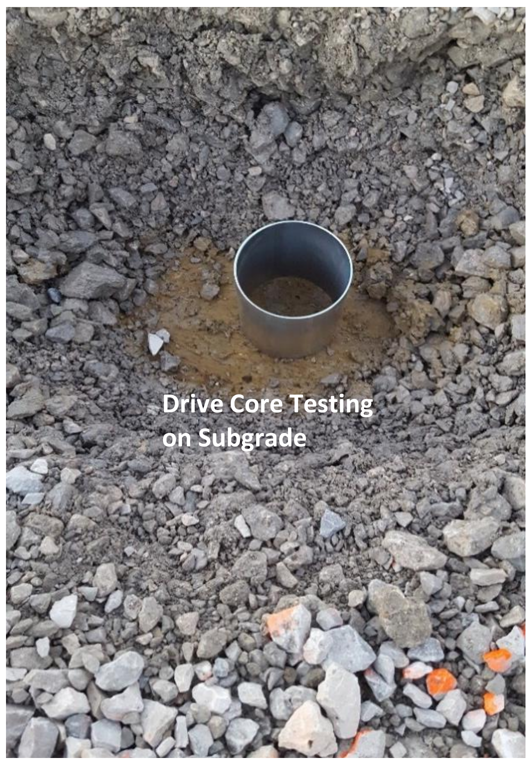
Site Conditions and Pictures





Pictures

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #1)

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Summary of Test Results

Summary of Cyclic APLT Test Results

Point #	4 psi cyclic stress @ surface $M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)	8 psi plate cyclic stress @ surface $M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)
1_Subbase	18,483	18,947	17,699	0.0005	19,558	20,727	17,938	0.0012
2_Subbase	14,223	16,961	10,839	0.0002	16,241	21,075	11,237	0.0009
3_Subbase	18,290	19,819	16,748	-0.0002	20,499	23,516	16,936	0.0010
4_Subbase	15,664	15,361	15,749	0.0000	17,949	19,722	15,761	0.0009
5_Subbase	13,969	13,661	14,495	0.0005	15,271	15,630	14,526	0.0012
6_Subbase	17,398	14,329	22,682	0.0004	21,050	18,151	25,395	0.0010
7_Subbase	21,430	26,779	16,382	-0.0001	22,800	27,849	17,896	0.0003
8_Subbase	19,395	20,684	17,719	-0.0007	19,230	20,450	17,551	-0.0007
AVG	**17,356**	**18,318**	**16,539**	**0.0001**	**19,075**	**20,890**	**17,155**	**0.0007**
COV	15%	23%	20%	588%	13%	17%	23%	88%

Point #	13 psi cyclic stress @ surface $M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)	18 psi plate cyclic stress @ surface $M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)
1_Subbase	20,828	23,362	18,136	0.0055	20,190	21,771	18,323	0.0357
2_Subbase	17,127	23,245	11,069	0.0045	17,508	24,801	10,826	0.0286
3_Subbase	22,451	26,382	18,031	0.0048	21,816	25,352	17,784	0.0261
4_Subbase	19,483	23,214	15,716	0.0049	18,083	20,560	15,377	0.0300
5_Subbase	16,580	17,725	14,653	0.0047	15,851	16,535	14,702	0.0301
6_Subbase	23,394	21,173	26,494	0.0047	23,218	20,509	27,095	0.0273
7_Subbase	23,671	30,235	17,827	0.0027	22,650	27,587	17,903	0.0261
8_Subbase	18,732	20,699	16,300	0.0030	18,248	19,932	16,132	0.0324
AVG	**20,283**	**23,254**	**17,278**	**0.0044**	**19,696**	**22,131**	**17,268**	**0.0295**
COV	14%	16%	25%	23%	14%	16%	27%	11%

Point #	28 psi cyclic stress @ surface $M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)	38 psi plate cyclic stress @ surface $M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)
1_Subbase	19,879	21,770	17,670	0.1605	20,243	23,643	16,724	0.3192
2_Subbase	16,968	23,898	10,454	0.1197	16,963	25,456	9,810	0.2368
3_Subbase	22,013	25,813	17,780	0.1121	22,219	27,624	16,725	0.2191
4_Subbase	18,376	21,922	14,768	0.1434	18,565	24,588	13,355	0.2948
5_Subbase	16,135	17,319	14,296	0.1414	16,192	18,366	13,087	0.2802
6_Subbase	23,436	20,278	28,129	0.1385	24,754	23,284	26,667	0.2746
7_Subbase	21,571	25,530	17,451	0.1119	21,118	26,079	16,448	0.2100
8_Subbase	17,780	19,775	15,432	0.1359	18,036	21,298	14,465	0.2741
AVG	**19,520**	**22,038**	**16,998**	**0.1329**	**19,761**	**23,792**	**15,910**	**0.2636**
COV	13%	13%	30%	13%	15%	12%	31%	14%

Summary of Test Results

Summary of AASHTO (2015) universal model parameters

Point #	$k^*_{1(Comp)}$	$k^*_{2(Comp)}$	$k^*_{3(Comp)}$	M_{r-Comp} R^2(Adj.)	Std. Error (psi)	$M_{r-Comp(pred)-BP}$ (psi)	$\sigma_{cyclic-BP}$ (psi)
1_Subbase	1,371.5	0.133	-0.722	0.730	368	20,434	21.0
2_Subbase	1,148.1	0.263	-1.395	0.972	199	17,460	21.7
3_Subbase	1,433.2	0.234	-1.104	0.923	430	22,397	25.2
4_Subbase	1,255.0	0.239	-1.290	0.735	590	18,940	21.3
5_Subbase	1,071.5	0.185	-0.919	0.848	344	16,350	23.6
6_Subbase	1,433.8	0.315	-1.256	0.939	641	24,302	31.3
7_Subbase	1,655.8	0.167	-1.315	0.845	359	23,148	13.6
8_Subbase	1,303.9	-0.051	0.047	0.874	221	20,337	2.0
AVG	**1,334.1**	**0.185**	**-0.994**	**0.858**	**394**	**20,421**	**20.0**
COV	14%	60%	-0.480	10%	40%	14%	44%

Point #	$k^*_{1(Base)}$	$k^*_{2(Base(}$	$k^*_{3(Base)}$	M_{r-Base} R^2(Adj.)	Std. Error (psi)
1_Subbase	1,420.3	0.163	-0.640	0.642	819
2_Subbase	1,456.1	0.385	-1.593	0.950	695
3_Subbase	1,594.1	0.281	-1.085	0.878	930
4_Subbase	1,307.0	0.354	-1.286	0.749	1,478
5_Subbase	1,066.7	0.225	-0.794	0.825	666
6_Subbase	1,219.7	0.369	-1.331	0.840	1,165
7_Subbase	2,064.4	0.159	-1.350	0.492	883
8_Subbase	1,340.5	-0.082	0.628	0.171	292
AVG	**1,433.6**	**0.232**	**-0.931**	**0.693**	**866**
COV	21%	67%	-0.755	37%	41%

Point #	$k^*_{1(SG)}$	$k^*_{2(SG)}$	$k^*_{3(SG)}$	M_{r-SG} R^2(Adj.)	Std. Error (psi)
1_Subbase	1,475.4	0.141	-1.743	0.884	183
2_Subbase	1,011.8	0.175	-3.294	0.968	90
3_Subbase	1,497.6	0.194	-2.104	0.670	290
4_Subbase	1,382.0	0.159	-2.655	0.932	242
5_Subbase	1,278.4	0.167	-2.528	0.807	250
6_Subbase	2,156.8	0.283	-1.776	0.952	402
7_Subbase	1,589.7	0.233	-2.589	0.911	208
8_Subbase	1,234.2	(0.022)	-1.214	0.951	269
AVG	**1,453.2**	**0.166**	**-2.238**	**0.885**	**242**
COV	23%	53%	-0.294	11%	37%

Summary of Test Results

Summary of Static PLT results

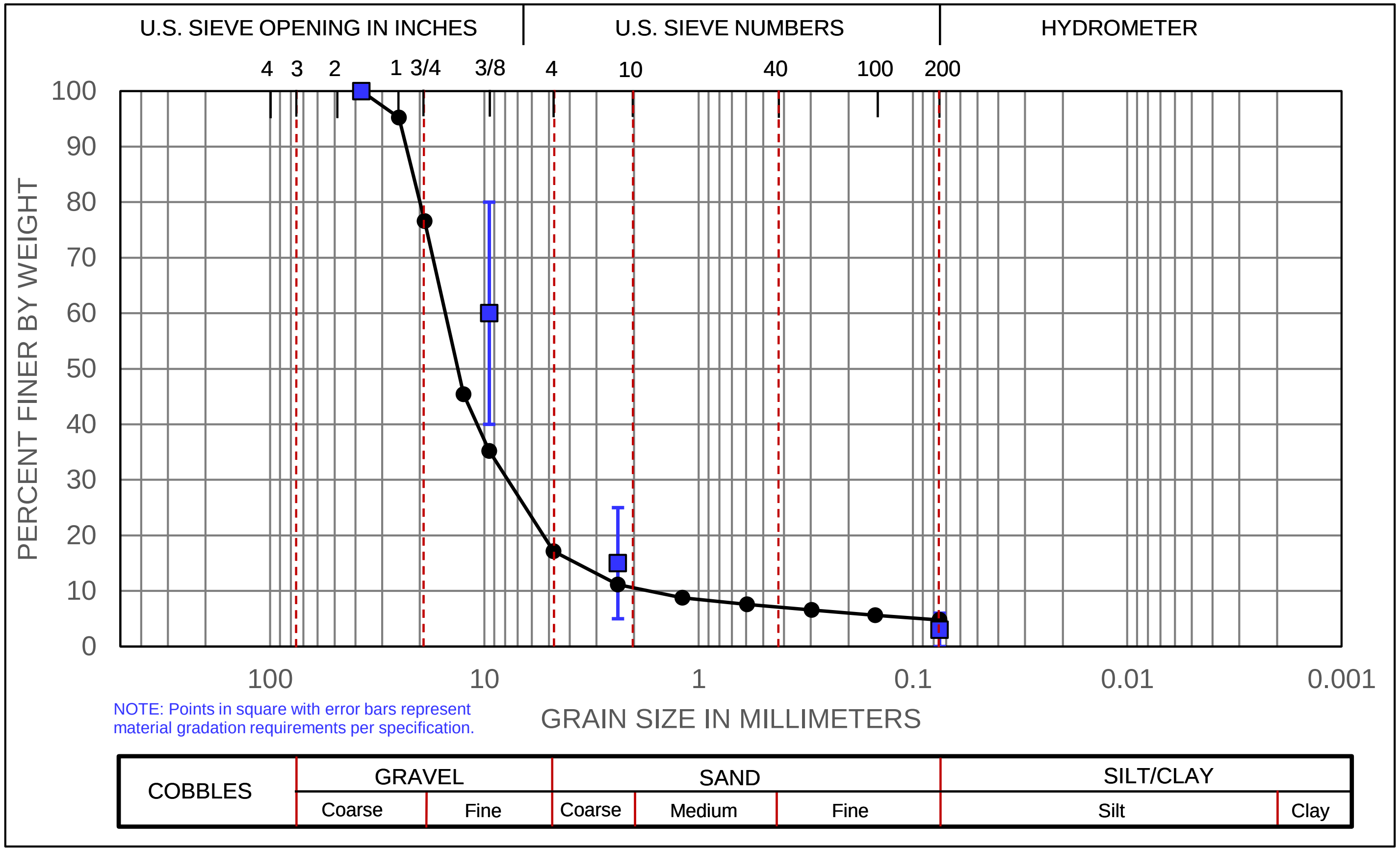
Point #	k_u (pci) at δ = 0.05 in.[a]	k_{u1} (pci) at 10 psi[b]	k_{u2} (pci) at 10 psi	Ratio of k_{u2}/k_{u1}
	30 in. static PLT			
9_Subbase	58	70	639	9.1

[a]per PCA design critera
[b]per AASHTO T222

Summary of DCP and LWD test results

Point #	Subbase Layer Thickness, H_1 (in.)	Avg. CBR (%)	St. Dev CBR (%)	Subgrade Layer Thickness, H_2 (in.)	Avg. CBR (%)	St. Dev CBR (%)	Ratio CBR_1/CBR_2	E_{LWD} (psi)
1_Subbase	8.9	4.1	1.9	12.0	6.4	4.4	0.6	9,204
2_Subbase	10.5	5.8	3.6	12.0	6.2	7.0	0.9	6,294
3_Subbase	9.5	7.3	2.3	12.0	3.3	2.6	2.2	9,918
4_Subbase	9.0	4.0	1.5	12.0	3.4	2.5	1.2	6,354
5_Subbase	10.9	6.3	2.9	12.0	3.9	5.7	1.6	6,195
6_Subbase	8.4	4.4	2.7	12.0	12.0	7.1	0.4	8,461
7_Subbase	8.7	7.1	4.3	12.0	3.4	1.5	2.1	8,975
8_Subbase	9.5	4.6	1.8	12.0	3.8	1.6	1.2	6,151
9_Subbase	8.5	7.2	2.8	12.0	4.4	2.1	1.6	5,447
AVG	**9.3**	**5.7**	**2.7**	**12.0**	**5.2**	**3.8**	**1.3**	**7,444**
COV	10%	25%	36%	0%	61%	59%	54%	21%

GRAIN SIZE DISTRIBUTION
ASTM D422/C136



Gradation Summary

% Gravel	82.9
% Sand	12.4
% Fines	4.8
D_{10} (mm)	1.811
D_{30} (mm)	8.132
D_{50} (mm)	13.457
D_{60} (mm)	15.544
D_{85} (mm)	21.712
C_u	8.6
C_c	2.3

Atterberg Limits

LL	NP
PL	NP
PI	NP

Classification

AASHTO:	A-1-a
USCS:	GW

MATERIAL: Gray Crushed Limestone Granular Subbase - Untrimmed (Iowa DOT Gradation 4121 - Virgin Material)
LOCATION: Hwy 20 EB near Early, Iowa (Project #1) **TESTED BY:** PV/DW
SAMPLE DATE: 10/12/2017 **TEST DATE:** 11/28/2017

Gradation and Soil Classification Test Results

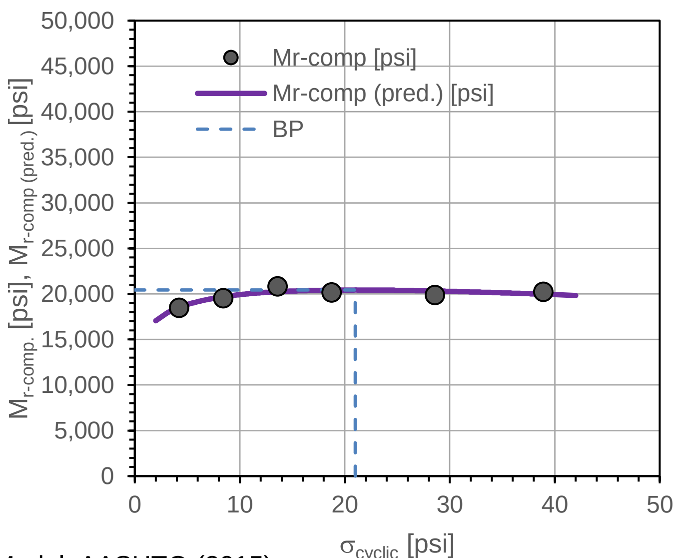
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #1)

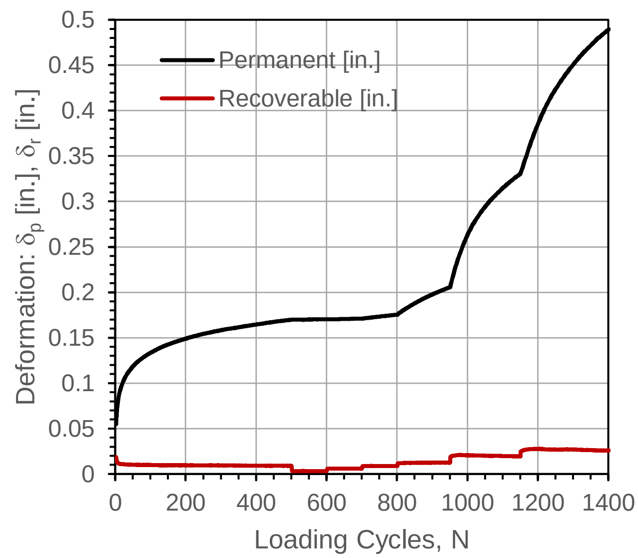
ingios GEOTECHNICS

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/12/2017	Time:	12:06:19 PM	Test ID	**STIC_Hwy20_12_1**
Tested By	DV, JV	Location:	Hwy20 EB Lane	Sta.	NA
Latitude,N:	42.474983	Longitude,W:	95.247414	Elev. (ft):	1438
Comments:	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.60	---	---	0.1698	---	0.172	---
1	100	4.23	18,483	18,523	0.1703	0.0005	0.135	Y
2	100	8.41	19,558	19,687	0.1710	0.0012	0.543	Y
3	100	13.60	20,828	20,243	0.1754	0.0055	0.790	N
4	150	18.75	20,190	20,420	0.2055	0.0357	0.910	N
5	200	28.59	19,879	20,324	0.3303	0.1605	0.842	N
6	250	38.91	20,243	19,967	0.4890	0.3192	0.886	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	1,371.5	1.04E-07
k^*_2	0.133	6.96E-02
k^*_3	-0.722	1.26E-01
Adj. R^2	0.730	
Std. Error [psi]	368	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	20,434
$\sigma_{cyclic\text{-}BP}$ [psi]	21.0

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #1)

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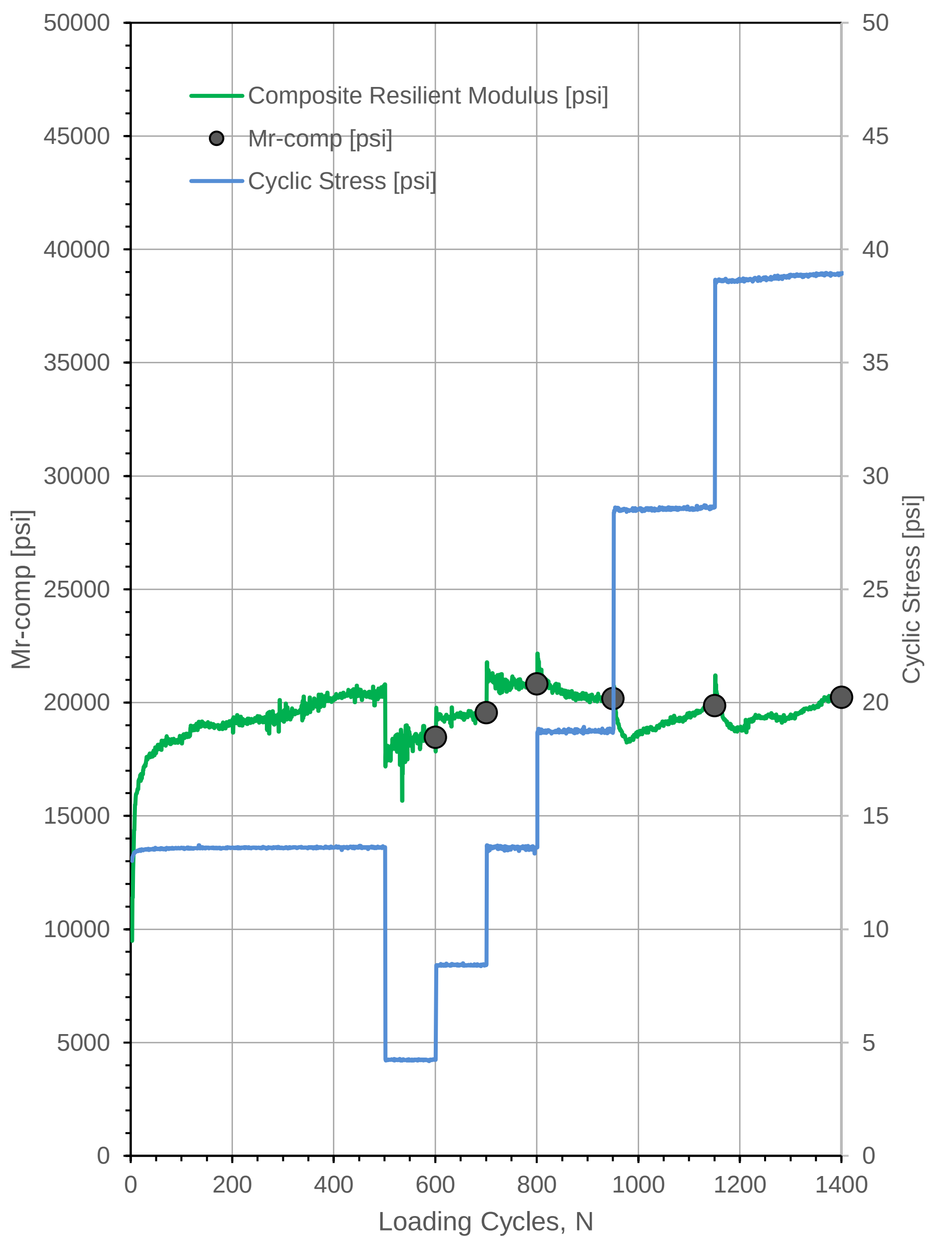
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/12/2017	Time:	12:06:19 PM	Test ID	**STIC_Hwy20_12_1**
Tested By	DV, JV	Location:	Cell 228	Sta.	NA
Latitude,N:	42.474983	Longitude,W:	95.247414	Elev. (ft):	1438
Comments:	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	17,052
3	17,860
4	18,417
5	18,831
6	19,152
7	19,407
8	19,613
9	19,781
10	19,920
11	20,034
12	20,127
13	20,204
14	20,266
15	20,316
16	20,356
17	20,386
18	20,408
21	20,434
22	20,432
23	20,425
24	20,414
25	20,400
26	20,382
27	20,362
28	20,339
29	20,313
30	20,285
31	20,255
32	20,224
33	20,190
34	20,155
35	20,119
36	20,082
37	20,043
38	20,004
39	19,963
40	19,922



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #1)

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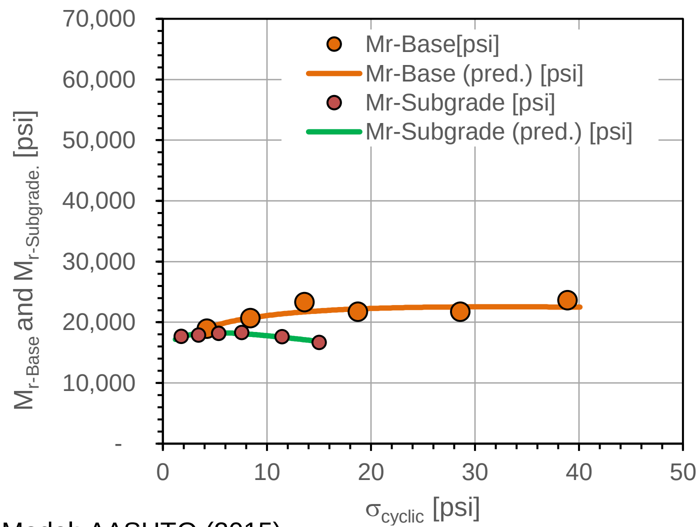
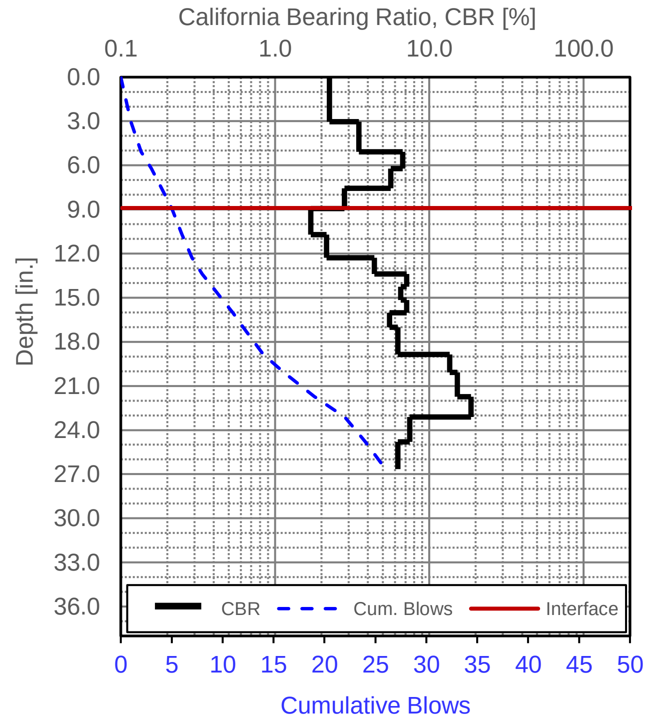
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/12/2017	Time:	12:06:19 PM	Test ID	**STIC_Hwy20_12_1**
Tested By	DV, JV	Location:	Hwy20 EB Lane	Sta.	NA
Latitude:	42.474983	Longitude:	95.247414	Elev. (ft):	1438
Comments:	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	13.60	---	---	---	---	---	---
1	100	4.23	18,947	19,018	1.76	17,699	17,579	1.07
2	100	8.41	20,727	20,716	3.44	17,938	18,136	1.16
3	100	13.60	23,362	21,706	5.39	18,136	18,269	1.29
4	100	18.75	21,771	22,198	7.60	18,323	18,122	1.19
5	100	28.59	21,770	22,538	11.47	17,670	17,533	1.23
6	100	38.91	23,643	22,503	15.01	16,724	16,847	1.41

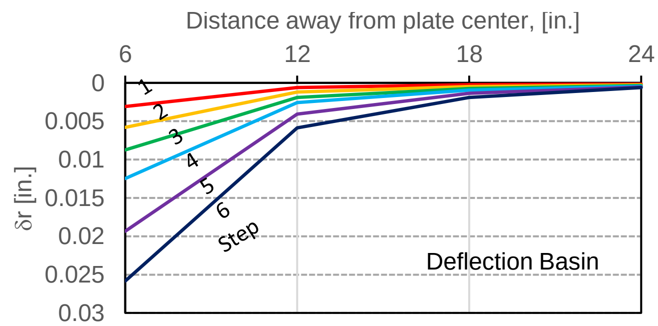




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\ (Base)}$	1420.3	9.79E-07
$k^*_{2\ (Base)}$	0.163	2.06E-01
$k^*_{3\ (Base)}$	-0.640	4.44E-01
Adj. R^2	0.642	
Std. Error [psi]	819	
$k^*_{1\ (Subgrade)}$	1475.4	4.13E-07
$k^*_{2\ (Subgrade)}$	0.141	2.62E-02
$k^*_{3\ (Subgrade)}$	-1.743	1.66E-02
Adj. R^2	0.884	
Std. Error [psi]	183	



In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

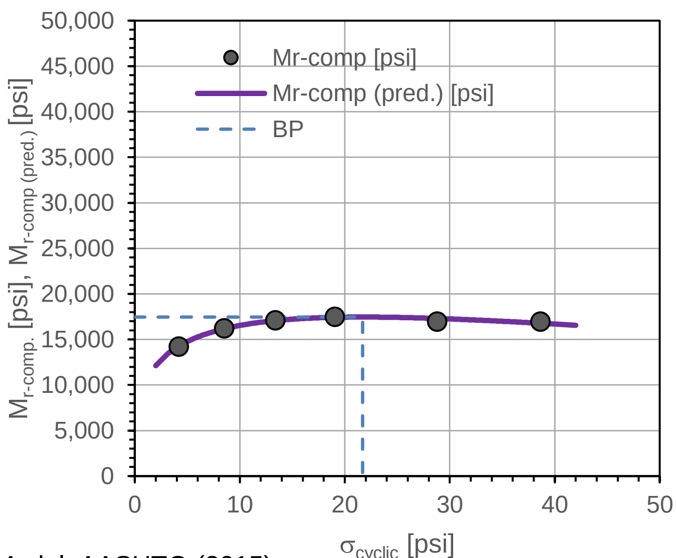
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #1)

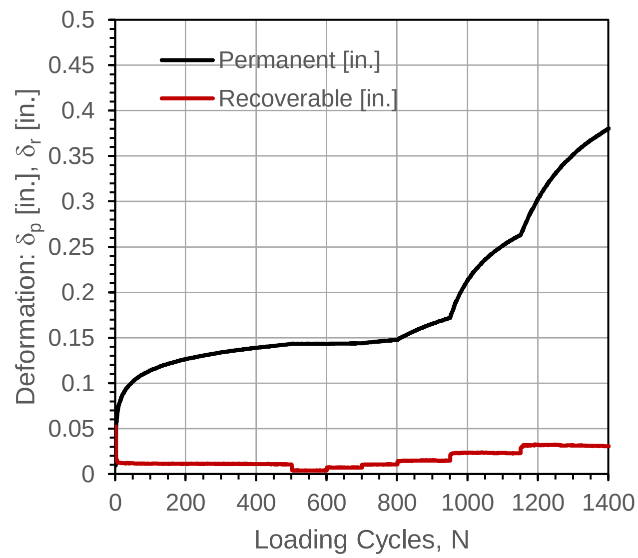
ingios GEOTECHNICS

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/12/2017	Time:	12:45:58 PM	Test ID	**STIC_Hwy20_12_2**
Tested By	DV, JV	Location:	Hwy20 EB Lane	Sta.	NA
Latitude,N:	42.474995	Longitude,W:	95.247757	Elev. (ft):	1431
Comments:	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-comp}}$ [psi]	$M_{r\text{-comp (pred.)}}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.38	---	---	0.1431	---	0.180	---
1	100	4.20	14,223	14,269	0.1433	0.0002	0.002	Y
2	100	8.51	16,241	16,175	0.1440	0.0009	0.434	Y
3	100	13.38	17,127	17,071	0.1476	0.0045	0.656	N
4	150	19.05	17,508	17,429	0.1717	0.0286	0.884	N
5	200	28.80	16,968	17,303	0.2628	0.1197	0.816	N
6	250	38.64	16,963	16,780	0.3799	0.2368	0.884	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	1,148.1	2.23E-08
k^*_2	0.263	2.51E-03
k^*_3	-1.395	6.01E-03
Adj. R^2	0.972	
Std. Error [psi]	199	

$M_{r\text{-comp (pred.)-BP}}$ [psi]	17,460
$\sigma_{cyclic\text{-BP}}$ [psi]	21.7

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #1)

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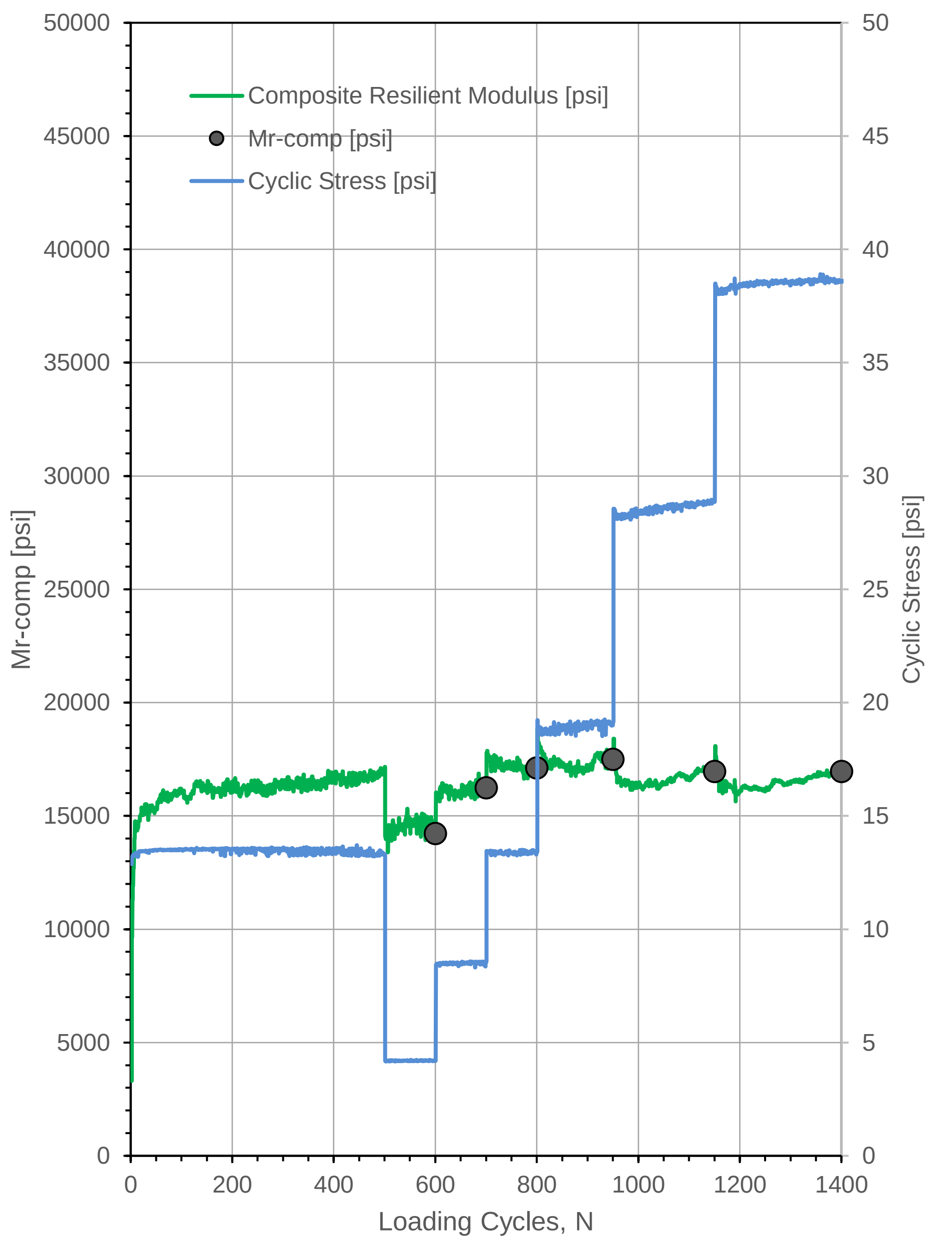
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/12/2017	Time:	12:45:58 PM	Test ID	**STIC_Hwy20_12_2**
Tested By	DV, JV	Location:	Cell 228	Sta.	NA
Latitude,N:	42.474995	Longitude,W:	95.247757	Elev. (ft):	1431
Comments:	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

σ_{cyclic} [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]
2	12,122
3	13,290
4	14,129
5	14,770
6	15,278
7	15,689
8	16,027
9	16,306
10	16,538
11	16,732
12	16,893
13	17,026
14	17,136
15	17,226
16	17,298
17	17,354
18	17,397
21	17,458
22	17,459
23	17,453
24	17,441
25	17,422
26	17,397
27	17,367
28	17,333
29	17,295
30	17,253
31	17,208
32	17,160
33	17,108
34	17,055
35	16,999
36	16,941
37	16,882
38	16,820
39	16,758
40	16,694



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

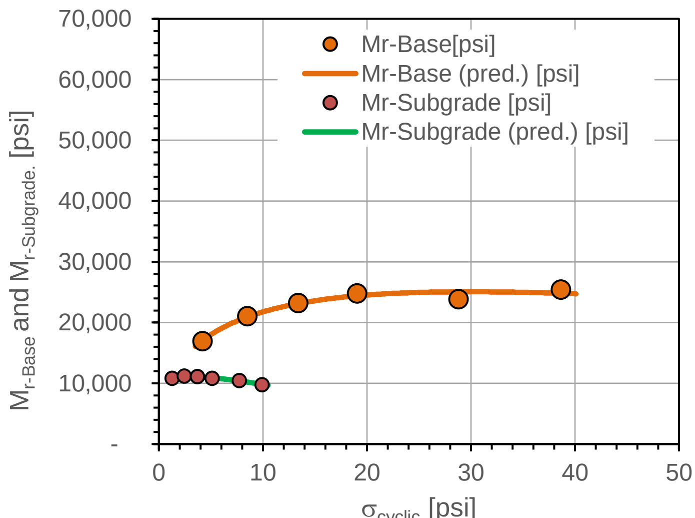
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #1)

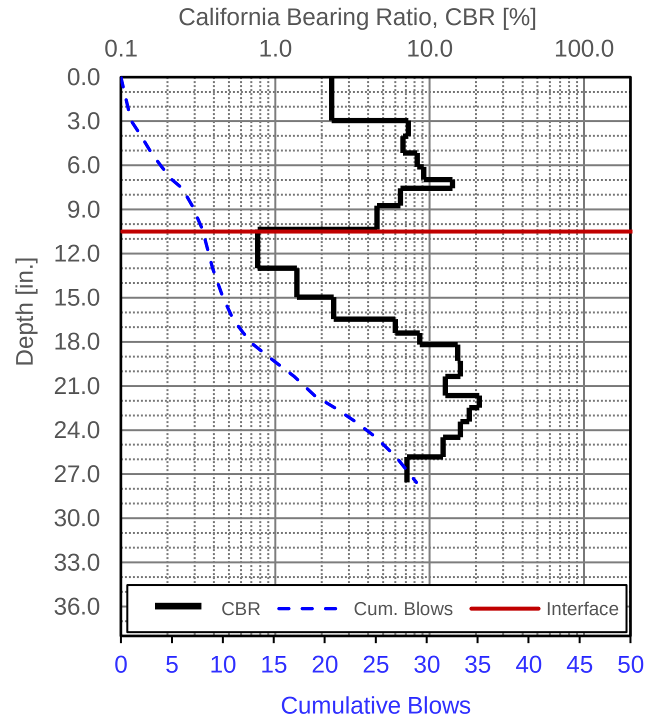
ingios GEOTECHNICS

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/12/2017	Time:	12:45:58 PM	Test ID	**STIC_Hwy20_12_2**
Tested By	DV, JV	Location:	Hwy20 EB Lane	Sta.	NA
Latitude:	42.474995	Longitude:	95.247757	Elev. (ft):	1431
Comments:	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	13.38	---	---	---	---	---	---
1	100	4.20	16,961	17,069	1.28	10,839	10,880	1.56
2	100	8.51	21,075	20,919	2.45	11,237	11,120	1.88
3	100	13.38	23,245	23,123	3.71	11,069	11,105	2.10
4	100	19.05	24,801	24,402	5.12	10,826	10,922	2.29
5	100	28.80	23,898	25,068	7.75	10,454	10,372	2.29
6	100	38.64	25,456	24,819	9.93	9,810	9,834	2.59

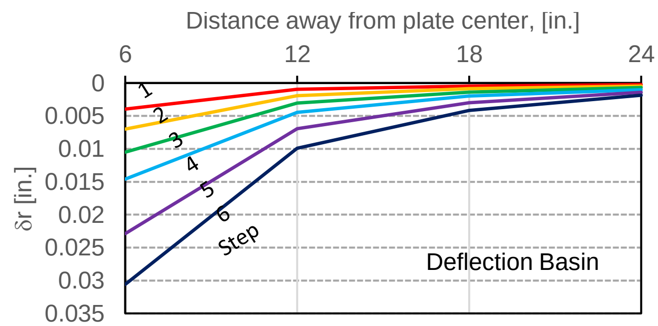




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\ (Base)}$	1456.1	2.93E-07
$k^*_{2\ (Base)}$	0.385	1.08E-02
$k^*_{3\ (Base)}$	-1.593	4.66E-02
Adj. R^2	0.950	
Std. Error [psi]	695	
$k^*_{1\ (Subgrade)}$	1011.8	7.85E-07
$k^*_{2\ (Subgrade)}$	0.175	1.39E-02
$k^*_{3\ (Subgrade)}$	-3.294	5.60E-03
Adj. R^2	0.968	
Std. Error [psi]	90	



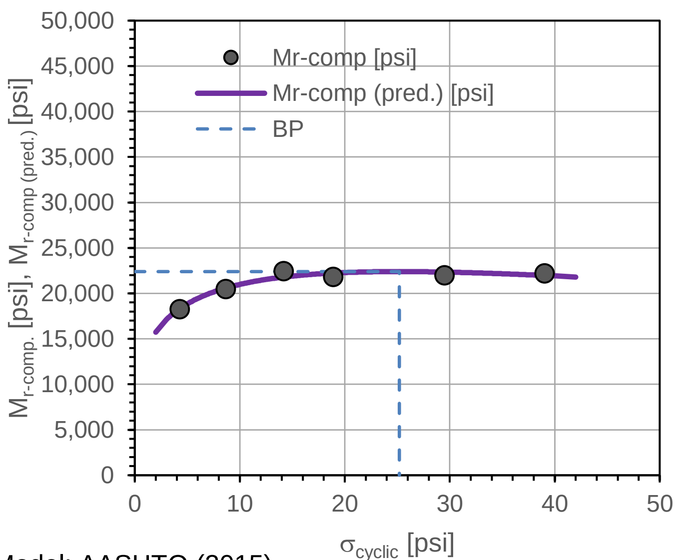
In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

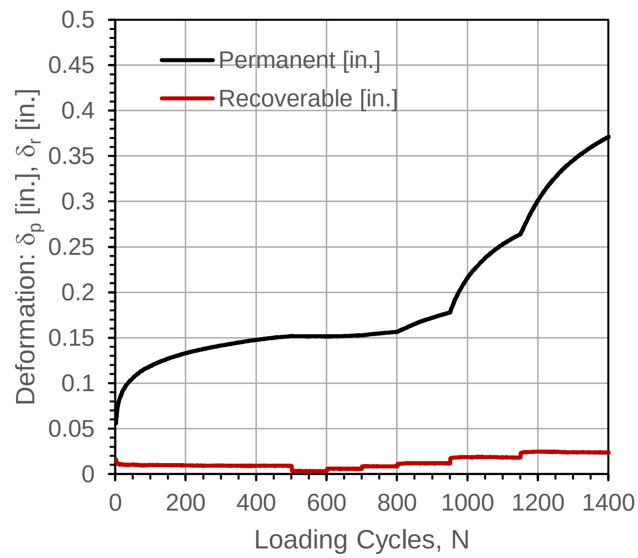
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Eastbound near Early, IA (Project #1)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/12/2017	Time:	1:22:13 PM	Test ID	**STIC_Hwy20_12_3**
Tested By	DV, JV	Location:	Hwy20 EB Lane	Sta.	NA
Latitude,N:	42.474995	Longitude,W:	95.248077	Elev. (ft):	1435
Comments:	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	14.19	---	---	0.1517	---	0.183	---
1	100	4.30	18,290	18,333	0.1514	-0.0002	-0.211	Y
2	100	8.67	20,499	20,588	0.1527	0.0010	0.679	Y
3	100	14.19	22,451	21,801	0.1565	0.0048	0.739	N
4	150	18.90	21,816	22,237	0.1777	0.0261	0.959	N
5	200	29.50	22,013	22,343	0.2638	0.1121	0.825	N
6	250	39.04	22,219	21,970	0.3708	0.2191	0.859	N





Model: AASHTO (2015)

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

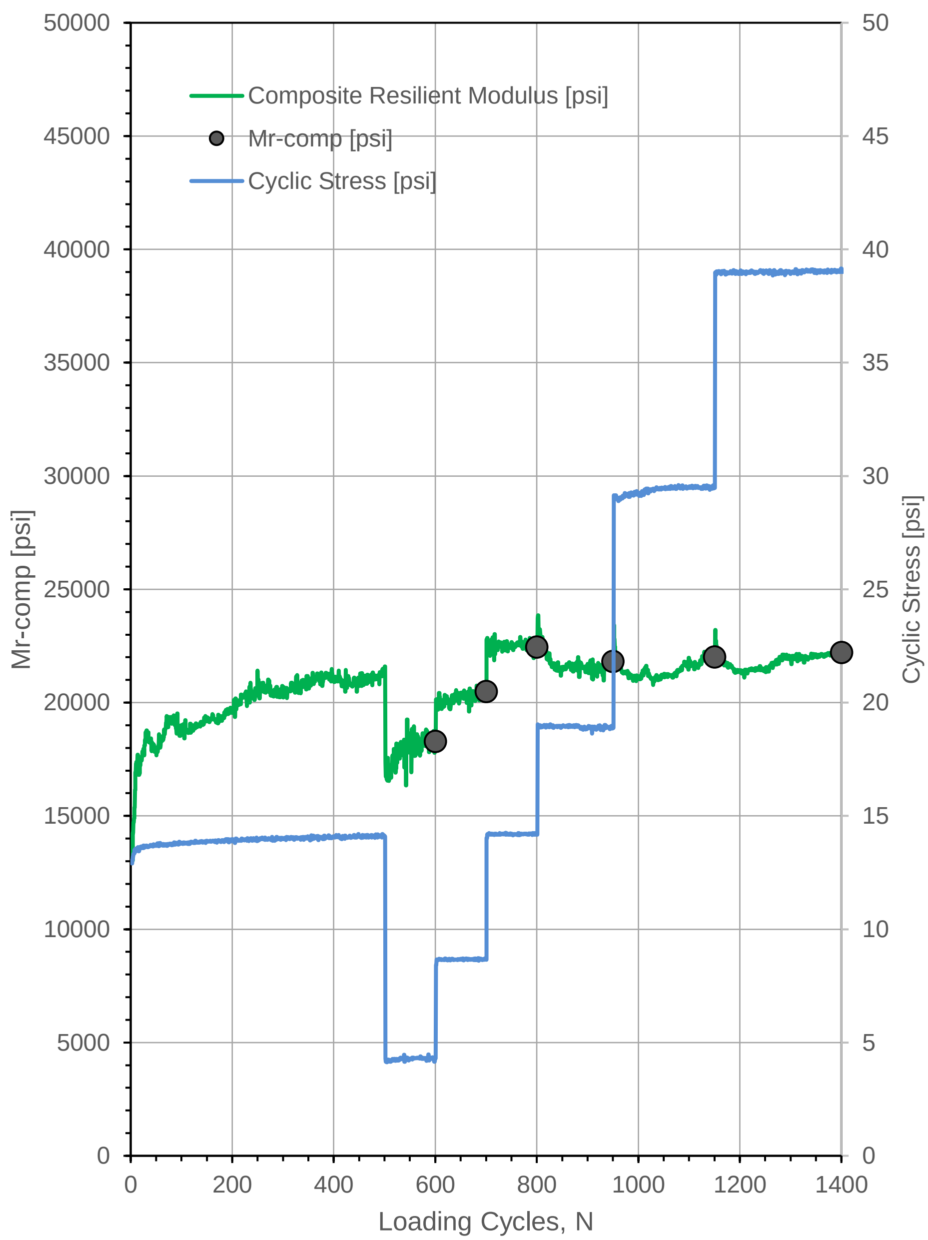
Parameter	Value	P-Value
k^*_1	1,433.2	9.50E-08
k^*_2	0.234	1.59E-02
k^*_3	-1.104	4.63E-02
Adj. R^2	0.923	
Std. Error [psi]	430	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	22,397
$\sigma_{cyclic\text{-}BP}$ [psi]	25.2

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/12/2017	Time:	1:22:13 PM	Test ID	**STIC_Hwy20_12_3**
Tested By	DV, JV	Location:	Cell 228	Sta.	NA
Latitude,N:	42.474995	Longitude,W:	95.248077	Elev. (ft):	1435
Comments:	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	15,735
3	17,104
4	18,088
5	18,844
6	19,448
7	19,941
8	20,351
9	20,694
10	20,985
11	21,232
12	21,442
13	21,621
14	21,774
15	21,903
16	22,013
17	22,105
18	22,181
21	22,331
22	22,360
23	22,380
24	22,392
25	22,397
26	22,395
27	22,386
28	22,373
29	22,354
30	22,331
31	22,304
32	22,273
33	22,238
34	22,200
35	22,159
36	22,116
37	22,070
38	22,022
39	21,972
40	21,920



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Eastbound near Early, IA (Project #1)

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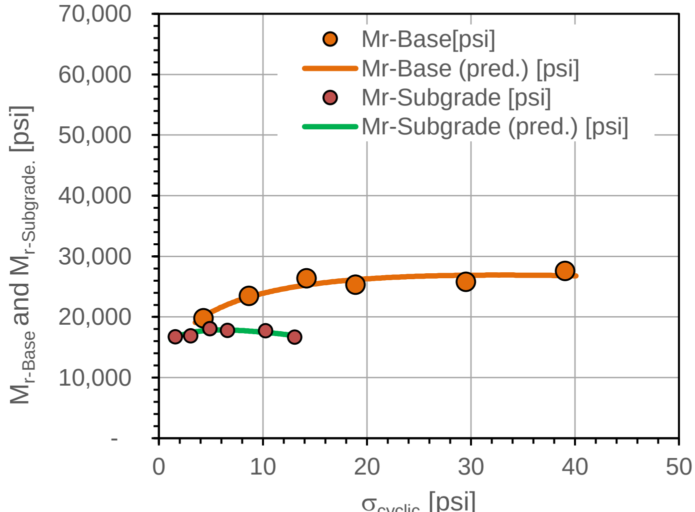
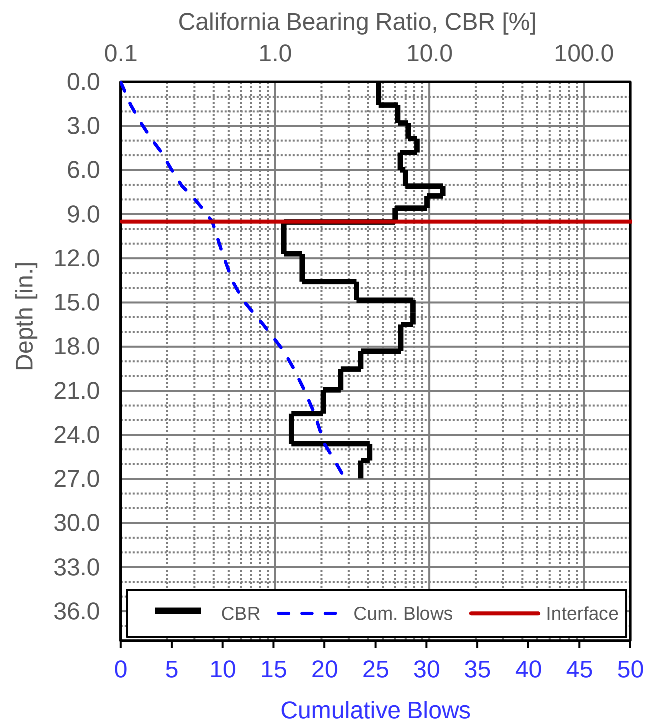
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/12/2017	Time:	1:22:13 PM	Test ID	**STIC_Hwy20_12_3**
Tested By	DV, JV	Location:	Hwy20 EB Lane	Sta.	NA
Latitude:	42.474995	Longitude:	95.248077	Elev. (ft):	1435
Comments:	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-Base}}$[psi]	$M_{r\text{-Base (pred.)}}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-Subgrade}}$ [psi]	$M_{r\text{-Subgrade (pred.)}}$ [psi]	Modulus Ratio
Conditioning	500	14.19	---	---	---	---	---	---
1	100	4.30	19,819	20,042	1.58	16,748	16,547	1.18
2	100	8.67	23,516	23,287	3.05	16,936	17,401	1.39
3	100	14.19	26,382	25,267	4.92	18,031	17,801	1.46
4	100	18.90	25,352	26,147	6.60	17,784	17,845	1.43
5	100	29.50	25,813	26,878	10.25	17,780	17,455	1.45
6	100	39.04	27,624	26,820	13.05	16,725	16,942	1.65

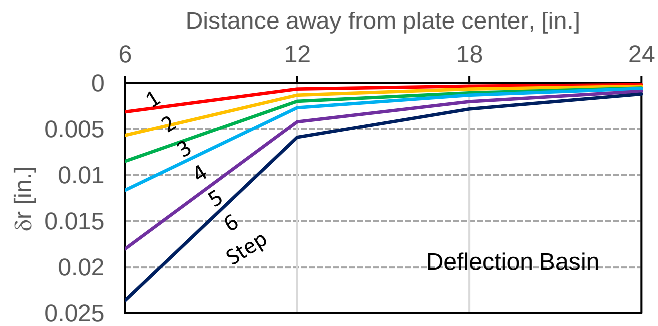




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\,(Base)}$	1594.1	5.84E-07
$k^*_{2\,(Base)}$	0.281	4.96E-02
$k^*_{3\,(Base)}$	-1.085	1.81E-01
Adj. R^2	0.878	
Std. Error [psi]	930	
$k^*_{1\,(Subgrade)}$	1497.6	3.84E-06
$k^*_{2\,(Subgrade)}$	0.194	6.46E-02
$k^*_{3\,(Subgrade)}$	-2.104	7.27E-02
Adj. R^2	0.670	
Std. Error [psi]	290	



In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #1)

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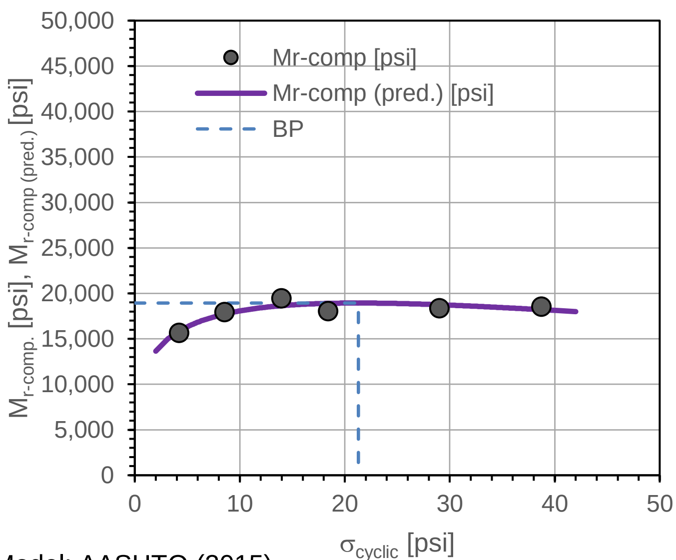
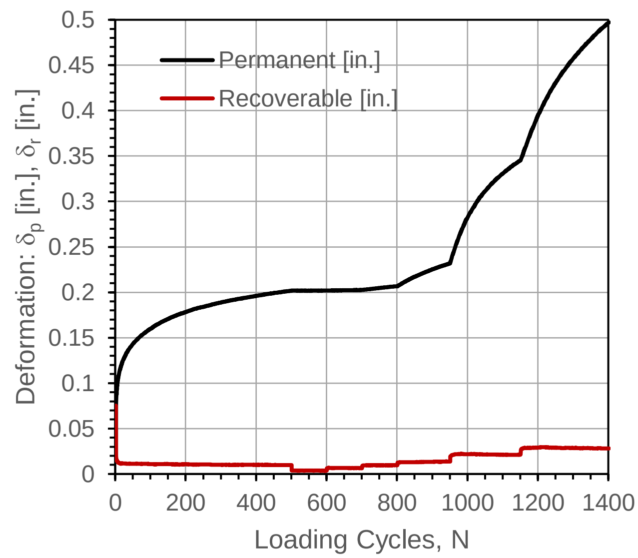
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/12/2017	Time:	1:58:12 PM	Test ID	**STIC_Hwy20_12_4**
Tested By	DV, JV	Location:	Cell 228	Sta.	NA
Latitude,N:	42.474987	Longitude,W:	95.248413	Elev. (ft):	1433
Comments:	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.98	---	---	0.2018	---	0.165	---
1	100	4.22	15,664	15,838	0.2018	0.0000	-0.012	Y
2	100	8.56	17,949	17,730	0.2027	0.0009	0.354	Y
3	100	13.98	19,483	18,647	0.2067	0.0049	0.685	N
4	150	18.42	18,083	18,904	0.2318	0.0300	0.945	N
5	200	29.01	18,376	18,751	0.3452	0.1434	0.824	N
6	250	38.73	18,565	18,207	0.4965	0.2948	0.921	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	1,255.0	5.54E-07
k^*_2	0.239	6.25E-02
k^*_3	-1.290	1.16E-01
Adj. R^2	0.735	
Std. Error [psi]	590	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	18,940
$\sigma_{cyclic\text{-}BP}$ [psi]	21.3

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #1)

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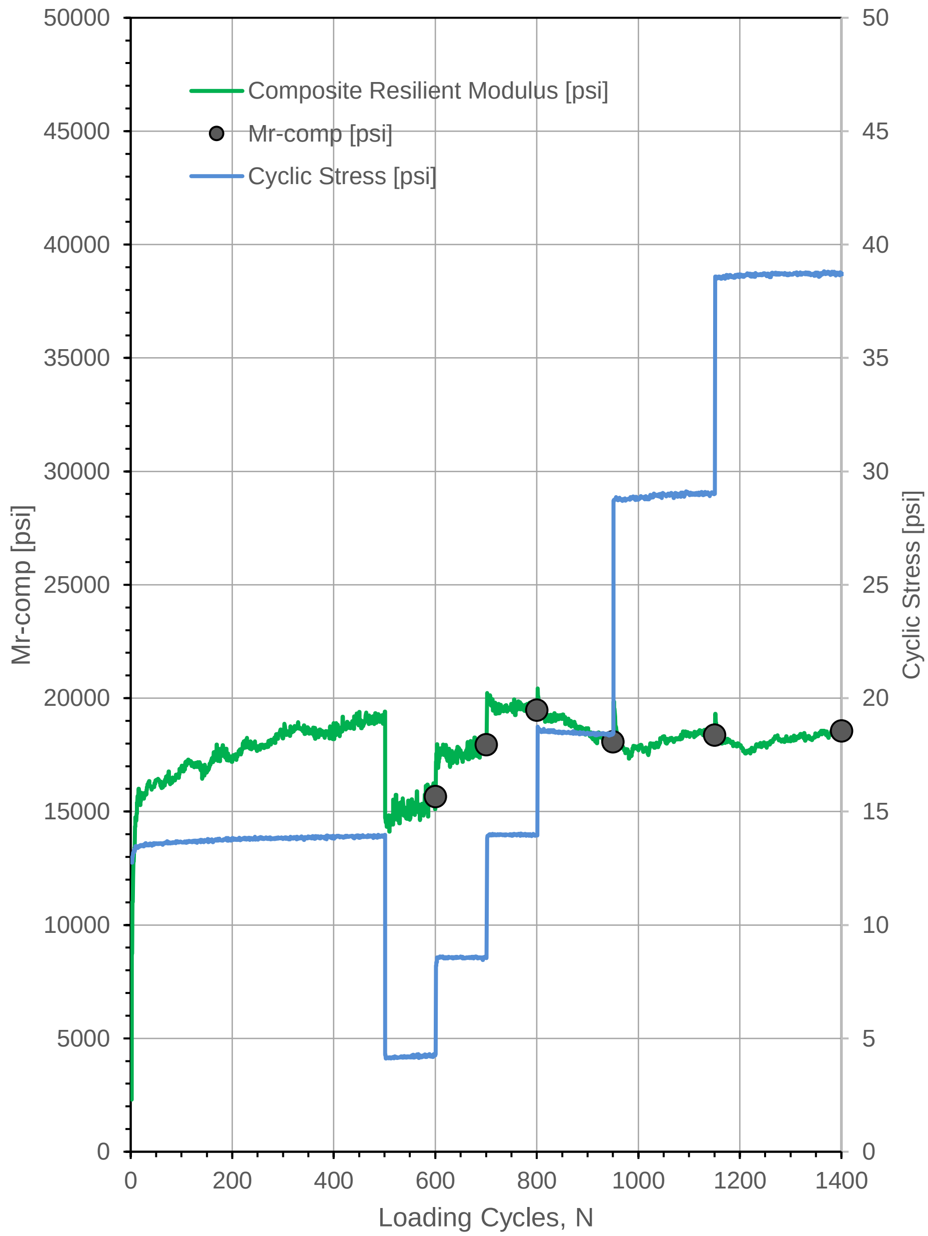
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/12/2017	Time:	1:58:12 PM	Test ID	**STIC_Hwy20_12_4**
Tested By	DV, JV	Location:	Cell 228	Sta.	NA
Latitude,N:	42.474987	Longitude,W:	95.248413	Elev. (ft):	1433
Comments:	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	13,648
3	14,835
4	15,681
5	16,323
6	16,829
7	17,237
8	17,569
9	17,844
10	18,071
11	18,259
12	18,415
13	18,544
14	18,649
15	18,734
16	18,801
17	18,853
18	18,891
21	18,940
22	18,938
23	18,929
24	18,912
25	18,890
26	18,862
27	18,830
28	18,793
29	18,752
30	18,707
31	18,659
32	18,608
33	18,554
34	18,498
35	18,440
36	18,380
37	18,318
38	18,254
39	18,189
40	18,123



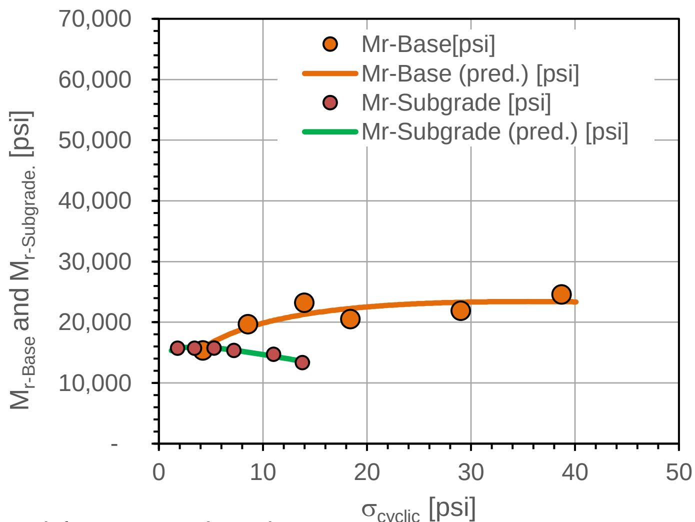
In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

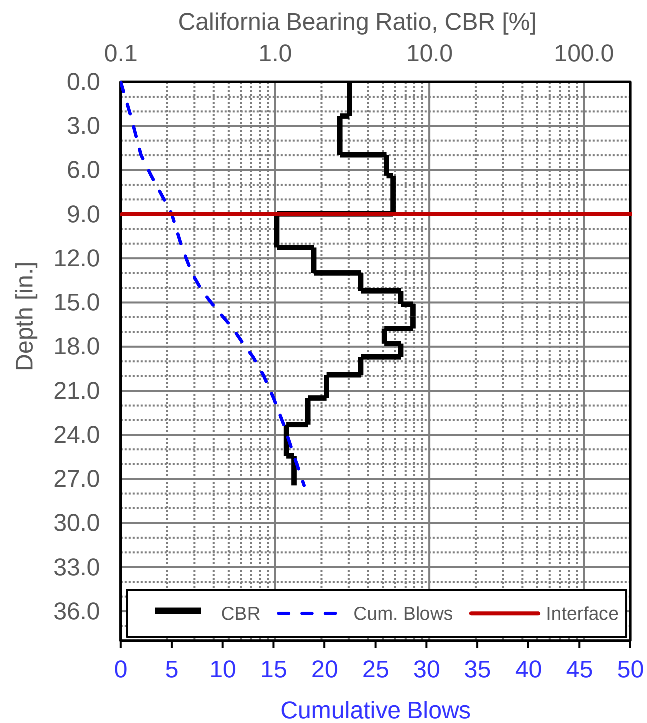
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #1)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/12/2017	Time:	1:58:12 PM	Test ID	**STIC_Hwy20_12_4**
Tested By	DV, JV	Location:	Cell 228	Sta.	NA
Latitude:	42.474987	Longitude:	95.248413	Elev. (ft):	1433
Comments:	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

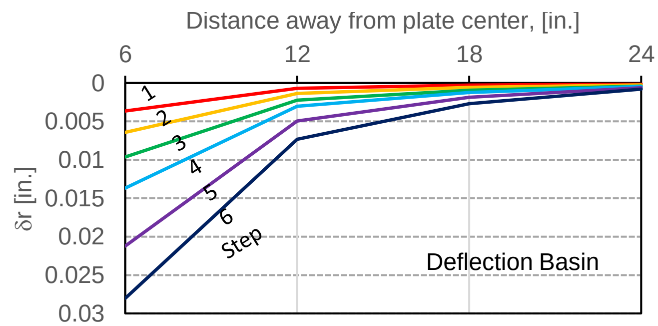
Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	13.98	---	---	---	---	---	---
1	100	4.22	15,361	15,757	1.80	15,749	15,640	0.98
2	100	8.56	19,722	19,133	3.42	15,761	15,927	1.25
3	100	13.98	23,214	21,291	5.33	15,716	15,779	1.48
4	100	18.42	20,560	22,283	7.22	15,377	15,403	1.34
5	100	29.01	21,922	23,295	11.04	14,768	14,386	1.48
6	100	38.73	24,588	23,389	13.81	13,355	13,583	1.84





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
$k^*_{1\ (Base)}$	1307.0	4.99E-06
$k^*_{2\ (Base)}$	0.354	1.33E-01
$k^*_{3\ (Base)}$	-1.286	3.74E-01
Adj. R^2	0.749	
Std. Error [psi]	1478	
$k^*_{1\ (Subgrade)}$	1382.0	2.41E-06
$k^*_{2\ (Subgrade)}$	0.159	7.69E-02
$k^*_{3\ (Subgrade)}$	-2.655	2.66E-02
Adj. R^2	0.932	
Std. Error [psi]	242	

In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #1)

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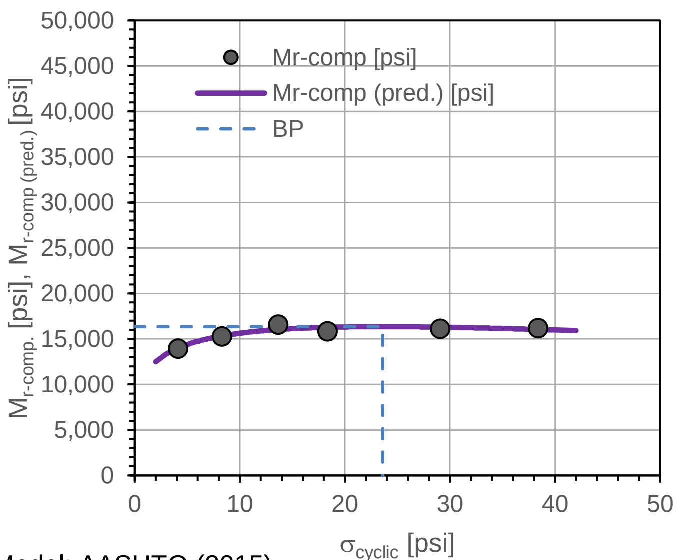
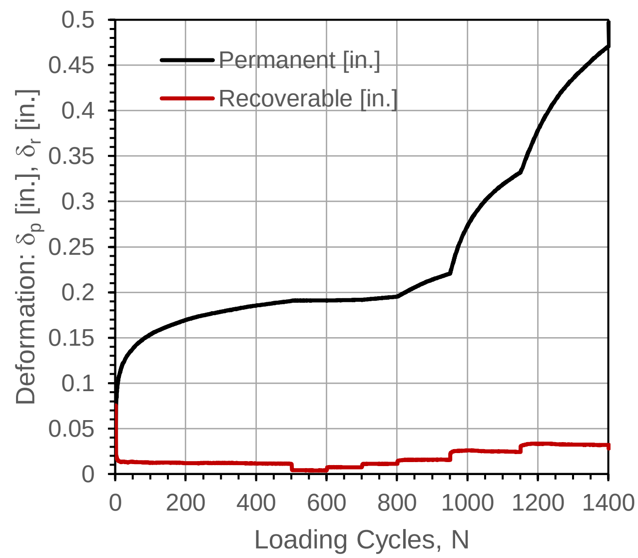
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/12/2017	Time:	2:34:44 PM	Test ID	**STIC_Hwy20_12_5**
Tested By	DV, JV	Location:	Hwy20 EB Lane	Sta.	NA
Latitude,N:	42.474995	Longitude,W:	95.248756	Elev. (ft):	1440
Comments:	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.66	---	---	0.1905	---	0.165	---
1	100	4.15	13,969	14,009	0.1910	0.0005	0.186	Y
2	100	8.30	15,271	15,330	0.1917	0.0012	0.495	Y
3	100	13.66	16,580	16,033	0.1952	0.0047	0.728	N
4	150	18.34	15,851	16,279	0.2206	0.0301	0.980	N
5	200	29.09	16,135	16,294	0.3318	0.1414	0.821	N
6	250	38.39	16,192	16,037	0.4706	0.2802	0.891	N



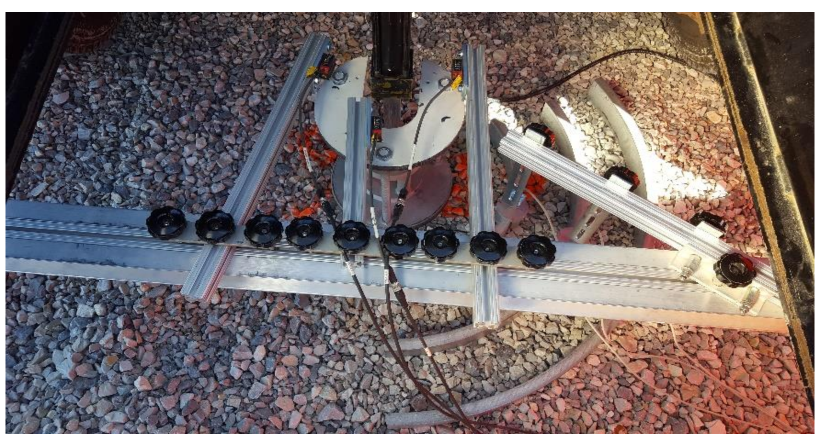


Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	1,071.5	1.62E-07
k^*_2	0.185	3.91E-02
k^*_3	-0.919	9.43E-02
Adj. R^2	0.848	
Std. Error [psi]	344	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	16,350
$\sigma_{cyclic\text{-}BP}$ [psi]	23.6



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #1)

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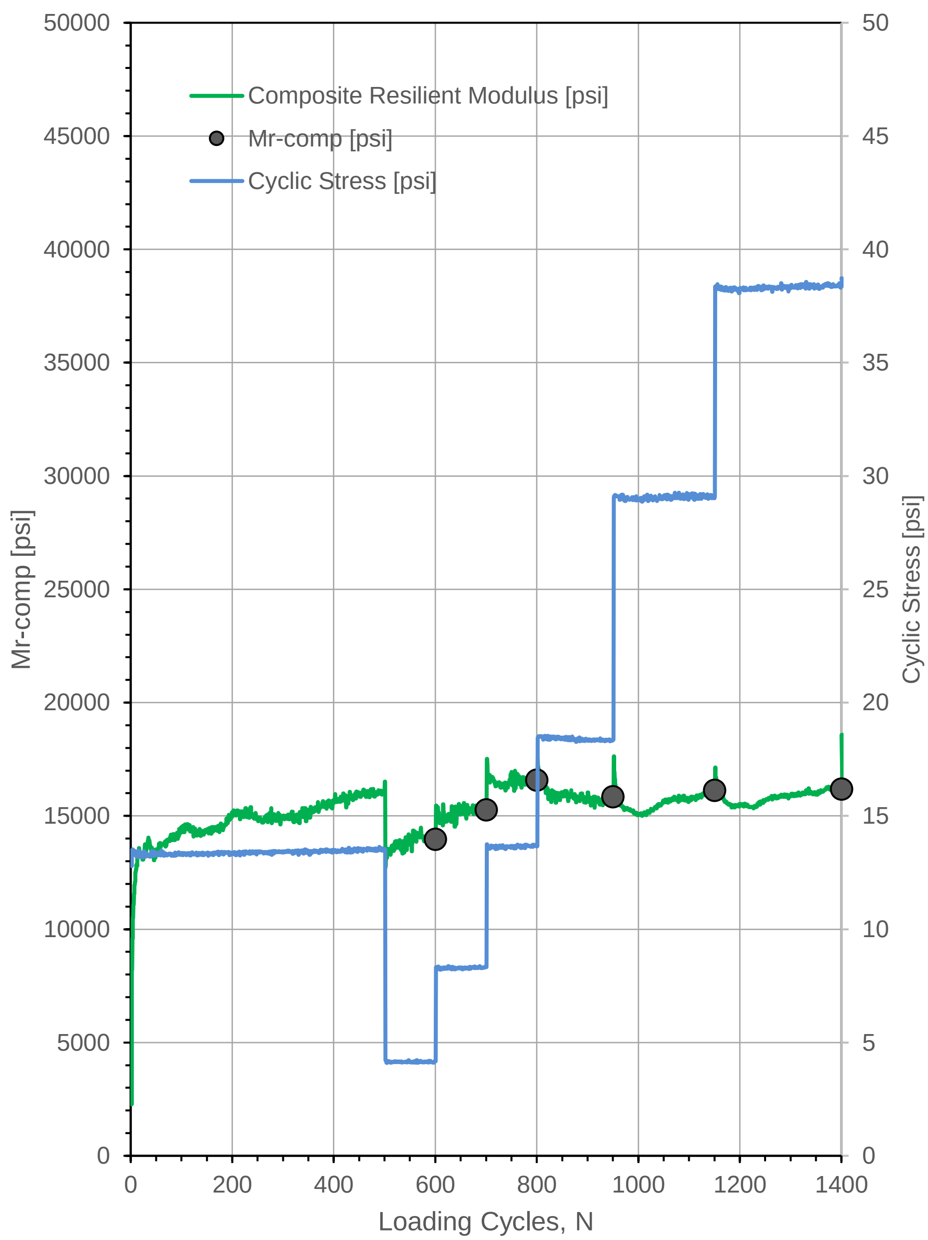
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/12/2017	Time:	2:34:44 PM	Test ID	**STIC_Hwy20_12_5**
Tested By	DV, JV	Location:	Cell 228	Sta.	NA
Latitude,N:	42.474995	Longitude,W:	95.248756	Elev. (ft):	1440
Comments:	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	12,496
3	13,340
4	13,936
5	14,387
6	14,743
7	15,030
8	15,266
9	15,462
10	15,626
11	15,764
12	15,880
13	15,978
14	16,060
15	16,128
16	16,185
17	16,231
18	16,268
21	16,335
22	16,345
23	16,350
24	16,350
25	16,346
26	16,338
27	16,327
28	16,313
29	16,296
30	16,276
31	16,254
32	16,230
33	16,204
34	16,177
35	16,147
36	16,116
37	16,084
38	16,051
39	16,016
40	15,980



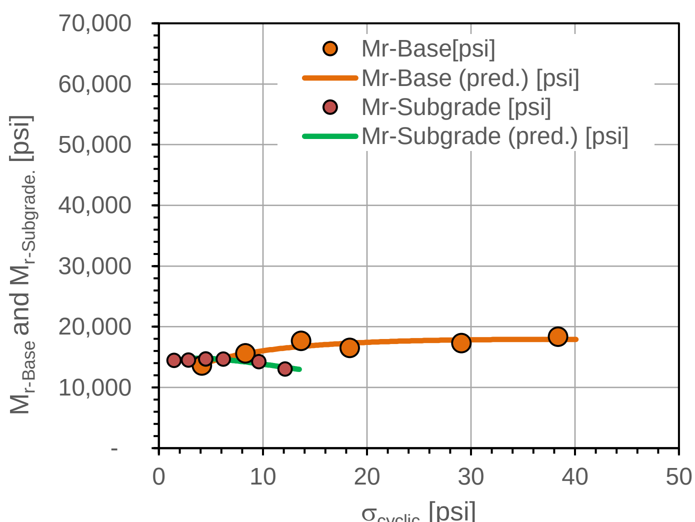
In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

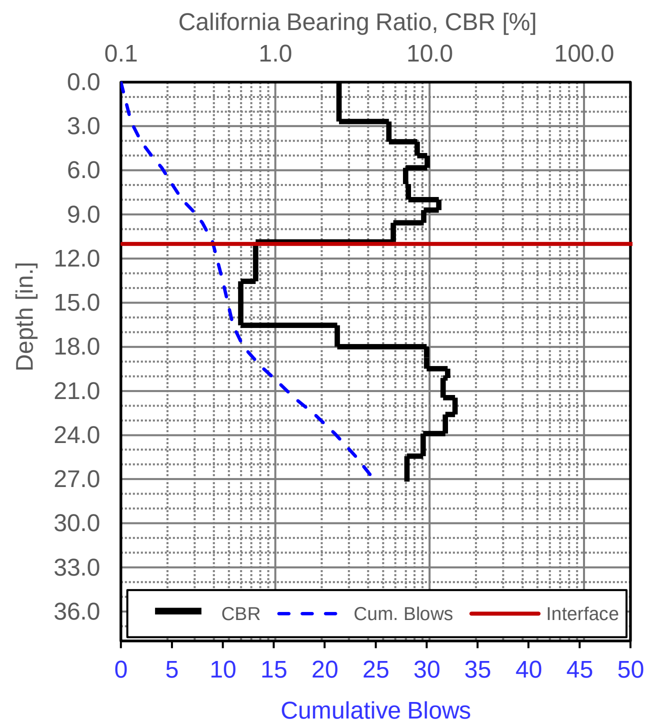
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #1)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/12/2017	Time:	2:34:44 PM	Test ID	**STIC_Hwy20_12_5**
Tested By	DV, JV	Location:	Hwy20 EB Lane	Sta.	NA
Latitude:	42.474995	Longitude:	95.248756	Elev. (ft):	1440
Comments:	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	13.66	---	---	---	---	---	---
1	100	4.15	13,661	13,788	1.47	14,495	14,348	0.94
2	100	8.30	15,630	15,595	2.83	14,526	14,744	1.08
3	100	13.66	17,725	16,746	4.51	14,653	14,791	1.21
4	100	18.34	16,535	17,297	6.18	14,702	14,609	1.12
5	100	29.09	17,319	17,839	9.60	14,296	13,932	1.21
6	100	38.39	18,366	17,916	12.13	13,087	13,325	1.40

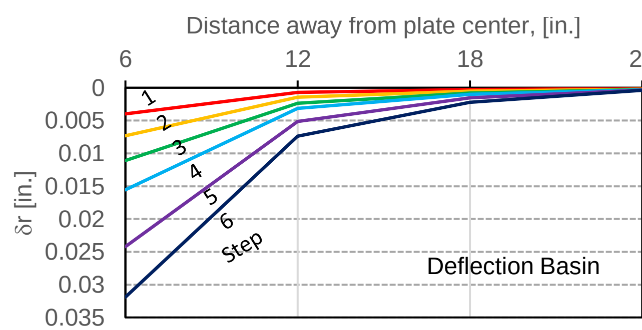




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\ (Base)}$	1066.7	9.99E-07
$k^*_{2\ (Base)}$	0.225	1.02E-01
$k^*_{3\ (Base)}$	-0.794	3.36E-01
Adj. R^2	0.825	
Std. Error [psi]	666	
$k^*_{1\ (Subgrade)}$	1278.4	4.76E-06
$k^*_{2\ (Subgrade)}$	0.167	9.75E-02
$k^*_{3\ (Subgrade)}$	-2.528	5.49E-02
Adj. R^2	0.807	
Std. Error [psi]	250	



In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #1)

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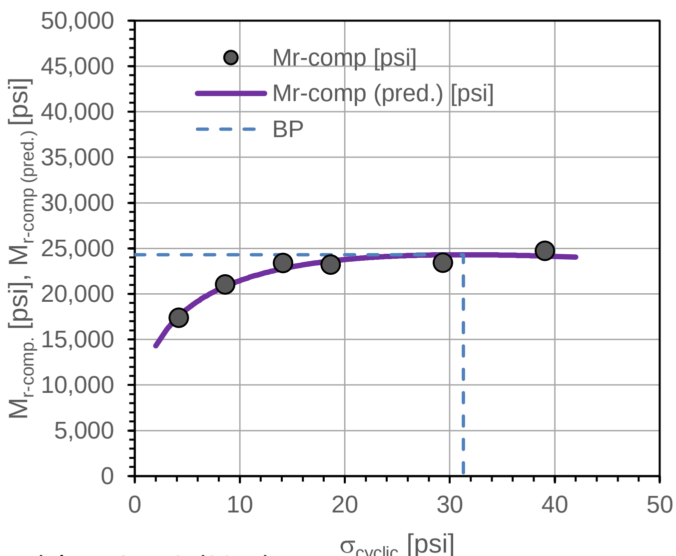
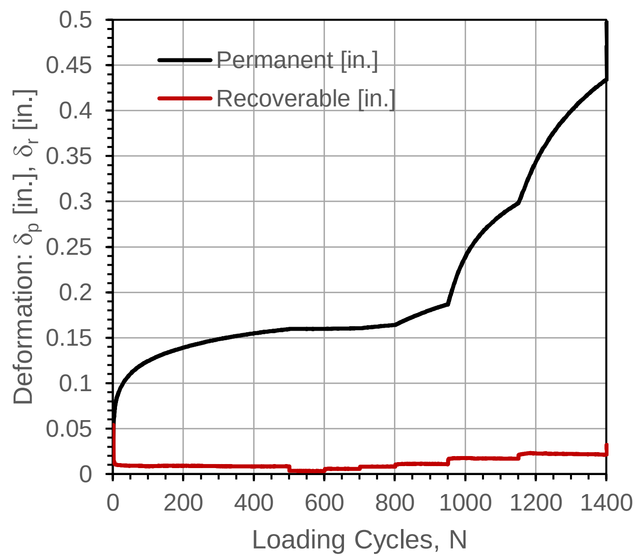
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/12/2017	Time:	3:11:54 PM	Test ID	**STIC_Hwy20_12_6**
Tested By	DV, JV	Location:	Hwy20 EB Lane	Sta.	NA
Latitude,N:	42.475014	Longitude,W:	95.249092	Elev. (ft):	1432
Comments:	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	14.12	---	---	0.1594	---	0.186	---
1	100	4.20	17,398	17,561	0.1598	0.0004	0.080	Y
2	100	8.62	21,050	20,824	0.1604	0.0010	0.502	Y
3	100	14.12	23,394	22,778	0.1640	0.0047	0.841	N
4	150	18.65	23,218	23,610	0.1867	0.0273	0.987	N
5	200	29.35	23,436	24,290	0.2979	0.1385	0.818	N
6	250	39.06	24,754	24,157	0.4340	0.2746	0.895	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	1,433.8	2.50E-07
k^*_2	0.315	1.62E-02
k^*_3	-1.256	7.12E-02
Adj. R^2	0.939	
Std. Error [psi]	641	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	24,302
$\sigma_{cyclic\text{-}BP}$ [psi]	31.3

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #1)

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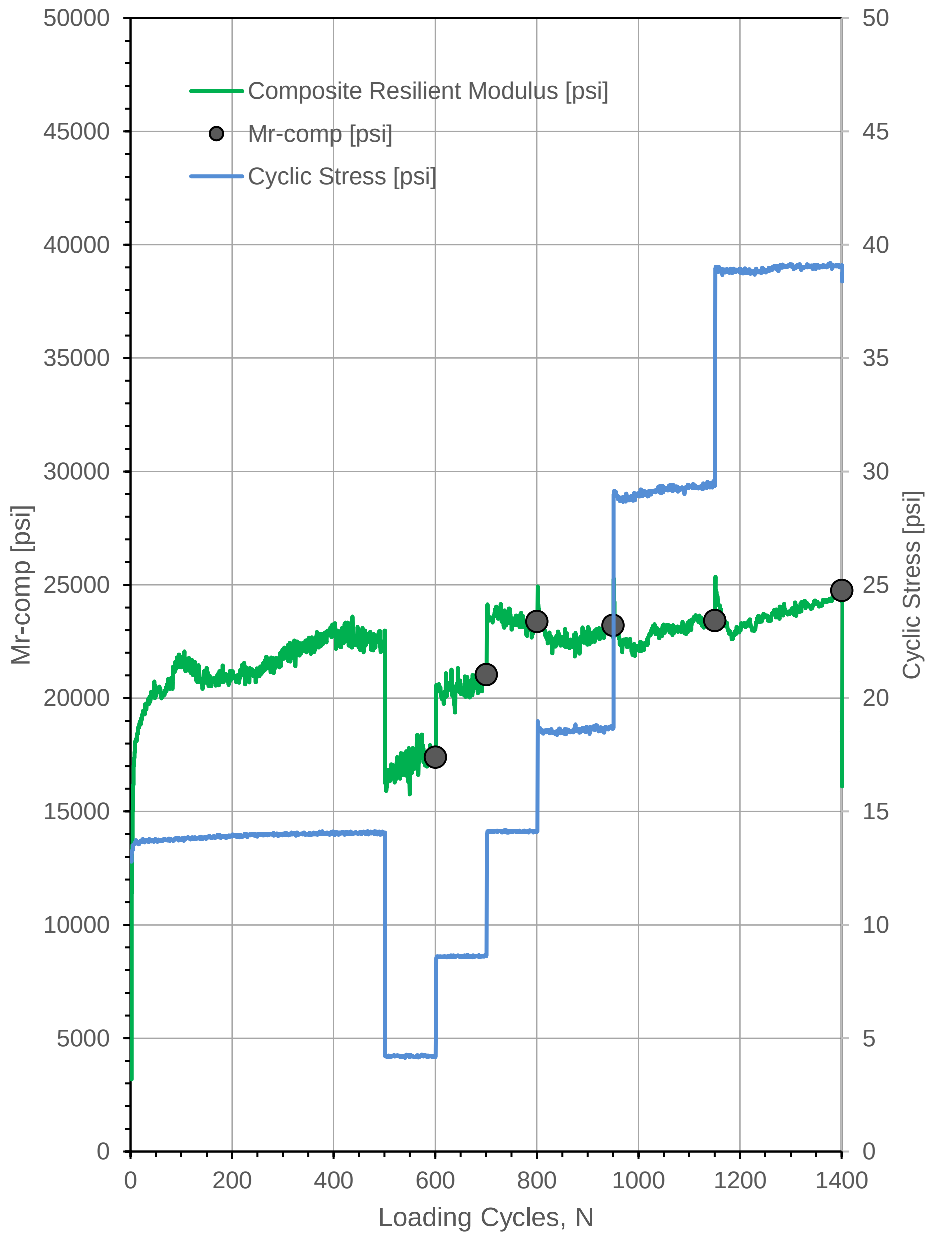
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/12/2017	Time:	3:11:54 PM	Test ID	**STIC_Hwy20_12_6**
Tested By	DV, JV	Location:	Cell 228	Sta.	NA
Latitude,N:	42.475014	Longitude,W:	95.249092	Elev. (ft):	1432
Comments:	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	14,302
3	16,038
4	17,333
5	18,358
6	19,197
7	19,901
8	20,499
9	21,013
10	21,459
11	21,848
12	22,188
13	22,486
14	22,748
15	22,979
16	23,183
17	23,361
18	23,518
21	23,879
22	23,968
23	24,044
24	24,109
25	24,162
26	24,206
27	24,240
28	24,267
29	24,285
30	24,296
31	24,301
32	24,300
33	24,294
34	24,282
35	24,265
36	24,245
37	24,220
38	24,191
39	24,159
40	24,124



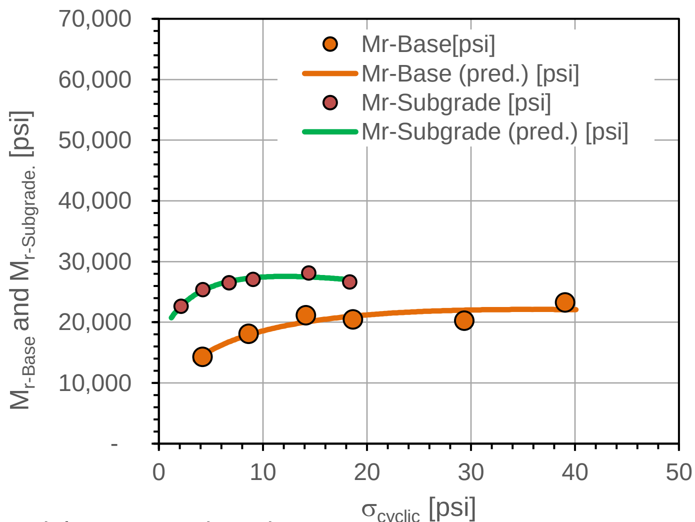
In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

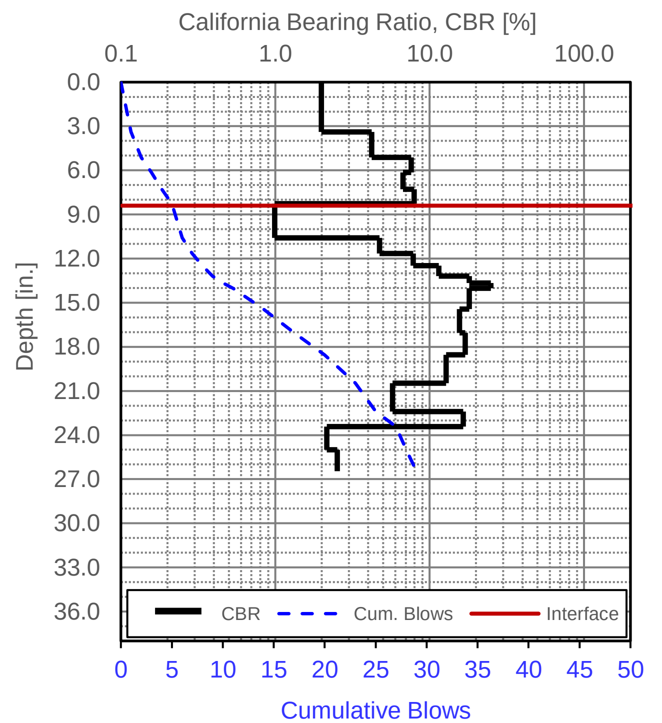
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #1)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/12/2017	Time:	3:11:54 PM	Test ID	**STIC_Hwy20_12_6**
Tested By	DV, JV	Location:	Hwy20 EB Lane	Sta.	NA
Latitude:	42.475014	Longitude:	95.249092	Elev. (ft):	1432
Comments:	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	14.12	---	---	---	---	---	---
1	100	4.20	14,329	14,567	2.12	22,682	22,685	0.63
2	100	8.62	18,151	17,898	4.23	25,395	25,240	0.71
3	100	14.12	21,173	20,029	6.77	26,494	26,718	0.80
4	100	18.65	20,509	21,010	9.05	27,095	27,326	0.76
5	100	29.35	20,278	22,000	14.40	28,129	27,473	0.72
6	100	39.06	23,284	22,094	18.36	26,667	27,009	0.87

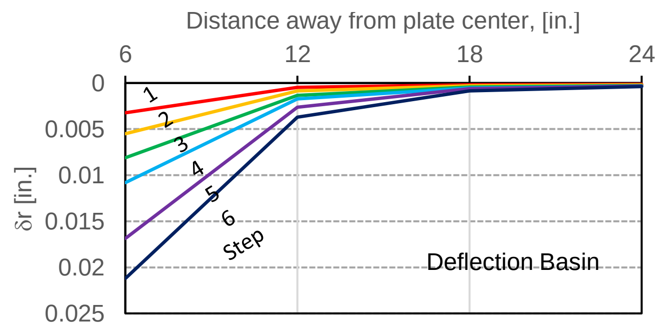




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\ (Base)}$	1219.7	2.47E-06
$k^*_{2\ (Base)}$	0.369	7.14E-02
$k^*_{3\ (Base)}$	-1.331	2.60E-01
Adj. R^2	0.840	
Std. Error [psi]	1165	
$k^*_{1\ (Subgrade)}$	2156.8	5.65E-07
$k^*_{2\ (Subgrade)}$	0.283	8.19E-03
$k^*_{3\ (Subgrade)}$	-1.776	2.23E-02
Adj. R^2	0.952	
Std. Error [psi]	402	



In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #1)

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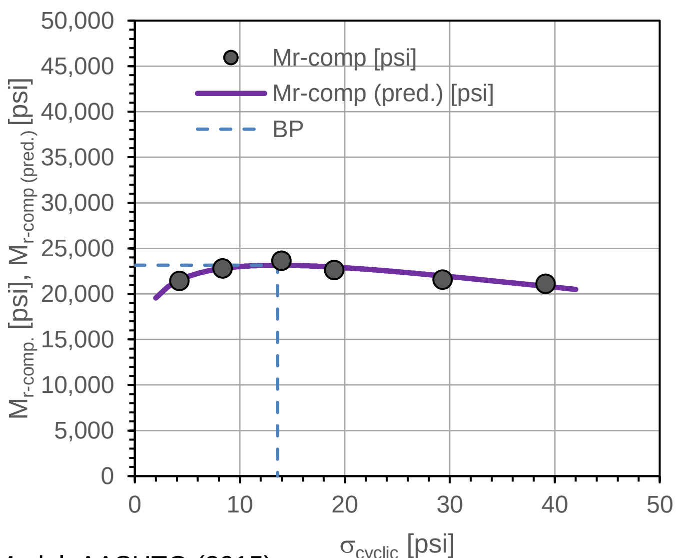
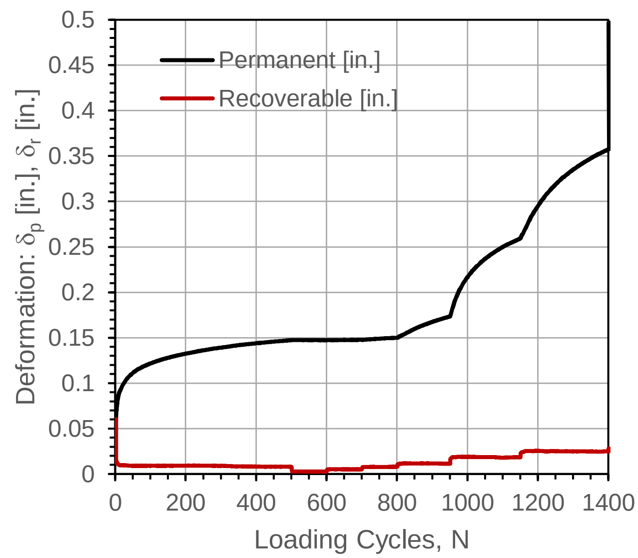
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/12/2017	Time:	3:46:45 PM	Test ID	**STIC_Hwy20_12_7**
Tested By	DV, JV	Location:	Hwy20 EB Lne	Sta.	NA
Latitude,N:	42.475006	Longitude,W:	95.249405	Elev. (ft):	1434
Comments:	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.97	---	---	0.1474	---	0.141	---
1	100	4.27	21,430	21,510	0.1472	-0.0001	-0.254	Y
2	100	8.38	22,800	22,802	0.1476	0.0003	0.272	Y
3	100	13.97	23,671	23,147	0.1500	0.0027	0.747	N
4	150	19.00	22,650	22,943	0.1734	0.0261	0.970	N
5	200	29.32	21,571	21,977	0.2593	0.1119	0.768	N
6	250	39.12	21,118	20,846	0.3573	0.2100	0.840	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	1,655.8	5.84E-08
k^*_2	0.167	2.65E-02
k^*_3	-1.315	2.02E-02
Adj. R^2	0.845	
Std. Error [psi]	359	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	23,148
$\sigma_{cyclic\text{-}BP}$ [psi]	13.6

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #1)

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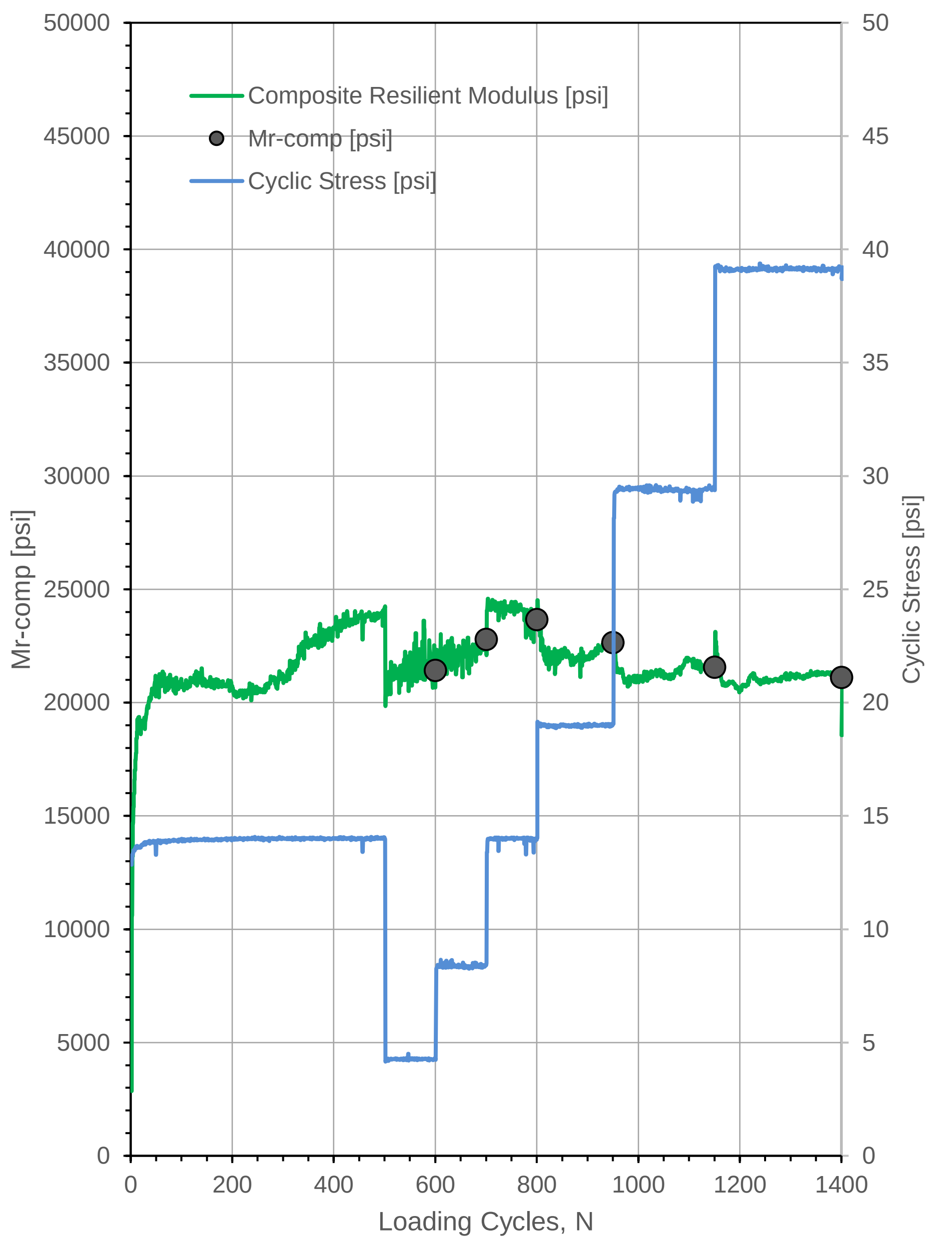
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/12/2017	Time:	3:46:45 PM	Test ID	**STIC_Hwy20_12_7**
Tested By	DV, JV	Location:	Cell 228	Sta.	NA
Latitude,N:	42.475006	Longitude,W:	95.249405	Elev. (ft):	1434
Comments:	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	19,551
3	20,633
4	21,356
5	21,870
6	22,248
7	22,529
8	22,738
9	22,892
10	23,003
11	23,077
12	23,123
13	23,145
14	23,147
15	23,132
16	23,101
17	23,059
18	23,006
21	22,795
22	22,712
23	22,623
24	22,529
25	22,432
26	22,331
27	22,227
28	22,121
29	22,012
30	21,902
31	21,789
32	21,676
33	21,561
34	21,446
35	21,330
36	21,213
37	21,095
38	20,978
39	20,860
40	20,742



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #1)

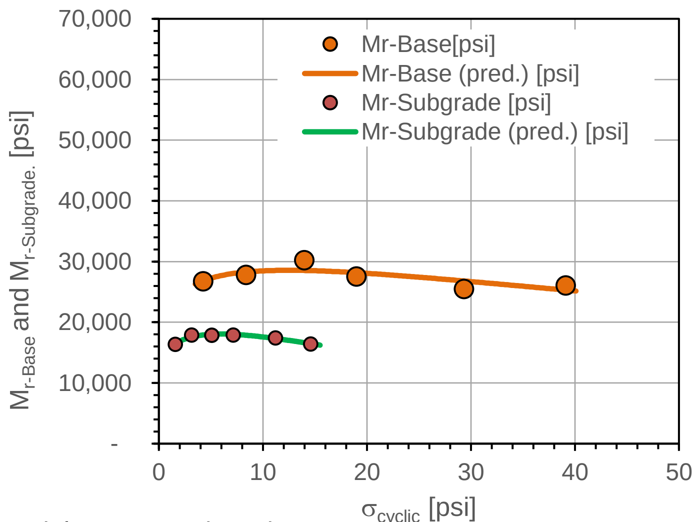
Automated Plate Load Test [APLT]

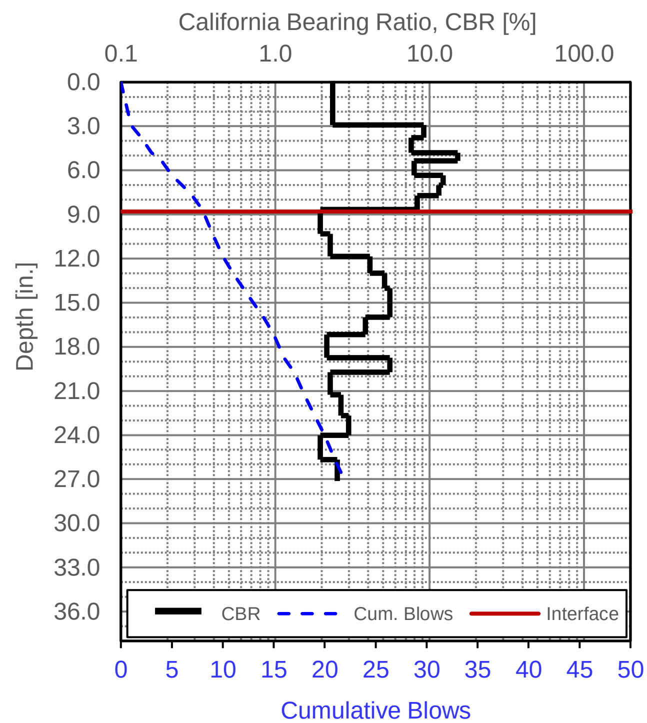
Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)

Date:	10/12/2017	Time:	3:46:45 PM	Test ID	**STIC_Hwy20_12_7**
Tested By	DV, JV	Location:	Hwy20 EB Lne	Sta.	NA
Latitude:	42.475006	Longitude:	95.249405	Elev. (ft):	1434

Comments: Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	13.97	---	---	---	---	---	---
1	100	4.27	26,779	26,860	1.58	16,382	16,487	1.63
2	100	8.38	27,849	28,279	3.14	17,896	17,573	1.56
3	100	13.97	30,235	28,536	5.11	17,827	18,028	1.70
4	100	19.00	27,587	28,170	7.15	17,903	18,009	1.54
5	100	29.32	25,530	26,808	11.20	17,451	17,325	1.46
6	100	39.12	26,079	25,301	14.60	16,448	16,480	1.59

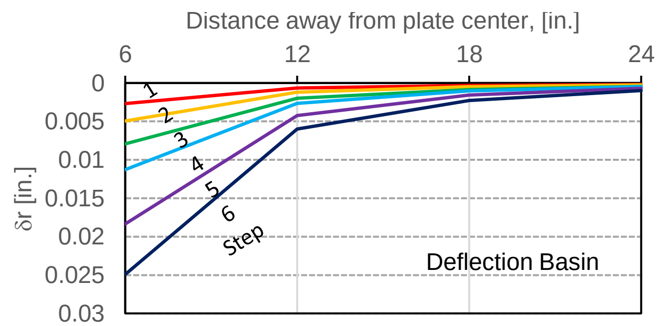




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\ (Base)}$	2064.4	8.13E-07
$k^*_{2\ (Base)}$	0.159	2.15E-01
$k^*_{3\ (Base)}$	-1.350	1.57E-01
Adj. R^2	0.492	
Std. Error [psi]	883	
$k^*_{1\ (Subgrade)}$	1589.7	5.63E-07
$k^*_{2\ (Subgrade)}$	0.233	7.98E-03
$k^*_{3\ (Subgrade)}$	-2.589	7.49E-03
Adj. R^2	0.911	
Std. Error [psi]	208	



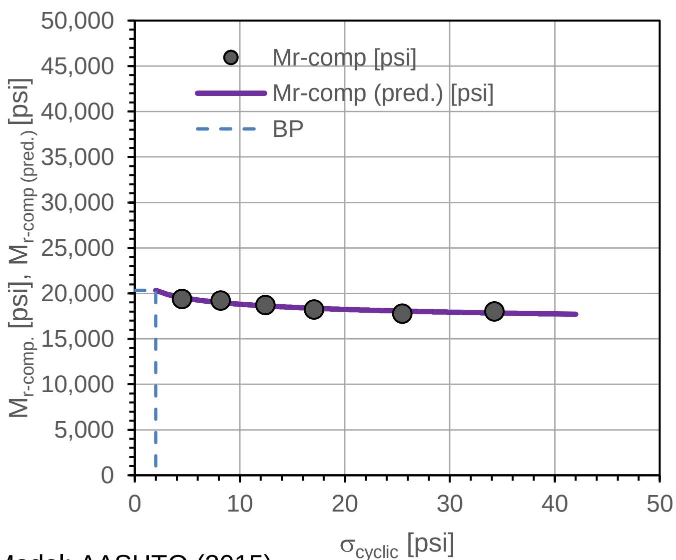
In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

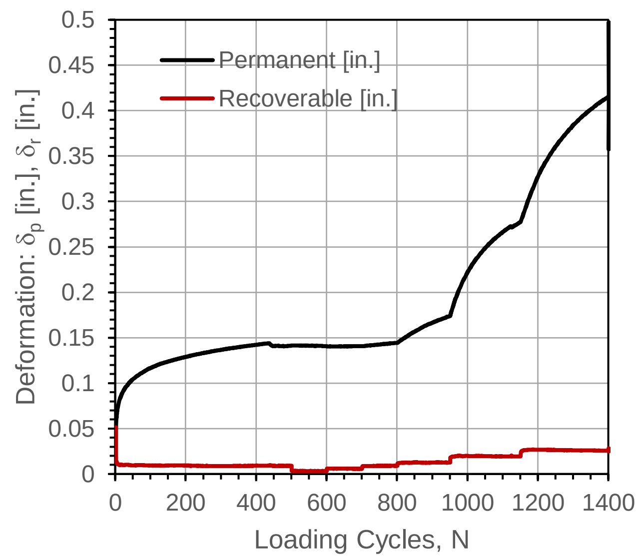
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #1)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/12/2017	Time:	4:23:53 PM	Test ID	**STIC_Hwy20_12_8**
Tested By	DV, JV	Location:	Cell 228	Sta.	NA
Latitude,N:	42.475002	Longitude,W:	95.249680	Elev. (ft):	1430
Comments:	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

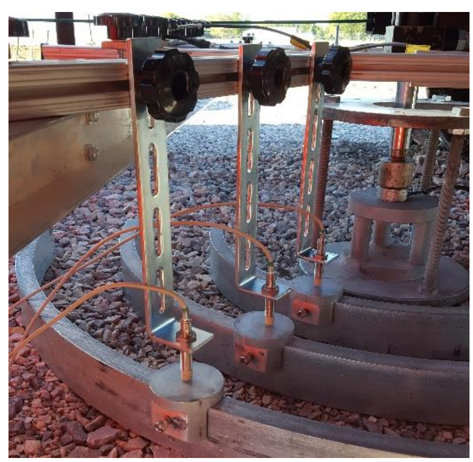
Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	12.45	---	---	0.1413	---	0.162	---
1	100	4.51	19,395	19,539	0.1407	-0.0007	-0.286	Y
2	100	8.18	19,230	18,989	0.1407	-0.0007	0.190	Y
3	100	12.45	18,732	18,623	0.1443	0.0030	0.824	N
4	150	17.07	18,248	18,363	0.1738	0.0324	0.931	N
5	200	25.48	17,780	18,055	0.2773	0.1359	0.823	N
6	250	34.26	18,036	17,845	0.4154	0.2741	0.882	N





Model: AASHTO (2015)

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



Parameter	Value	P-Value
k^*_1	1,303.9	3.82E-08
k^*_2	-0.051	2.42E-01
k^*_3	0.047	8.70E-01
Adj. R^2	0.874	
Std. Error [psi]	221	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	20,337
$\sigma_{cyclic\text{-}BP}$ [psi]	2.0

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Eastbound near Early, IA (Project #1)

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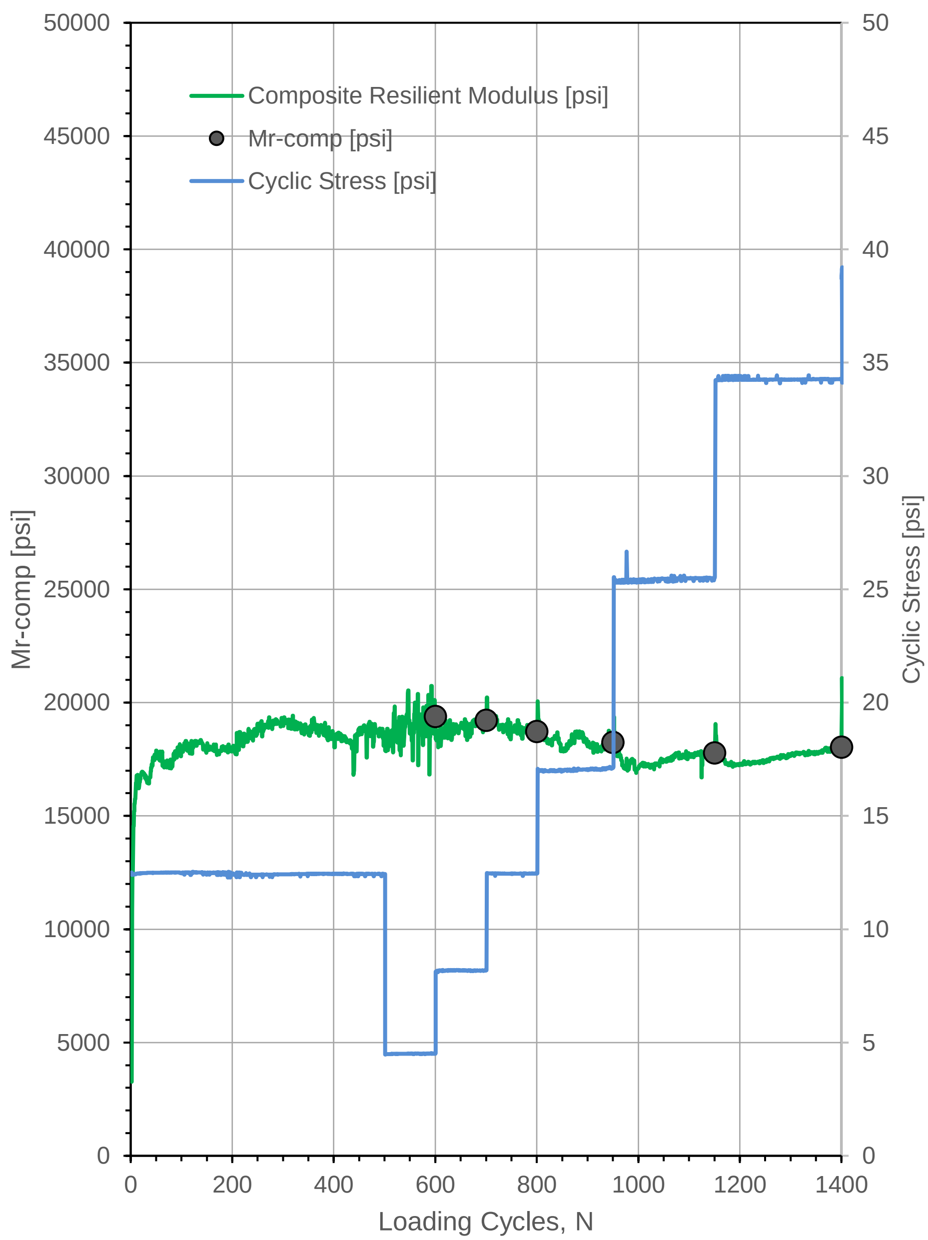
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/12/2017	Time:	4:23:53 PM	Test ID	**STIC_Hwy20_12_8**
Tested By	DV, JV	Location:	Cell 228	Sta.	NA
Latitude,N:	42.475002	Longitude,W:	95.249680	Elev. (ft):	1430
Comments:	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	20,337
3	19,932
4	19,653
5	19,440
6	19,270
7	19,129
8	19,008
9	18,903
10	18,811
11	18,729
12	18,654
13	18,587
14	18,525
15	18,468
16	18,416
17	18,367
18	18,321
21	18,201
22	18,165
23	18,132
24	18,100
25	18,069
26	18,040
27	18,013
28	17,987
29	17,961
30	17,937
31	17,914
32	17,892
33	17,871
34	17,850
35	17,830
36	17,811
37	17,793
38	17,775
39	17,758
40	17,741



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC

Project ID: SIA-00001

Location: Hwy 20, Eastbound near Early, IA (Project #1)

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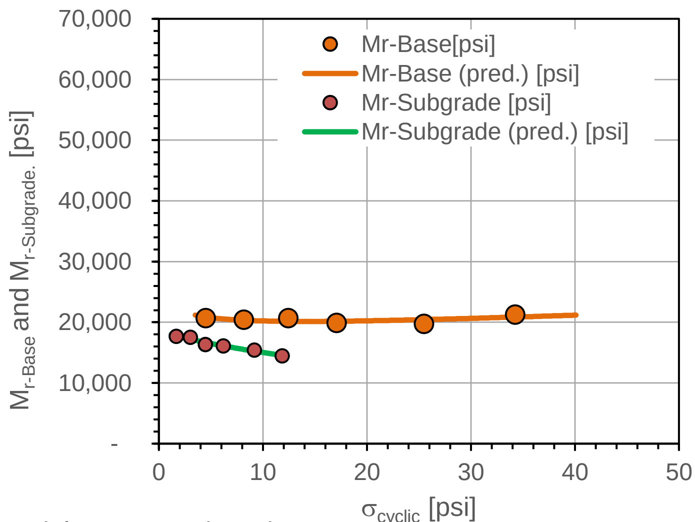
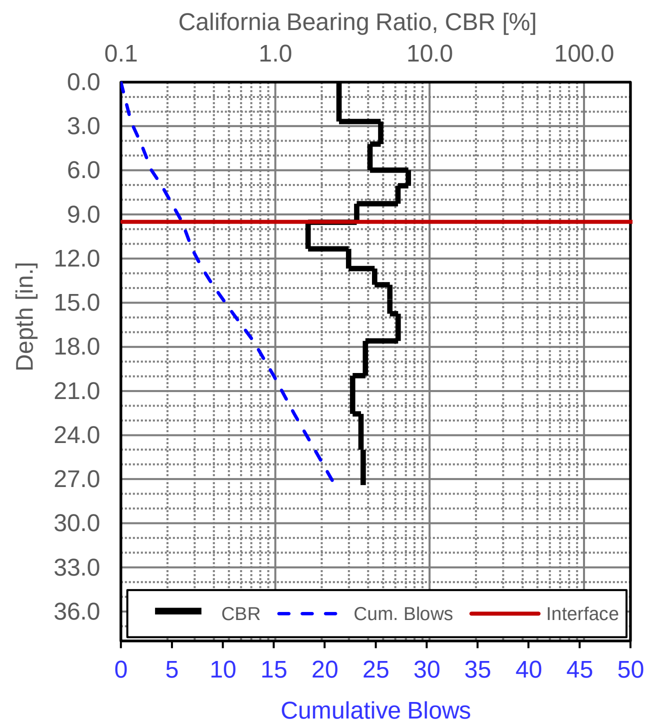
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/12/2017	Time:	4:23:53 PM	Test ID	**STIC_Hwy20_12_8**
Tested By	DV, JV	Location:	Cell 228	Sta.	NA
Latitude:	42.475002	Longitude:	95.249680	Elev. (ft):	1430
Comments:	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	12.45	---	---	---	---	---	---
1	100	4.51	20,684	20,863	1.66	17,719	17,796	1.17
2	100	8.18	20,450	20,330	3.02	17,551	17,216	1.17
3	100	12.45	20,699	20,154	4.49	16,300	16,673	1.27
4	100	17.07	19,932	20,171	6.21	16,132	16,108	1.24
5	100	25.48	19,775	20,438	9.17	15,432	15,244	1.28
6	100	34.26	21,298	20,859	11.85	14,465	14,551	1.47

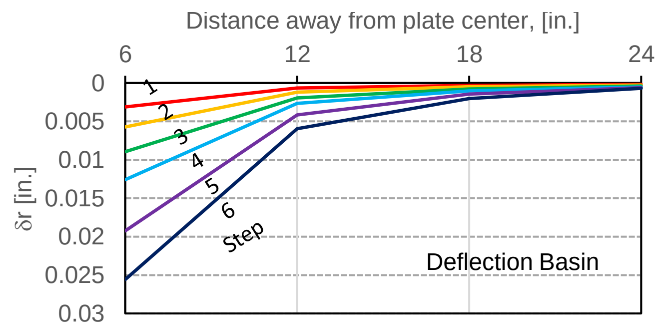




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\ (Base)}$	1340.5	2.91E-07
$k^*_{2\ (Base)}$	-0.082	3.19E-01
$k^*_{3\ (Base)}$	0.628	3.12E-01
Adj. R^2	0.171	
Std. Error [psi]	292	
$k^*_{1\ (Subgrade)}$	1234.2	3.88E-06
$k^*_{2\ (Subgrade)}$	-0.022	7.57E-01
$k^*_{3\ (Subgrade)}$	-1.214	2.16E-01
Adj. R^2	0.951	
Std. Error [psi]	269	



In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #1)

Automated Plate Load Test [APLT]

Test:	In-Situ Static Plate Load Test: Two Loading Cycles.				
Date:	10/12/2017	Time:	5:49:23 PM	Test ID	**Hwy20_30Static_9**
Tested By	DW, JV	Location:	Hwy20 EB Lane	Sta.	NA
Latitude:	42.47498833	Longitude:	95.25001667	Elev. (ft):	1436
Comments:	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

Cycle	Stage	Load Step	Target Applied Load (lbs)	Target Applied Stress (psi)	Actual Applied Stress (psi)	Deformation (in.) Sensor 1	Sensor 2	Sensor 3	Average Def. (in.)
0	Seating	0	707	1	1.29	0.0234	0.0166	0.0245	0.0215
Zero load and deformation sensors after applying the seating stress.									
1	Seating	0	0	0	0.00	0.0000	0.0000	0.0000	0.0000
1	Load	1	1767	2.5	2.50	0.0603	0.0353	0.0597	0.0518
1	Load	2	3534	5	5.01	0.0985	0.0655	0.0980	0.0873
1	Load	3	5301	7.5	7.50	0.1281	0.0921	0.1314	0.1172
1	Load	4	7069	10	9.99	0.1533	0.1151	0.1592	0.1426
1	Load	5	8836	12.5	12.45	0.1786	0.1360	0.1845	0.1663
1	Load	6	10603	15	14.62	0.1988	0.1562	0.2060	0.1870
1	Unload	7	7069	10	9.74	0.1930	0.1512	0.2009	0.1817
1	Unload	8	3534	5	4.47	0.1843	0.1440	0.1923	0.1735
1	Unload	9	1767	2.5	2.49	0.1793	0.1396	0.1873	0.1687
2	Load	10	3534	5	5.01	0.1822	0.1417	0.1895	0.1711
2	Load	11	7069	10	9.98	0.1901	0.1483	0.1974	0.1786
2	Load	12	10603	15	14.74	0.2031	0.1597	0.2118	0.1915
2	Unload	13	1767	2.5	2.42	0.1836	0.1424	0.1916	0.1725
2	Unload	14	0	0	0.00	0.1756	0.1361	0.1844	0.1654

Plate Diameter:	30.0	in.
Shape factor:	2.67	
Material Type:	B	A = Cohesive, B = Granular, C = Intermediate
Poisson's ratio:	0.35	
Design Stress:	10.0	psi
Target Deformation:	0.05	in.

AASHTO T222 Method
PCA Design Criteria

k_{u1} (pci) @ design stress:	70
k_u (pci) @ δ = 0.05 in.:	58

Modulus at target deformation

Stress @ δ = 0.05 in. (psi)	2.9
E_1 (psi)	2,050
k'_u (pci)	58
k_u (pci)	58

Plate Bending Correction for

$$k'_u \geq 100 \text{ and } 1{,}000 \text{ pci}$$

$$k_u = -39.9178 + 5.5076\,[k'_u]^{0.7019}$$

Modulus at target/design applied stress

First Loading Cycle

δ_1 (in.)	0.1423
E_1 (psi)	2,467
k'_{u1} (pci)	70
k_{u1} (pci)	70

Second Loading Cycle

δ_2 (in.)	0.0105
E_2 (psi)	22,414
k'_{u2} (pci)	952
k_{u2} (pci)	639
E_2 / E_1 or k_2 / k_1 Ratio	9.1

In-situ Modulus of Subgrade Reaction (k) and Elastic Modulus

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #1)

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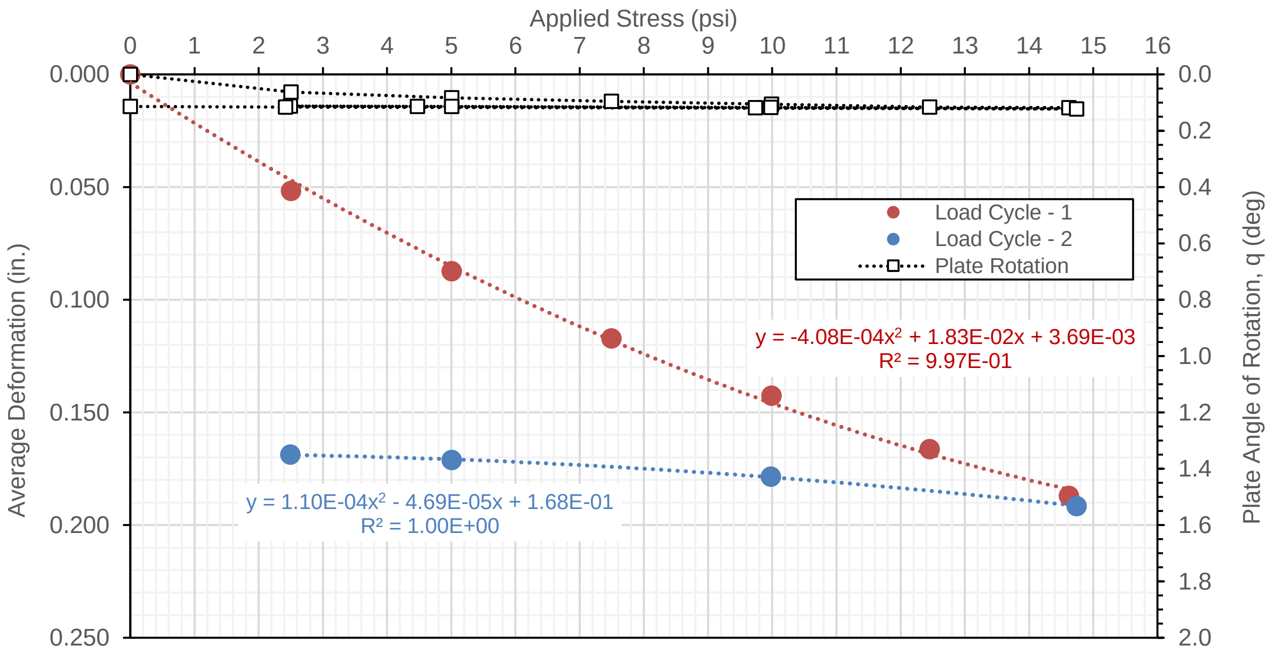
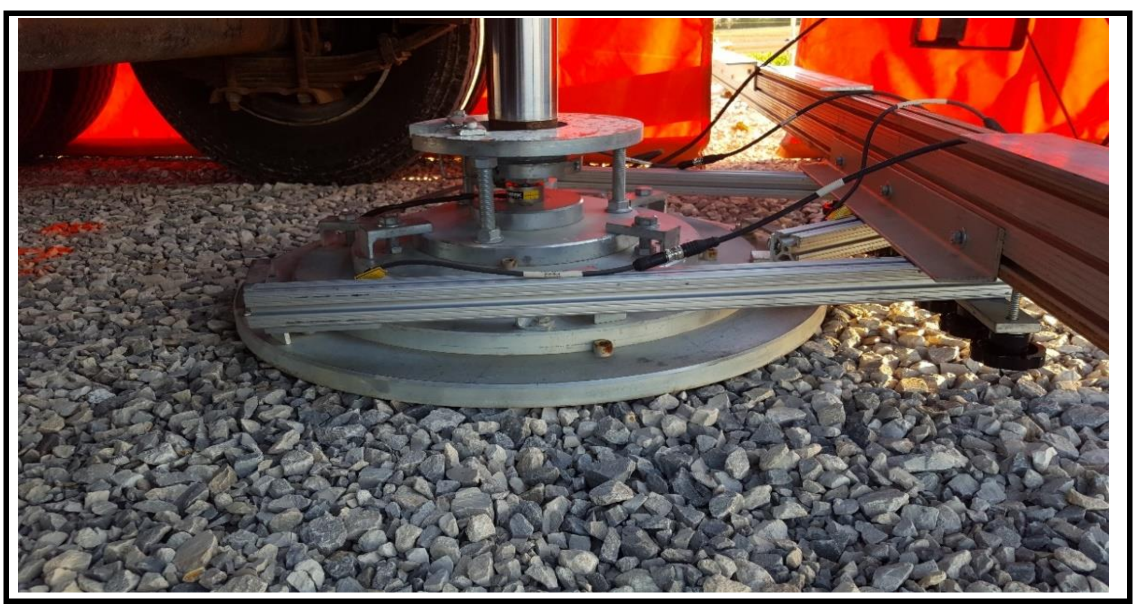
Polynomial Fit Parameters

First Cycle		*Second Cycle*			
a_1	-4.08E-04	a_1	1.10E-04	θ_{max} (deg)	0.1230
a_2	1.83E-02	a_2	-4.69E-05		
R^2	1.00	R^2	1.00		

NOTES:
1. Test performed per AASHTO T222/ASTM D1196.
2. k-value determined using:
(a) calculated stress at 0.05 in. plate deformation (d) for first loading cycle, per PCA design guidelines, and
(b) for a defined target stress and calculating corresponding plate deformations using polynomial fit parameters.





Date of Test	10/12/2017	Test ID	Pt1	Operator	DW, JV	ASTM	D6951
Latitude	42.4749830		Longitude	95.2474140		Elevation (ft)	1445
Location	Hwy20 EB Lane		Station	NA			
Comments	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming. Subgrade assumed as CL in DCP-CBR calculations.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	45.4	4.1	6.3	1,387
Avg. Subgrade Layer (top 12 in.)	23.2	6.4	8.4	1,875
Ratio of Avg. Top/Bottom Layer	2.0	0.6	0.7	0.7
Std.Dev.Subbase Layer	21.8	1.9	3.8	831
Std. Dev. Subgrade Layer (top 12 in.)	9.8	4.4	6.6	1,453

NOTES:

Subgrade is classified as CL

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

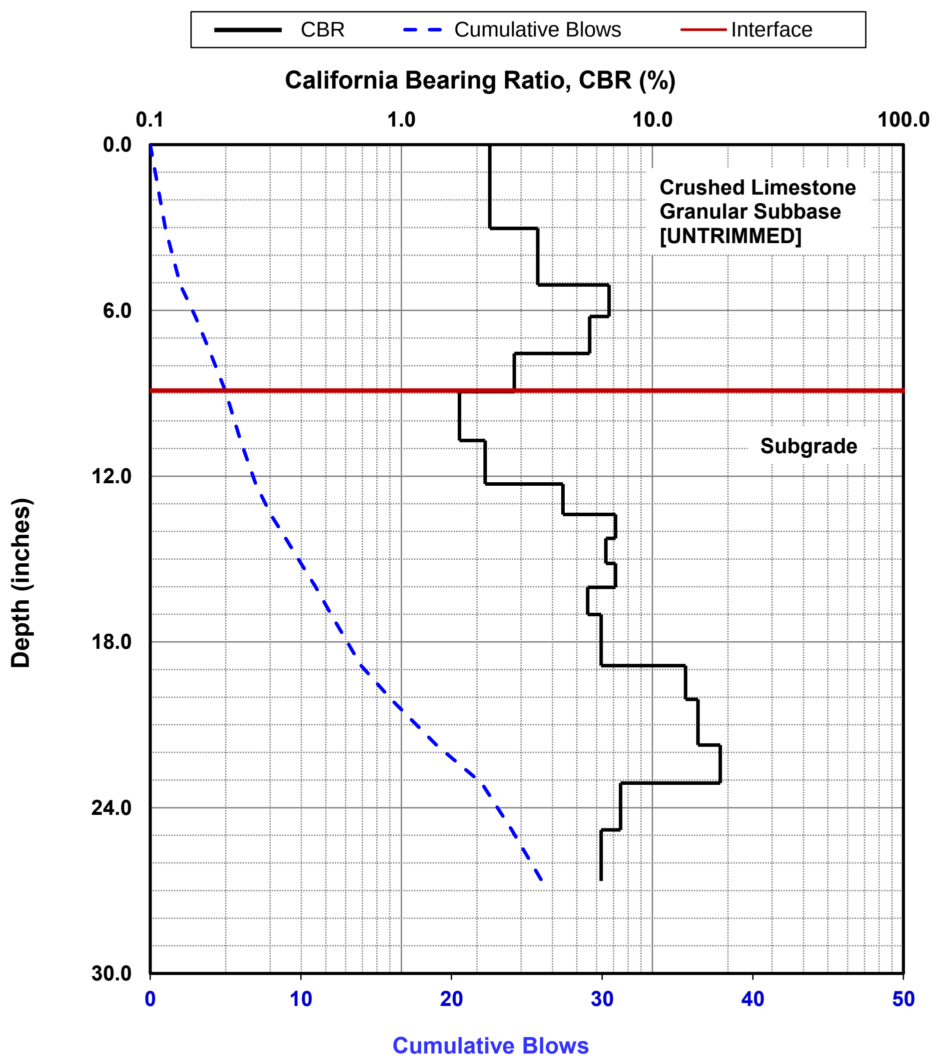
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Eastbound near Early, IA (Project #1)

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Date of Test	10/12/2017	Test ID	Pt2	Operator	DW, JV	ASTM	D6951
Latitude	42.4749950		Longitude	95.2477570		Elevation (ft)	1438
Location	Hwy20 EB Lane		Station	NA			
Comments	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming. Subgrade assumed as CL in DCP-CBR calculations.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	32.9	5.8	7.9	1,764
Avg. Subgrade Layer (top 12 in.)	23.7	6.2	8.2	1,825
Ratio of Avg. Top/Bottom Layer	1.4	0.9	1.0	1.0
Std.Dev.Subbase Layer	22.3	3.6	5.8	1,289
Std. Dev. Subgrade Layer (top 12 in.)	18.8	7.0	8.9	1,987

NOTES:

Subgrade is classified as CL

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

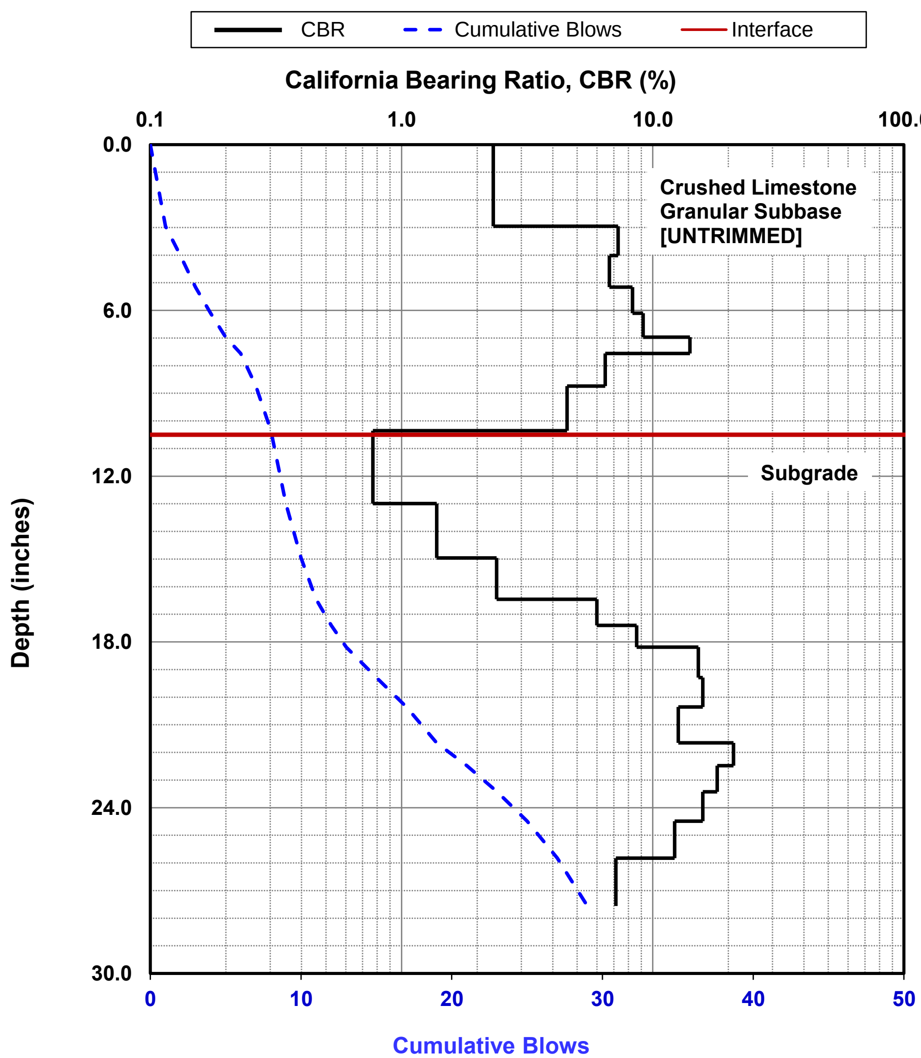
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Eastbound near Early, IA (Project #1)

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Date of Test	10/12/2017	Test ID	Pt3	Operator	DW, JV	ASTM	D6951
Latitude	42.4749950		Longitude	95.2480770		Elevation (ft)	1442
Location	Hwy20 EB Lane		Station	NA			
Comments	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming. Subgrade assumed as CL in DCP-CBR calculations.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	26.9	7.3	9.1	2,048
Avg. Subgrade Layer (top 12 in.)	32.2	3.3	5.5	1,213
Ratio of Avg. Top/Bottom Layer	0.8	2.2	1.7	1.7
Std.Dev.Subbase Layer	7.5	2.3	4.4	953
Std. Dev. Subgrade Layer (top 12 in.)	12.3	2.6	4.8	1,043

NOTES:

Subgrade is classified as CL

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

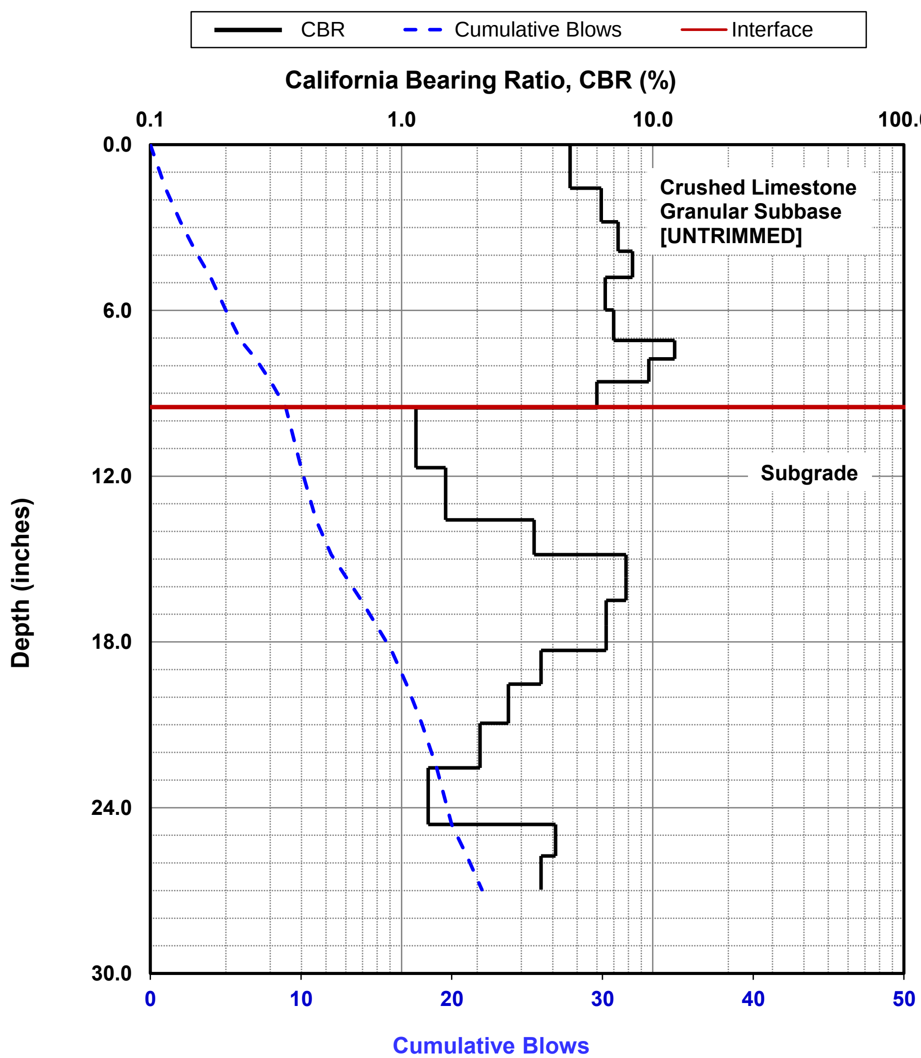
[2]E (ksi) = $(17.6\ CBR^{0.64}) \times 0.1450377$

[3]S_u (psf) = $(3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Eastbound near Early, IA (Project #1)

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Date of Test	10/12/2017	Test ID	Pt4	Operator	DW, JV	ASTM	D6951
Latitude	42.4749870	Longitude		95.2484130		Elevation (ft)	1440
Location	Hwy20 EB Lane	Station		NA			
Comments	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming. Subgrade assumed as CL in DCP-CBR calculations.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	45.6	4.0	6.2	1,383
Avg. Subgrade Layer (top 12 in.)	31.8	3.4	5.6	1,235
Ratio of Avg. Top/Bottom Layer	1.4	1.2	1.1	1.1
Std.Dev.Subbase Layer	15.5	1.5	3.3	721
Std. Dev. Subgrade Layer (top 12 in.)	12.1	2.5	4.6	1,010

NOTES:

Subgrade is classified as CL

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

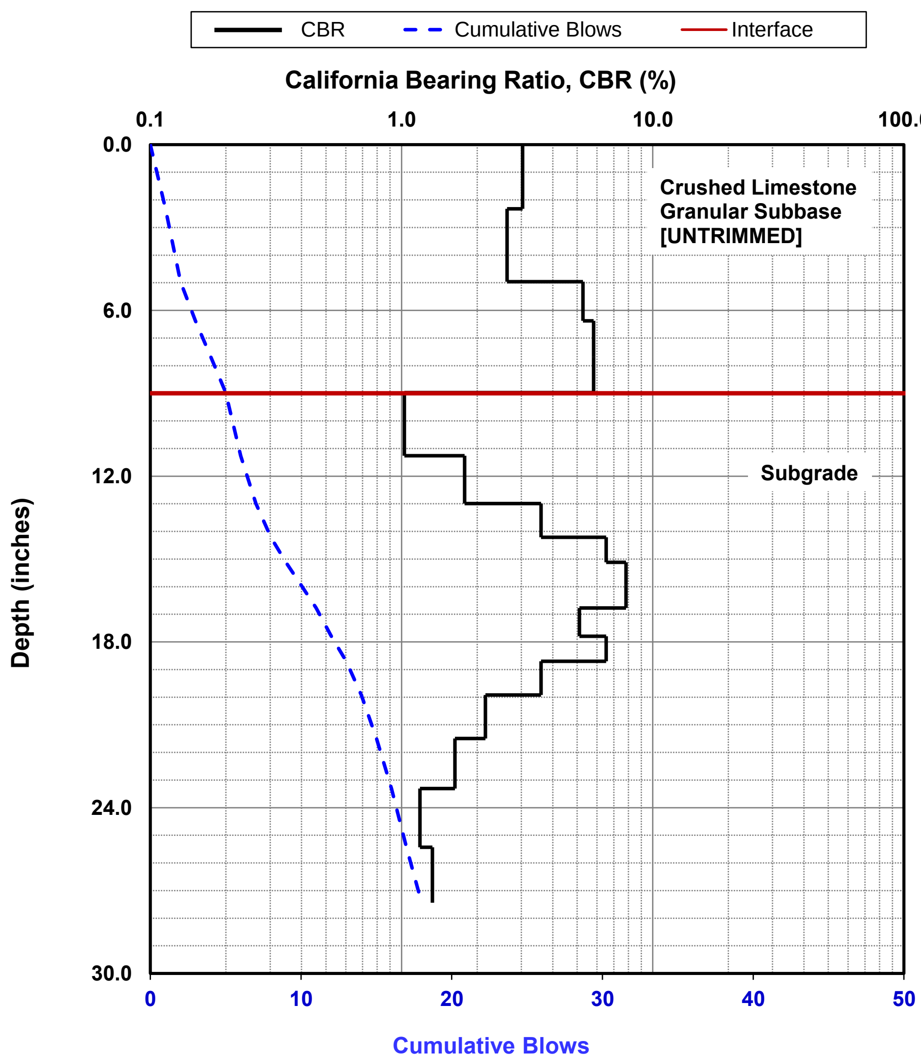
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Eastbound near Early, IA (Project #1)

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Date of Test	10/12/2017	Test ID	Pt5	Operator	DW, JV	ASTM	D6951
Latitude	42.4749950		Longitude	95.2487560		Elevation (ft)	1447
Location	Hwy20 EB Lane		Station	NA			
Comments	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming. Subgrade assumed as CL in DCP-CBR calculations.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	30.7	6.3	8.3	1,857
Avg. Subgrade Layer (top 12 in.)	29.8	3.9	6.1	1,346
Ratio of Avg. Top/Bottom Layer	1.0	1.6	1.4	1.4
Std.Dev.Subbase Layer	18.5	2.9	5.1	1,110
Std. Dev. Subgrade Layer (top 12 in.)	25.0	5.7	7.8	1,741

NOTES:

Subgrade is classified as CL

[1] $CBR = 292/DPI^{1.12}$

[1] $CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

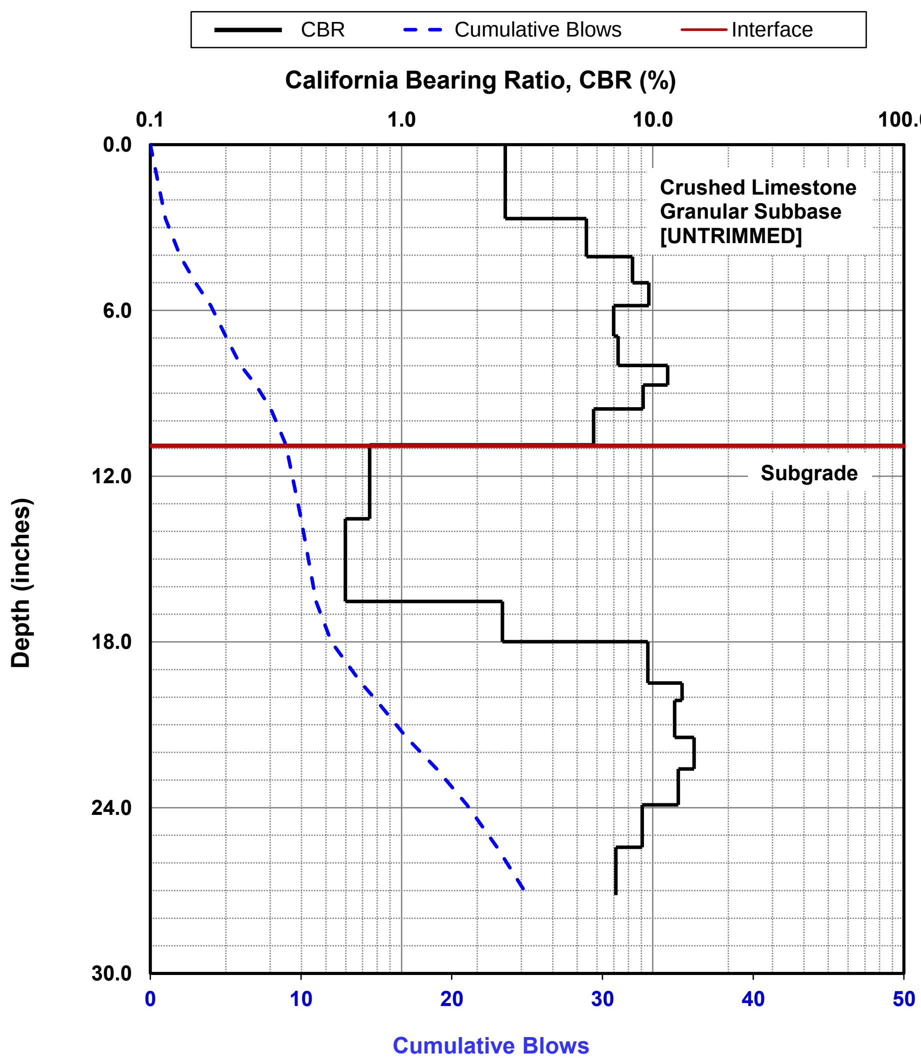
[2] $E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3] $S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2] Powell et al. (1986)

[3] Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Eastbound near Early, IA (Project #1)

Date of Test	10/12/2017	Test ID	Pt6	Operator	DW, JV	ASTM	D6951
Latitude	42.4750140		Longitude	95.2490920		Elevation (ft)	1439
Location	Hwy20 EB Lane		Station	NA			
Comments	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming. Subgrade assumed as CL in DCP-CBR calculations.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	42.0	4.4	6.6	1,470
Avg. Subgrade Layer (top 12 in.)	17.2	12.0	12.6	2,852
Ratio of Avg. Top/Bottom Layer	2.4	0.4	0.5	0.5
Std.Dev.Subbase Layer	29.2	2.7	4.8	1,062
Std. Dev. Subgrade Layer (top 12 in.)	14.6	7.1	9.0	2,013

NOTES:

Subgrade is classified as CL

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019 DPI)^2$

for CL soils with CBR < 10

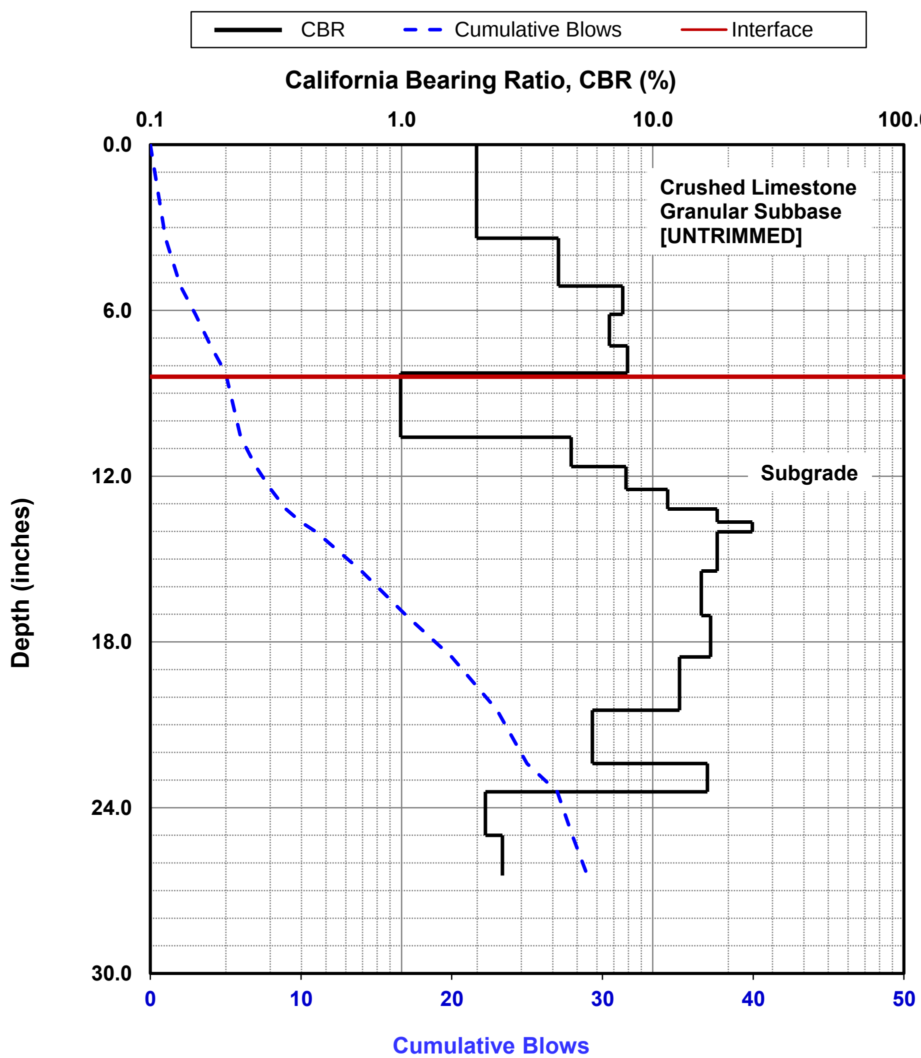
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2] Powell et al. (1986)

[3] Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name: Iowa DOT STIC

Project ID: SIA-00001

Location: Hwy 20, Eastbound near Early, IA (Project #1)

Date of Test	10/12/2017	Test ID	Pt7	Operator	DW, JV	ASTM	D6951
Latitude	42.4750060		Longitude	95.2494050		Elevation (ft)	1441
Location	Hwy20 EB Lane		Station	NA			
Comments	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming. Subgrade assumed as CL in DCP-CBR calculations.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	27.5	7.1	9.0	2,014
Avg. Subgrade Layer (top 12 in.)	32.0	3.4	5.6	1,224
Ratio of Avg. Top/Bottom Layer	0.9	2.1	1.6	1.6
Std.Dev.Subbase Layer	23.8	4.3	6.4	1,428
Std. Dev. Subgrade Layer (top 12 in.)	7.1	1.5	3.4	729

NOTES:

Subgrade is classified as CL

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

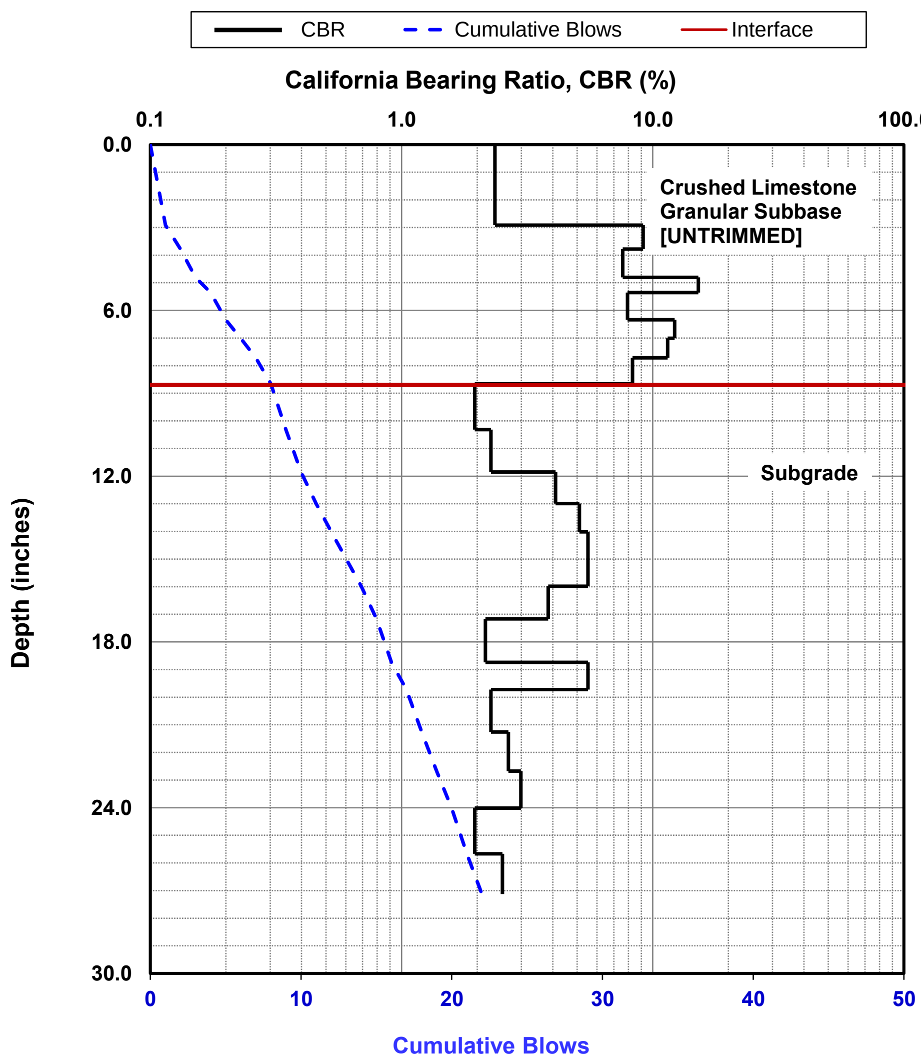
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Eastbound near Early, IA (Project #1)

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Date of Test	10/12/2017	Test ID	Pt8	Operator	DW, JV	ASTM	D6951
Latitude	42.4750020	Longitude		95.2496800		Elevation (ft)	1437
Location	Hwy20 EB Lane	Station		NA			
Comments	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming. Subgrade assumed as CL in DCP-CBR calculations.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	40.3	4.6	6.8	1,515
Avg. Subgrade Layer (top 12 in.)	30.1	3.8	6.0	1,329
Ratio of Avg. Top/Bottom Layer	1.3	1.2	1.1	1.1
Std.Dev.Subbase Layer	17.2	1.8	3.7	809
Std. Dev. Subgrade Layer (top 12 in.)	7.3	1.6	3.4	734

NOTES:

Subgrade is classified as CL

[1] $CBR = 292/DPI^{1.12}$

[1] $CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

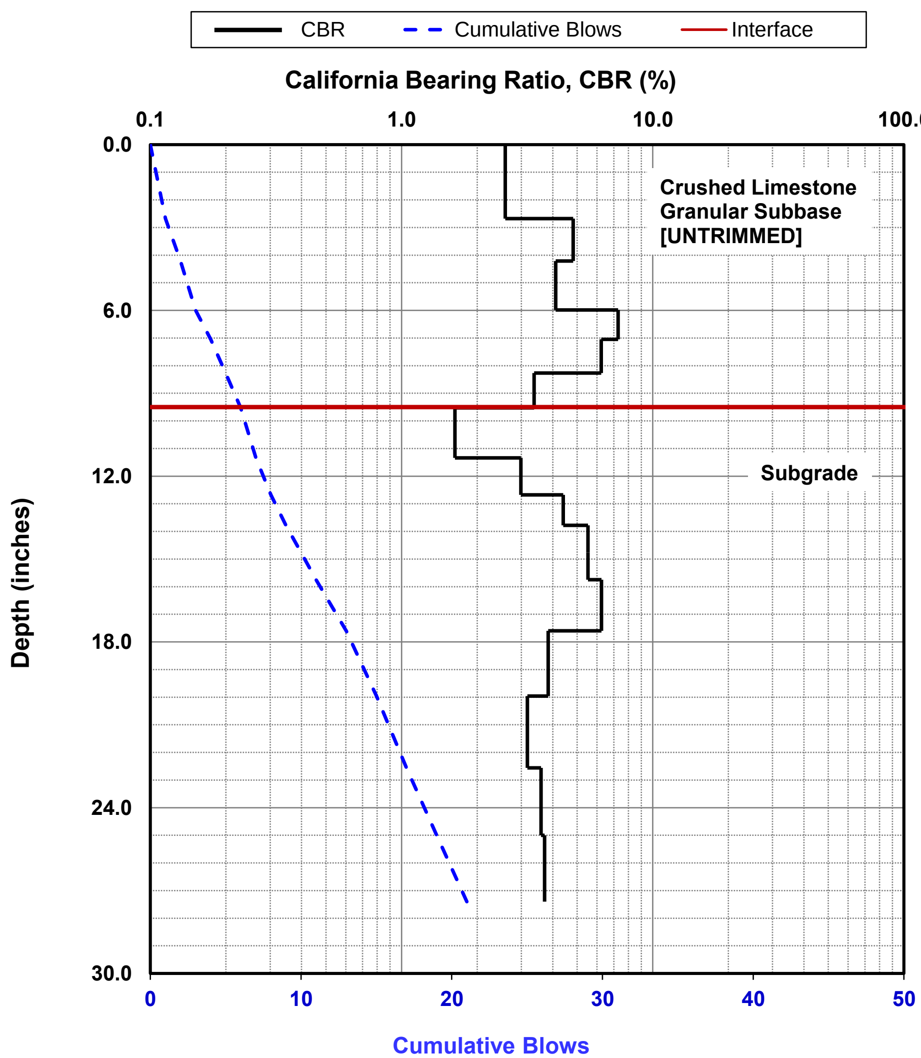
[2] $E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3] $S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2] Powell et al. (1986)

[3] Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Eastbound near Early, IA (Project #1)

Date of Test	10/12/2017	Test ID	Pt9	Operator	DW, JV	ASTM	D6951
Latitude	42.4749883	Longitude	95.2496800			Elevation (ft)	1436
Location	Hwy20 EB Lane	Station	NA				
Comments	Virgin aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming. Subgrade assumed as CL in DCP-CBR calculations.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	27.1	7.2	9.1	2,035
Avg. Subgrade Layer (top 12 in.)	28.0	4.4	6.6	1,462
Ratio of Avg. Top/Bottom Layer	1.0	1.6	1.4	1.4
Std.Dev.Subbase Layer	10.9	2.8	5.0	1,092
Std. Dev. Subgrade Layer (top 12 in.)	8.3	2.1	4.1	894

NOTES:

Subgrade is classified as CL

[1] $CBR = 292/DPI^{1.12}$

[1] $CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

[2] $E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3] $S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2] Powell et al. (1986)

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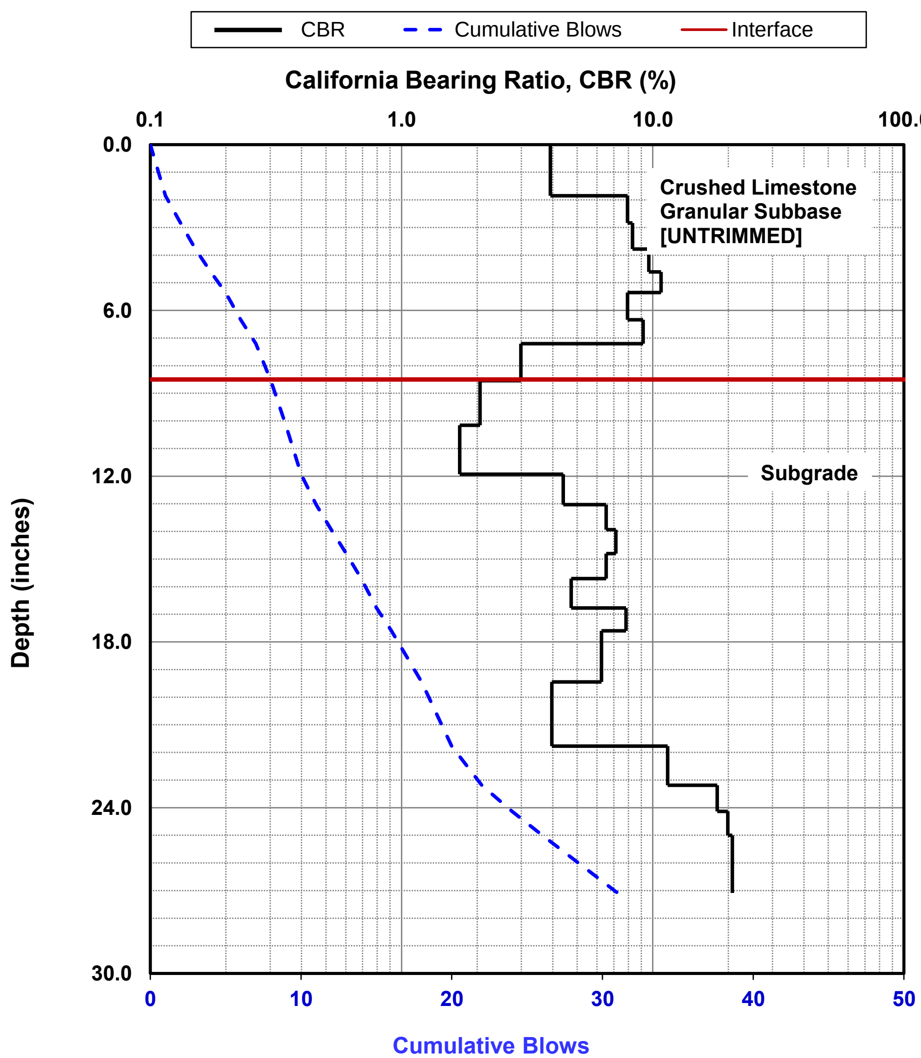

Dynamic Cone Penetrometer (DCP) Test Results	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Eastbound near Early, IA (Project #1)

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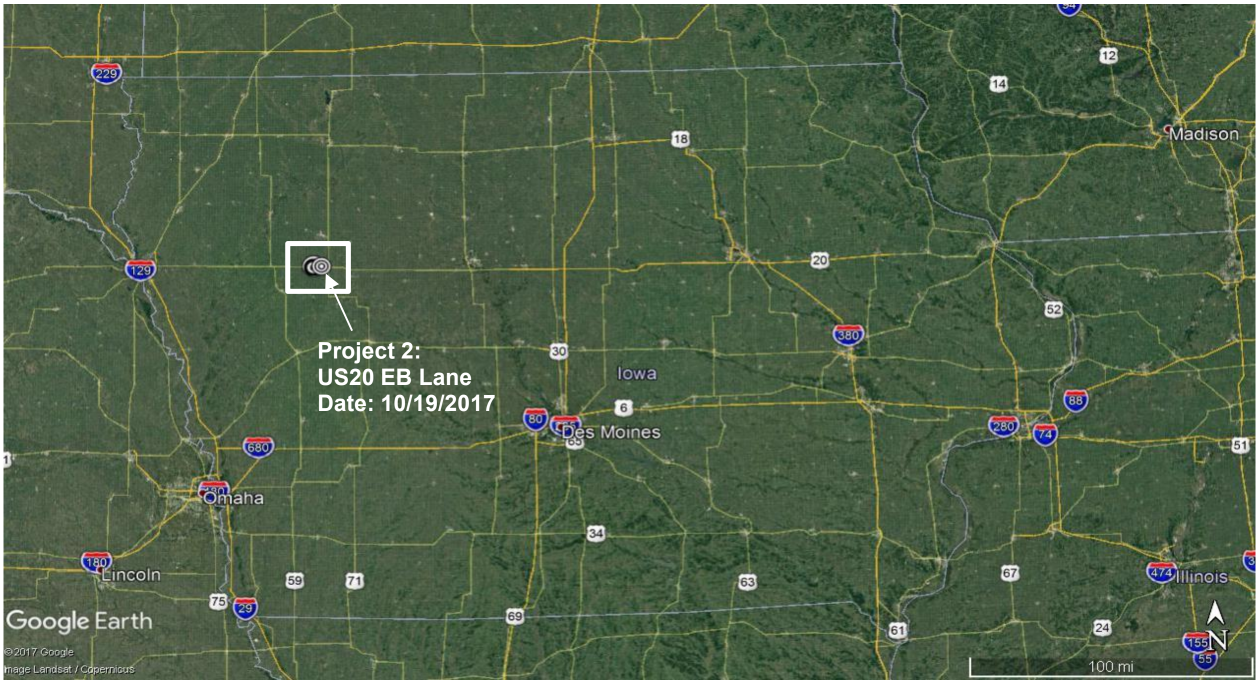
Field Project # 2

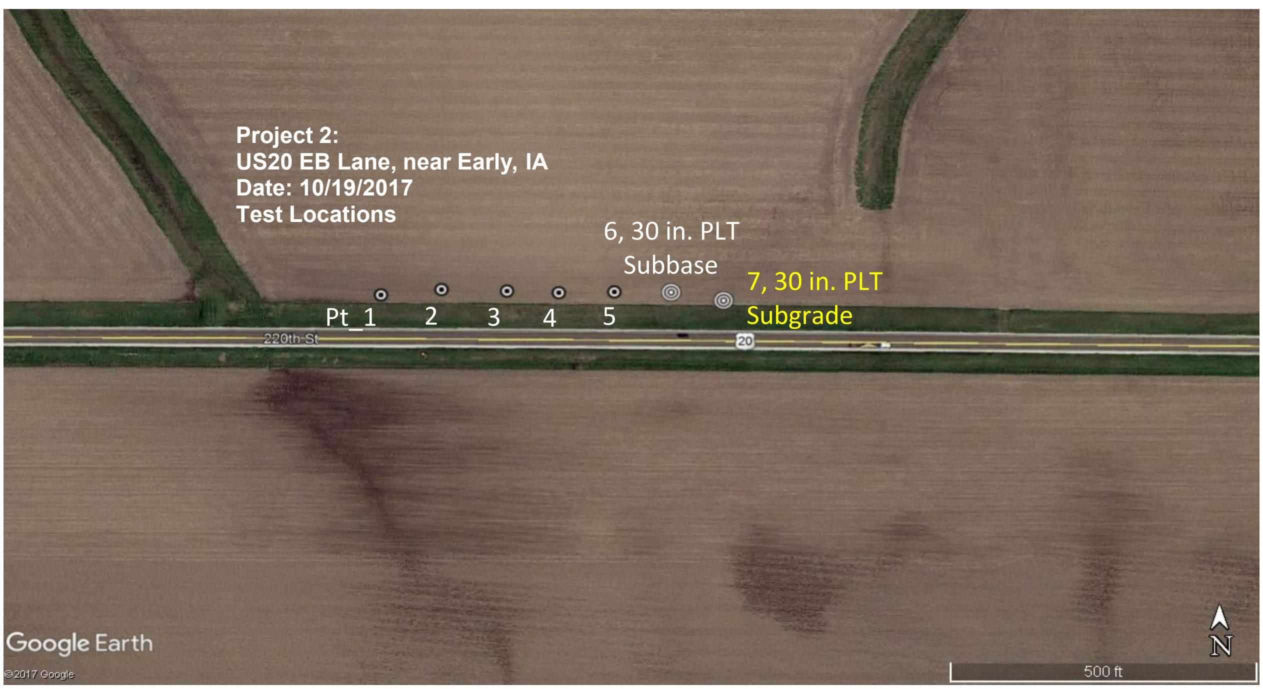
Hwy 20 EB, Early, Sac County, IA

10/19/2017

Granular subbase (recycled concrete) over select subgrade

Project Location and Test Locations





Test Locations	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Eastbound near Early, IA (Project #2)

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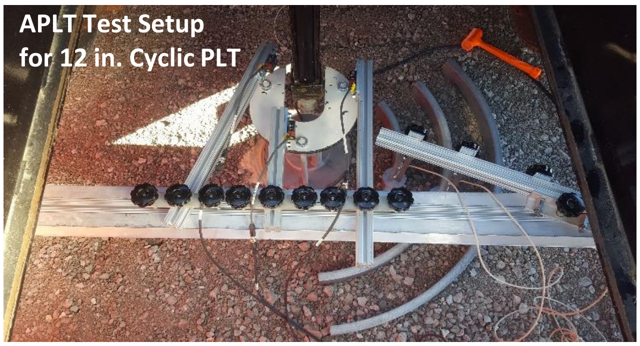
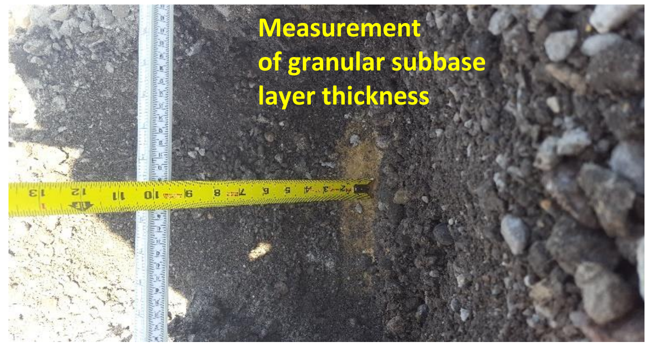
Site Conditions and Pictures





Pictures	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Eastbound near Early, IA (Project #2)

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Summary of Test Results

Summary of Cyclic APLT Test Results

Point #	4 psi cyclic stress @ surface: $M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)	8 psi plate cyclic stress @ surface: $M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)
1_Subbase	16,194	13,411	23,199	0.0003	17,776	14,777	25,013	0.0005
2_Subbase	21,705	20,350	24,036	0.0004	20,640	19,509	23,018	0.0006
3_Subbase	17,423	13,550	27,331	0.0001	18,898	15,057	28,315	0.0000
4_Subbase	26,577	22,471	34,855	0.0003	25,425	20,452	36,763	0.0004
5_Subbase	18,588	14,400	30,112	-0.0001	21,715	17,320	32,658	0.0006
AVG	**20,097**	**16,836**	**27,907**	**0.0002**	**20,891**	**17,423**	**29,153**	**0.0004**
COV	21%	25%	17%	100%	14%	15%	19%	53%

Point #	13 psi cyclic stress @ surface: $M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)	18 psi plate cyclic stress @ surface: $M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)
1_Subbase	20,228	17,921	25,451	0.0026	19,057	16,124	26,215	0.0155
2_Subbase	22,999	22,053	24,609	0.0029	21,862	20,426	24,894	0.0162
3_Subbase	21,311	17,944	28,339	0.0016	20,724	16,831	30,166	0.0121
4_Subbase	28,092	23,162	38,971	0.0019	26,914	21,502	40,138	0.0144
5_Subbase	23,447	19,494	32,942	0.0025	22,983	18,833	33,399	0.0159
AVG	**23,215**	**20,115**	**30,062**	**0.0023**	**22,308**	**18,743**	**30,963**	**0.0148**
COV	13%	12%	20%	24%	13%	12%	20%	11%

Point #	28 psi cyclic stress @ surface: $M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)	38 psi plate cyclic stress @ surface: $M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)
1_Subbase	18,388	15,925	24,098	0.0702	18,014	15,837	22,822	0.1389
2_Subbase	21,941	20,816	24,184	0.0693	21,339	20,296	23,111	0.1364
3_Subbase	20,245	16,872	27,811	0.0473	20,113	17,366	25,746	0.0956
4_Subbase	26,801	21,793	38,373	0.0598	28,325	24,060	37,171	0.1125
5_Subbase	24,034	18,938	37,915	0.0721	24,913	20,118	37,110	0.1398
AVG	**22,282**	**18,869**	**30,476**	**0.0637**	**22,541**	**19,536**	**29,192**	**0.1247**
COV	15%	13%	23%	16%	18%	16%	25%	16%

Summary of Test Results

Summary of AASHTO (2015) universal model parameters

$M_{r\text{-}Comp}$

Point #	$k^*_{1(Comp)}$	$k^*_{2(Comp)}$	$k^*_{3(Comp)}$	R^2(Adj.)	Std. Error (psi)	$M_{r\text{-}Comp(pred)\text{-}BP}$ (psi)	$\sigma_{cyclic\text{-}BP}$ (psi)
1_Subbase	1,338.8	0.294	-1.836	0.779	568	19,393	17.8
2_Subbase	1,509.8	0.058	-0.396	-0.080	287	22,012	16.1
3_Subbase	1,386.3	0.253	-1.388	0.855	500	20,855	20.8
4_Subbase	1,767.1	-0.005	0.245	0.205	575	28,013	39.0
5_Subbase	1,454.3	0.230	-0.808	0.938	548	24,531	37.2
AVG	**1,491.2**	**0.166**	**-0.837**	**0.540**	**495**	**22,961**	**26.2**
COV	11%	79%	-0.976	83%	24%	15%	42%

$M_{r\text{-}Base}$

Point #	$k^*_{1(Base)}$	$k^*_{2(Base(}$	$k^*_{3(Base)}$	R^2(Adj.)	Std. Error (psi)
1_Subbase	1,126.6	0.330	-1.915	0.642	749
2_Subbase	1,426.0	0.067	-0.431	-0.065	320
3_Subbase	1,095.7	0.290	-1.359	0.792	685
4_Subbase	1,392.1	-0.101	0.942	0.255	699
5_Subbase	1,195.4	0.316	-1.353	0.885	679
AVG	**1,247.2**	**0.181**	**-0.823**	**0.502**	**626**
COV	12%	105%	-1.362	79%	28%

$M_{r\text{-}SG}$

Point #	$k^*_{1(SG)}$	$k^*_{2(SG)}$	$k^*_{3(SG)}$	R^2(Adj.)	Std. Error (psi)
1_Subbase	2,484.8	0.319	-3.492	0.923	354
2_Subbase	1,884.5	0.111	-1.268	0.163	400
3_Subbase	2,592.5	0.250	-2.655	0.684	706
4_Subbase	3,290.6	0.255	-2.140	0.904	547
5_Subbase	2,198.9	0.082	0.328	0.875	986
AVG	**2,490.3**	**0.204**	**-1.845**	**0.710**	**599**
COV	21%	50%	-0.791	45%	43%

Summary of Test Results

Summary of Static PLT results

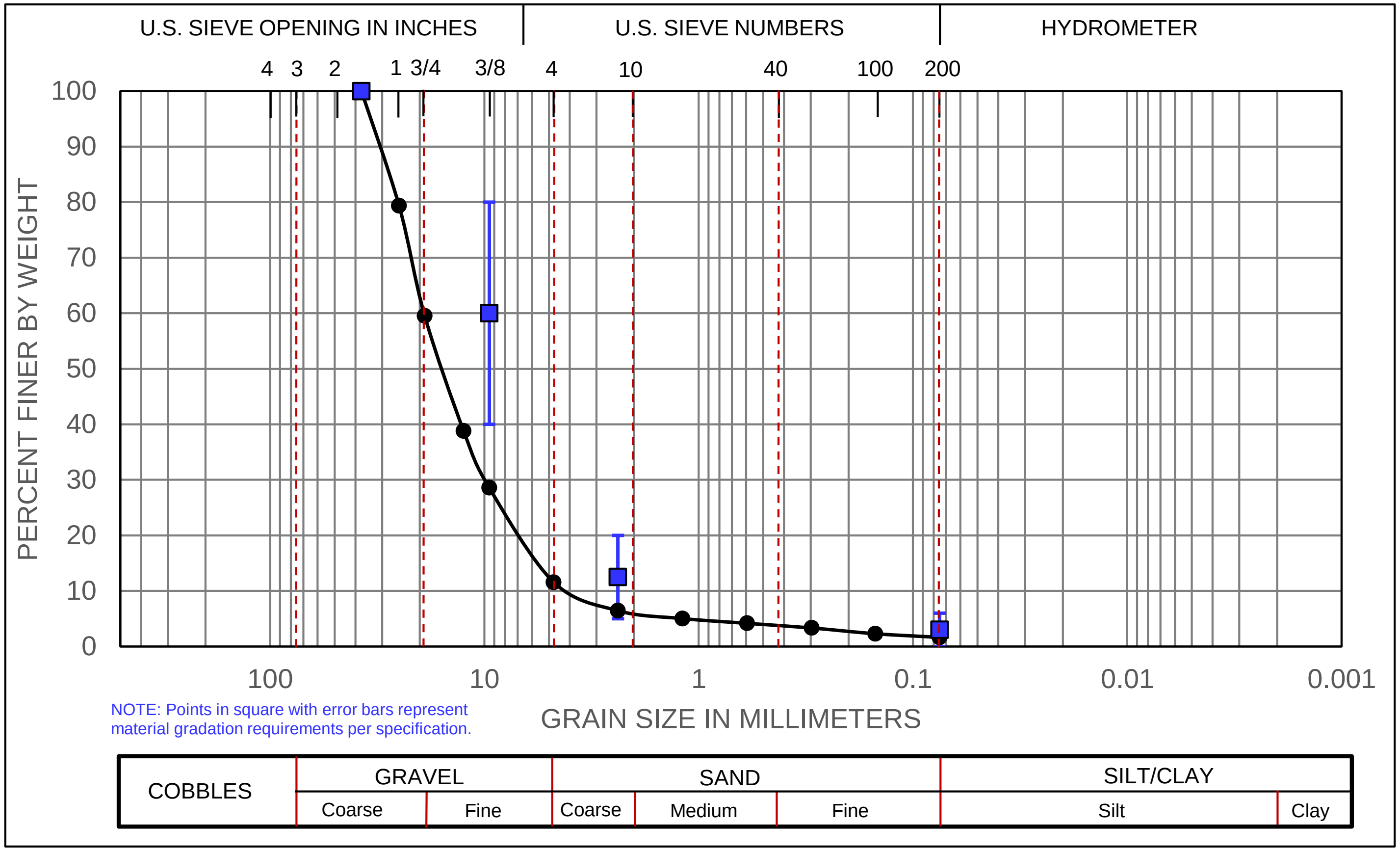
	30 in. static PLT			
Point #	k_u (pci) at δ = 0.05 in.[a]	k_{u1} (pci) at 10 psi[b]	k_{u2} (pci) at 10 psi	Ratio of k_{u2}/k_{u1}
6_Subbase	76	91	504	5.5
7_Subgrade	89	98	394	4.0

[a]per PCA design critera
[b]per AASHTO T222

Summary of DCP and LWD test results

	Subbase Layer			Subgrade Layer			Ratio	
Point #	Thickness, H_1 (in.)	Avg. CBR (%)	St. Dev CBR (%)	Thickness, H_2 (in.)	Avg. CBR (%)	St. Dev CBR (%)	CBR_1/CBR_2	E_{LWD} (psi)
1_Subbase	10.5	7.4	3.8	12.0	6.6	6.2	1.1	7,310
2_Subbase	10.8	4.8	3.6	12.0	7.0	8.7	0.7	9,799
3_Subbase	9.8	5.3	2.8	12.0	11.6	8.3	0.5	8,812
4_Subbase	9.7	5.4	3.2	12.0	13.3	8.9	0.4	11,539
5_Subbase	10.1	6.0	2.2	12.0	15.4	7.8	0.4	9,408
6_Subbase	11.0	9.4	3.2	12.0	14.9	7.6	0.6	7,181
7_Subgrade	NA	NA	NA	12.0	11.7	7.4	NA	2,914
AVG	**10.3**	**6.4**	**3.1**	**12.0**	**11.5**	**7.8**	**0.6**	**8,138**
COV	5%	27%	19%	0%	31%	12%	45%	34%

GRAIN SIZE DISTRIBUTION
ASTM D422/C136



Gradation Summary

% Gravel	88.4
% Sand	9.9
% Fines	1.6
D_{10} (mm)	4.021
D_{30} (mm)	9.909
D_{50} (mm)	16.005
D_{60} (mm)	19.133
D_{85} (mm)	28.419
C_u	4.8
C_c	1.3

Atterberg Limits

LL	NP
PL	NP
PI	NP

Classification

AASHTO:	A-1-a
USCS:	GW

MATERIAL: Gray Crushed Recycled Granular Subbase - Untrimmed (Iowa DOT Gradation 4121 - Recycled Material)

LOCATION: Hwy 20 EB near Early, Iowa (Project #2) **TESTED BY:** PV/DW

SAMPLE DATE: 10/19/2017 **TEST DATE:** 11/28/2017

Gradation and Soil Classification Test Results

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #2)

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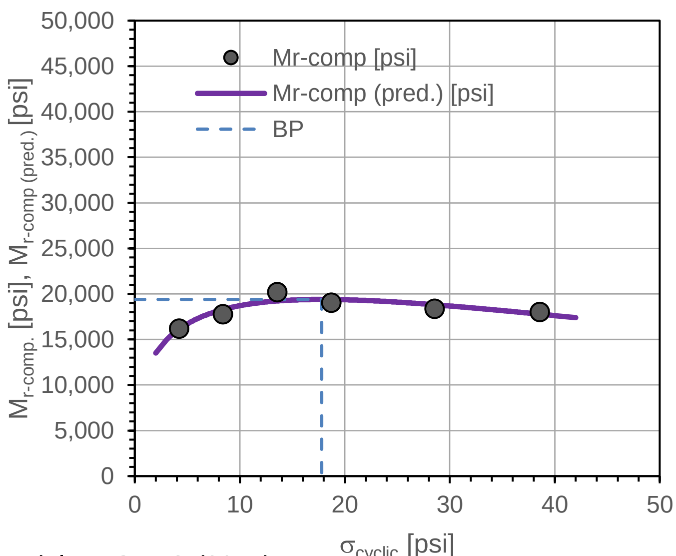
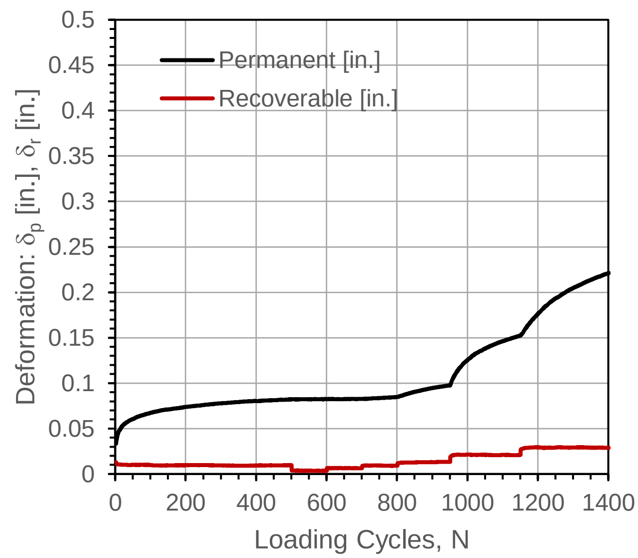
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/19/2017	Time:	11:24:40 AM	Test ID	**Hwy20_12_pt1**
Tested By	DW, JV	Location:	Hwy20 EB Lane	Sta.	NA
Latitude,N:	42.474854	Longitude,W:	95.198730	Elev. (ft):	1358
Comments:	Recyled aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-comp}}$ [psi]	$M_{r\text{-comp (pred.)}}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.58	---	---	0.0821	---	0.144	---
1	100	4.21	16,194	16,126	0.0825	0.0003	0.100	Y
2	100	8.39	17,776	18,284	0.0826	0.0005	0.098	Y
3	100	13.58	20,228	19,228	0.0847	0.0026	0.776	N
4	150	18.71	19,057	19,387	0.0976	0.0155	0.889	N
5	200	28.56	18,388	18,811	0.1523	0.0702	0.721	N
6	250	38.59	18,014	17,778	0.2210	0.1389	0.866	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	1,338.8	4.59E-07
k^*_2	0.294	3.25E-02
k^*_3	-1.836	4.64E-02
Adj. R^2	0.779	
Std. Error [psi]	568	

$M_{r\text{-comp (pred.)-BP}}$ [psi]	19,393
$\sigma_{cyclic\text{-BP}}$ [psi]	17.8

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

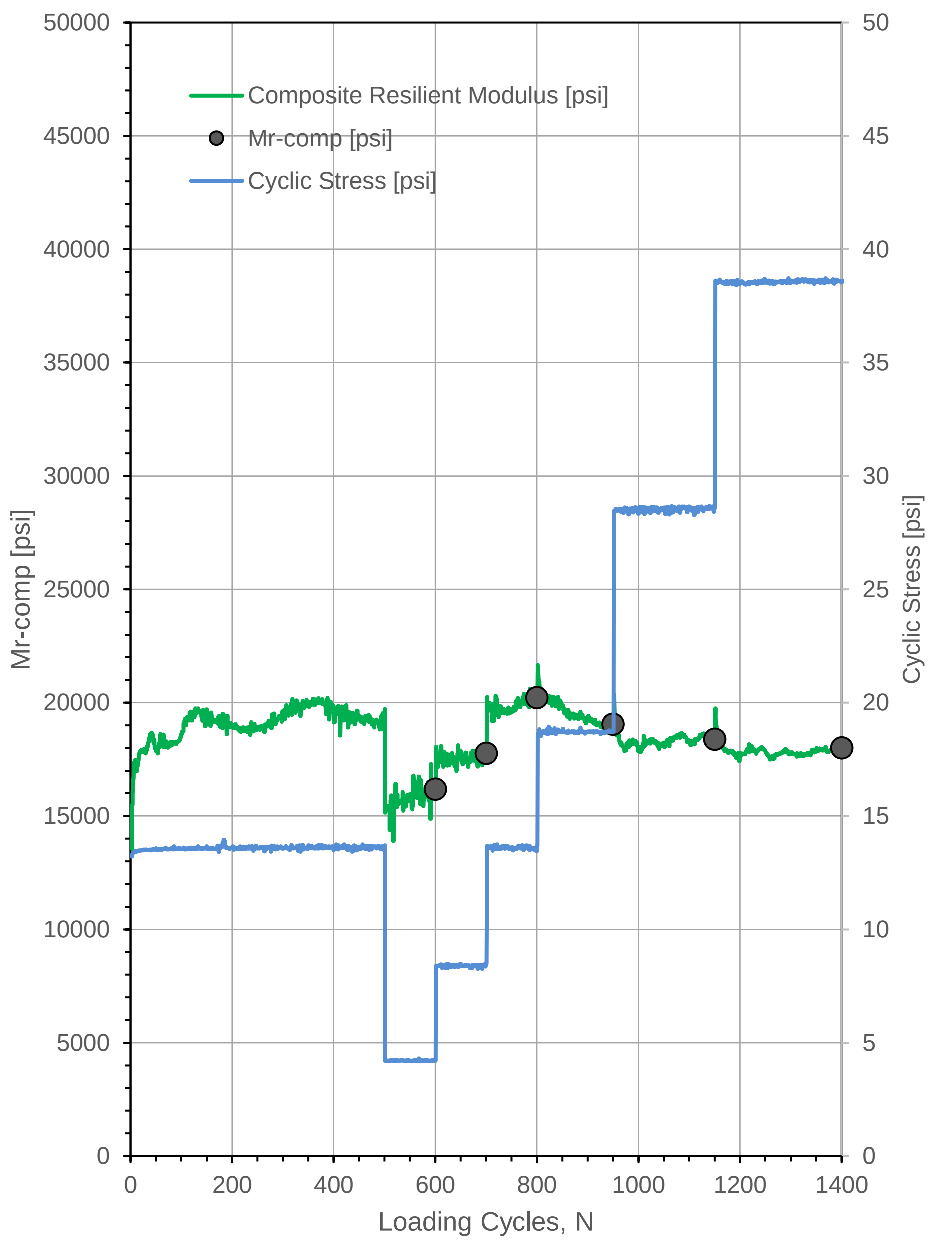
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Eastbound near Early, IA (Project #2)

ingios GEOTECHNICS

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/19/2017	Time:	11:24:40 AM	Test ID	**Hwy20_12_pt1**
Tested By	DW, JV	Location:	Hwy20 EB Lane	Sta.	NA
Latitude,N:	42.474854	Longitude,W:	95.198730	Elev. (ft):	1358
Comments:	Recyled aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	13,513
3	14,934
4	15,947
5	16,711
6	17,307
7	17,780
8	18,158
9	18,462
10	18,706
11	18,901
12	19,054
13	19,173
14	19,262
15	19,325
16	19,366
17	19,388
18	19,393
21	19,326
22	19,282
23	19,229
24	19,168
25	19,100
26	19,025
27	18,945
28	18,861
29	18,771
30	18,678
31	18,582
32	18,483
33	18,381
34	18,277
35	18,171
36	18,063
37	17,954
38	17,843
39	17,731
40	17,619



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

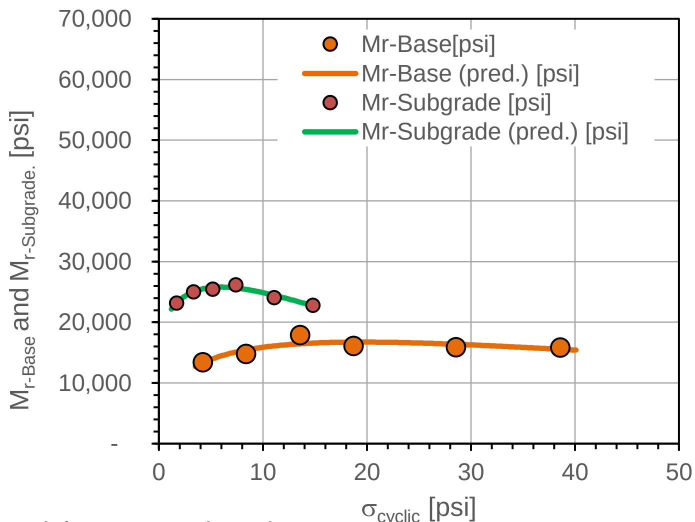
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Eastbound near Early, IA (Project #2)

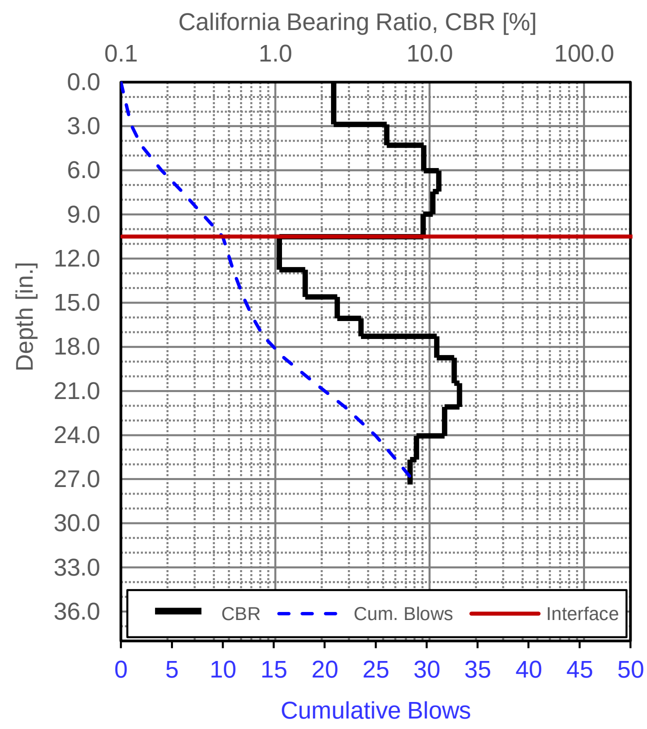
ingios GEOTECHNICS

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/19/2017	Time:	11:24:40 AM	Test ID	**Hwy20_12_pt1**
Tested By	DW, JV	Location:	Hwy20 EB Lane	Sta.	NA
Latitude:	42.474854	Longitude:	95.198730	Elev. (ft):	1358
Comments:	Recyled aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$ [psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	13.58	---	---	---	---	---	---
1	100	4.21	13,411	13,326	1.69	23,199	23,159	0.58
2	100	8.39	14,777	15,443	3.35	25,013	25,052	0.59
3	100	13.58	17,921	16,463	5.19	25,451	25,751	0.70
4	100	18.71	16,124	16,733	7.39	26,215	25,652	0.62
5	100	28.56	15,925	16,379	11.09	24,098	24,448	0.66
6	100	38.59	15,837	15,553	14.80	22,822	22,726	0.69

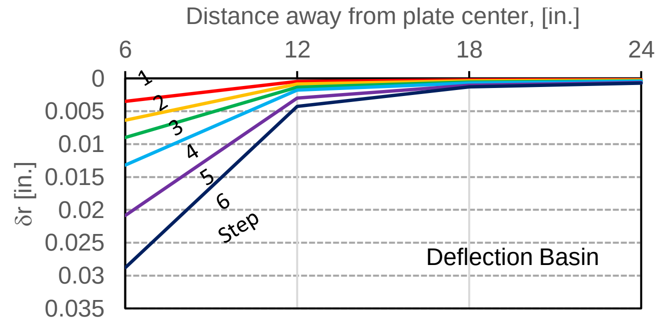




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\ (Base)}$	1126.6	2.16E-06
$k^*_{2\ (Base)}$	0.330	8.07E-02
$k^*_{3\ (Base)}$	-1.915	1.27E-01
Adj. R^2	0.642	
Std. Error [psi]	749	
$k^*_{1\ (Subgrade)}$	2484.8	8.90E-07
$k^*_{2\ (Subgrade)}$	0.319	6.87E-03
$k^*_{3\ (Subgrade)}$	-3.492	5.96E-03
Adj. R^2	0.923	
Std. Error [psi]	354	



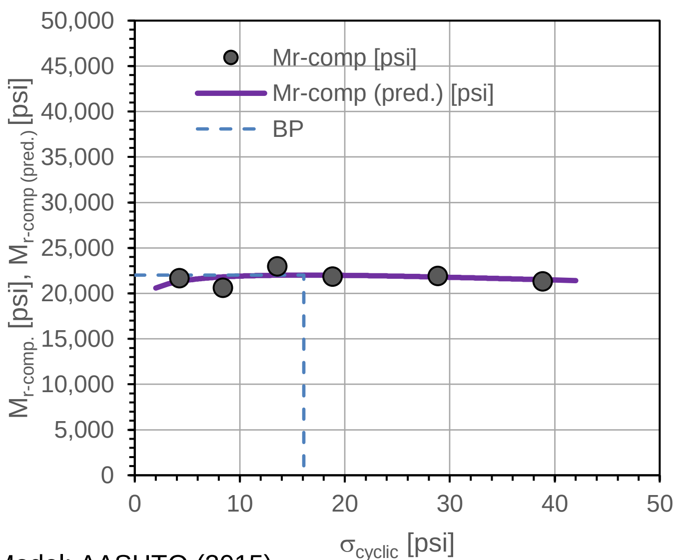
In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

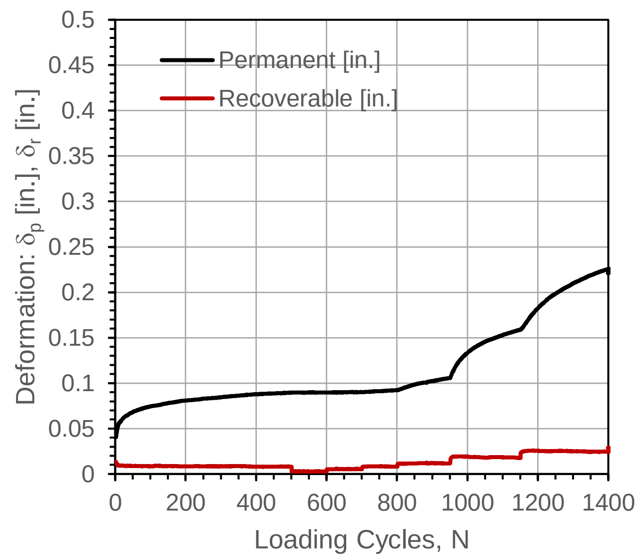
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Eastbound near Early, IA (Project #2)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/19/2017	Time:	12:05:57 PM	Test ID	**Hwy20_12_pt2**
Tested By	DW, JV	Location:	Hwy20 EB Lane	Sta.	NA
Latitude,N:	42.474880	Longitude,W:	95.198364	Elev. (ft):	1343
Comments:	Recyled aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.58	---	---	0.0894	---	0.126	---
1	100	4.24	21,705	21,312	0.0898	0.0004	0.000	Y
2	100	8.40	20,640	21,814	0.0901	0.0006	0.163	Y
3	100	13.58	22,999	21,996	0.0923	0.0029	0.650	N
4	150	18.85	21,862	21,998	0.1056	0.0162	0.947	N
5	200	28.86	21,941	21,802	0.1588	0.0693	0.718	N
6	250	38.87	21,339	21,504	0.2259	0.1364	0.897	N



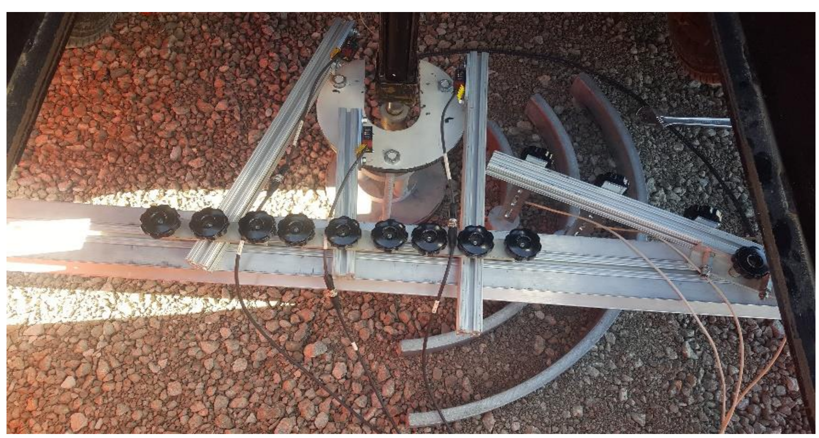


Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	1,509.8	6.07E-07
k^*_2	0.058	5.54E-01
k^*_3	-0.396	5.73E-01
Adj. R^2	-0.080	
Std. Error [psi]	287	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	22,012
$\sigma_{cyclic\text{-}BP}$ [psi]	16.1



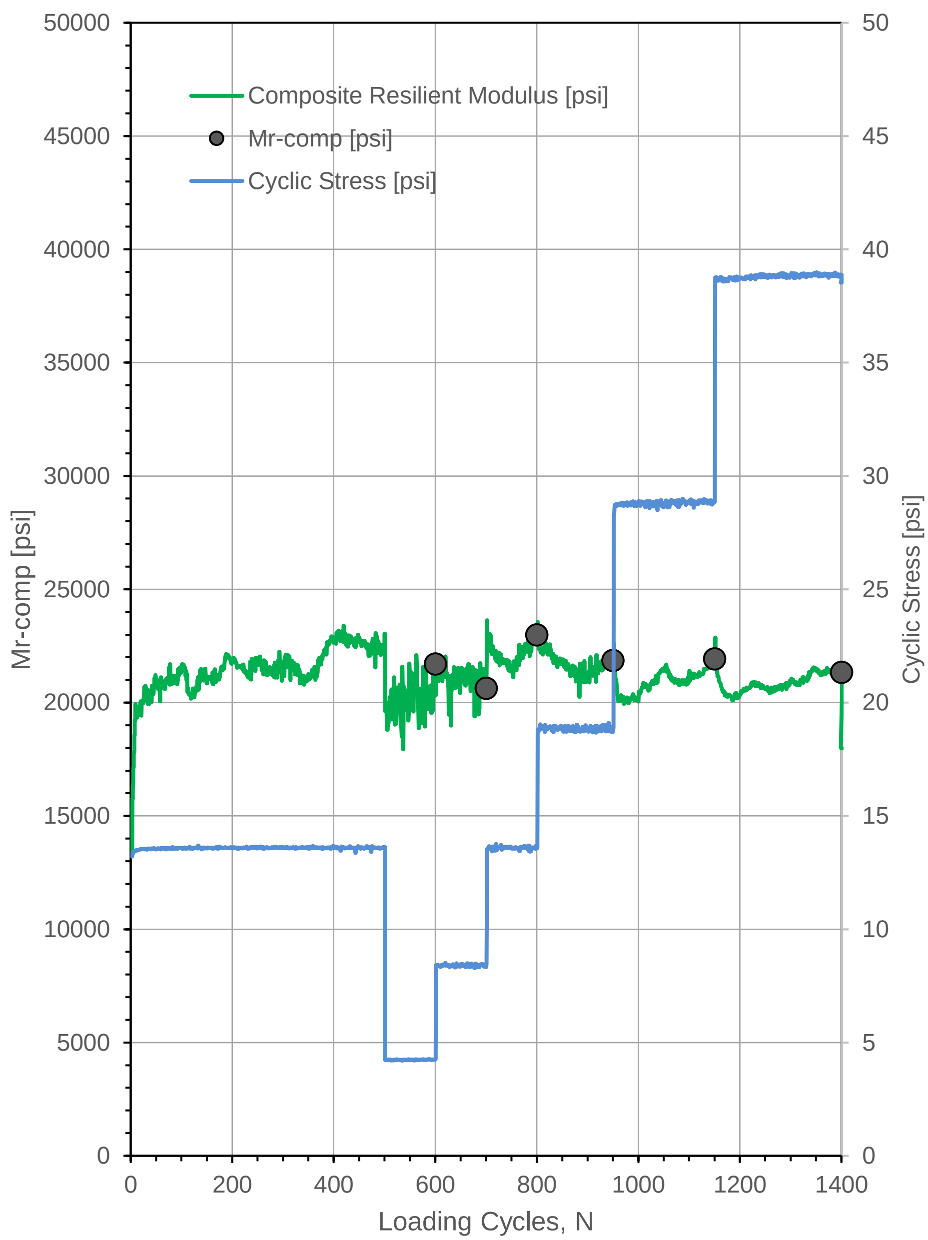
In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #2)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/19/2017	Time:	12:05:57 PM	Test ID	**Hwy20_12_pt2**
Tested By	DW, JV	Location:	Hwy20 EB Lane	Sta.	NA
Latitude,N:	42.474880	Longitude,W:	95.198364	Elev. (ft):	1343
Comments:	Recyled aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	20,588
3	20,993
4	21,260
5	21,451
6	21,593
7	21,702
8	21,786
9	21,851
10	21,901
11	21,939
12	21,967
13	21,988
14	22,001
15	22,009
16	22,012
17	22,010
18	22,005
21	21,971
22	21,955
23	21,937
24	21,918
25	21,896
26	21,873
27	21,849
28	21,824
29	21,798
30	21,771
31	21,743
32	21,714
33	21,685
34	21,655
35	21,625
36	21,594
37	21,563
38	21,531
39	21,499
40	21,467



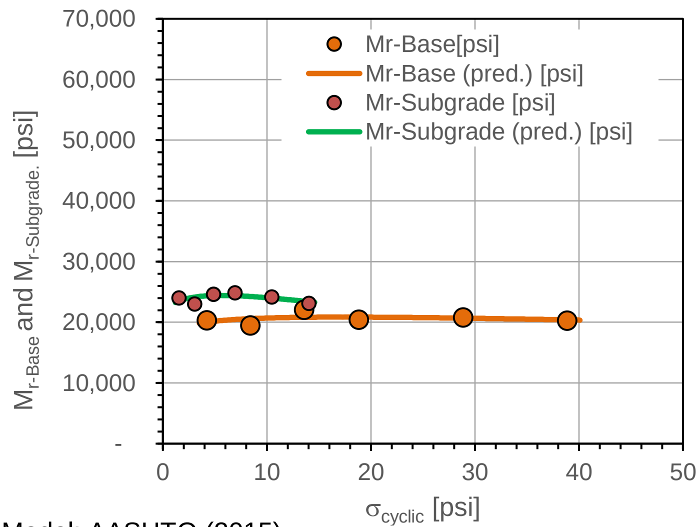
In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

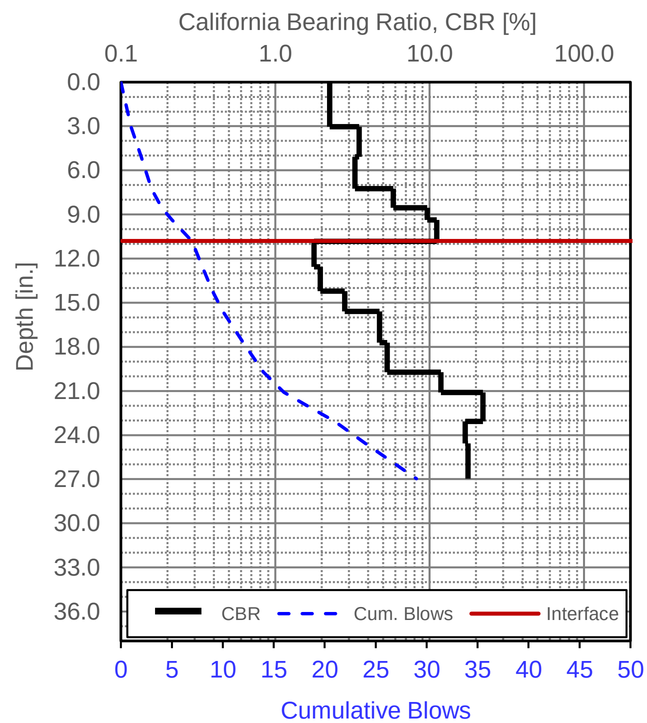
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #2)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/19/2017	Time:	12:05:57 PM	Test ID	**Hwy20_12_pt2**
Tested By	DW, JV	Location:	Hwy20 EB Lane	Sta.	NA
Latitude:	42.474880	Longitude:	95.198364	Elev. (ft):	1343
Comments:	Recyled aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-Base}}$[psi]	$M_{r\text{-Base (pred.)}}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-Subgrade}}$ [psi]	$M_{r\text{-Subgrade (pred.)}}$ [psi]	Modulus Ratio
Conditioning	500	13.58	---	---	---	---	---	---
1	100	4.24	20,350	20,025	1.55	24,036	23,508	0.85
2	100	8.40	19,509	20,595	3.06	23,018	24,152	0.85
3	100	13.58	22,053	20,822	4.87	24,609	24,406	0.90
4	100	18.85	20,426	20,851	6.93	24,894	24,382	0.82
5	100	28.86	20,816	20,683	10.47	24,184	23,983	0.86
6	100	38.87	20,296	20,400	14.03	23,111	23,380	0.88

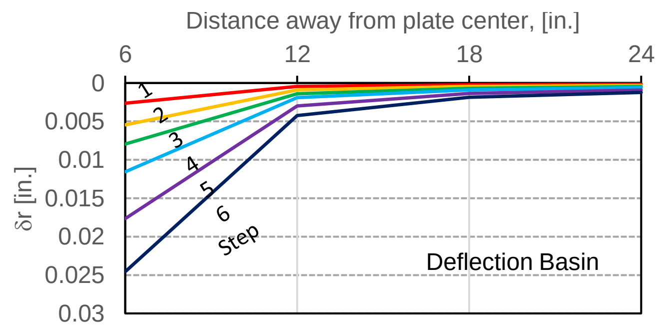




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\ (Base)}$	1426.0	8.86E-07
$k^*_{2\ (Base)}$	0.067	5.44E-01
$k^*_{3\ (Base)}$	-0.431	5.84E-01
Adj. R^2	-0.065	
Std. Error [psi]	320	
$k^*_{1\ (Subgrade)}$	1884.5	9.40E-06
$k^*_{2\ (Subgrade)}$	0.111	3.36E-01
$k^*_{3\ (Subgrade)}$	-1.268	3.18E-01
Adj. R^2	0.163	
Std. Error [psi]	400	



In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #2)

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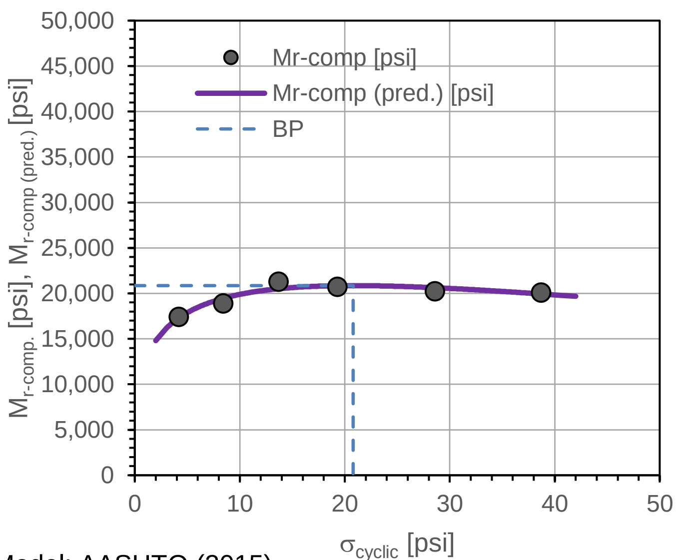
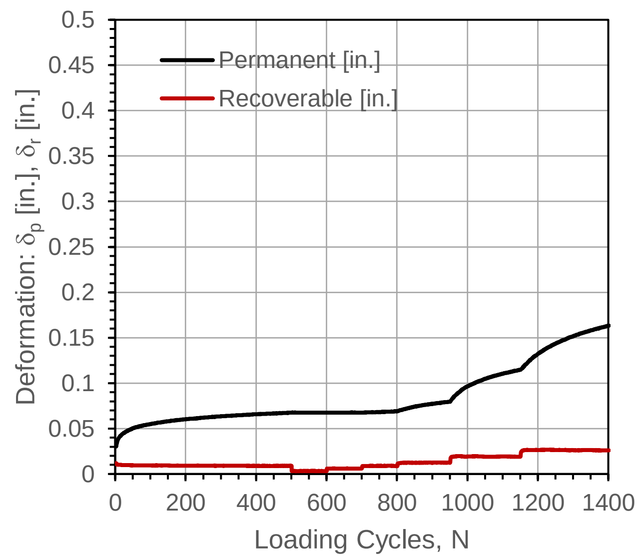
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/19/2017	Time:	12:42:13 PM	Test ID	**Hwy20_12_pt3**
Tested By	DW, JV	Location:	Hwy20 EB Lane	Sta.	NA
Latitude,N:	42.474873	Longitude,W:	95.197968	Elev. (ft):	1345
Comments:	Recyled aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

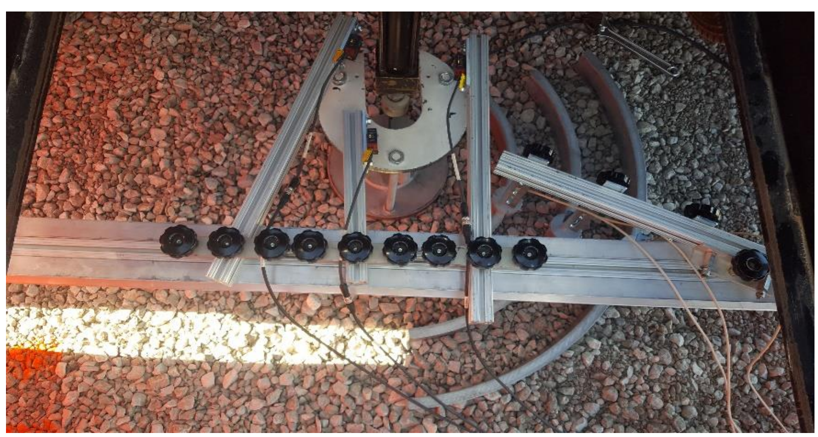
Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.71	---	---	0.0675	---	0.136	---
1	100	4.21	17,423	17,311	0.0675	0.0001	-0.073	Y
2	100	8.42	18,898	19,455	0.0675	0.0000	0.193	Y
3	100	13.71	21,311	20,514	0.0690	0.0016	0.573	Y
4	150	19.31	20,724	20,843	0.0796	0.0121	0.814	N
5	200	28.59	20,245	20,625	0.1148	0.0473	0.749	N
6	250	38.72	20,113	19,937	0.1631	0.0956	0.836	N





Model: AASHTO (2015)

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



Parameter	Value	P-Value
k^*_1	1,386.3	2.35E-07
k^*_2	0.253	2.69E-02
k^*_3	-1.388	5.32E-02
Adj. R^2	0.855	
Std. Error [psi]	500	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	20,855
$\sigma_{cyclic\text{-}BP}$ [psi]	20.8

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Eastbound near Early, IA (Project #2)

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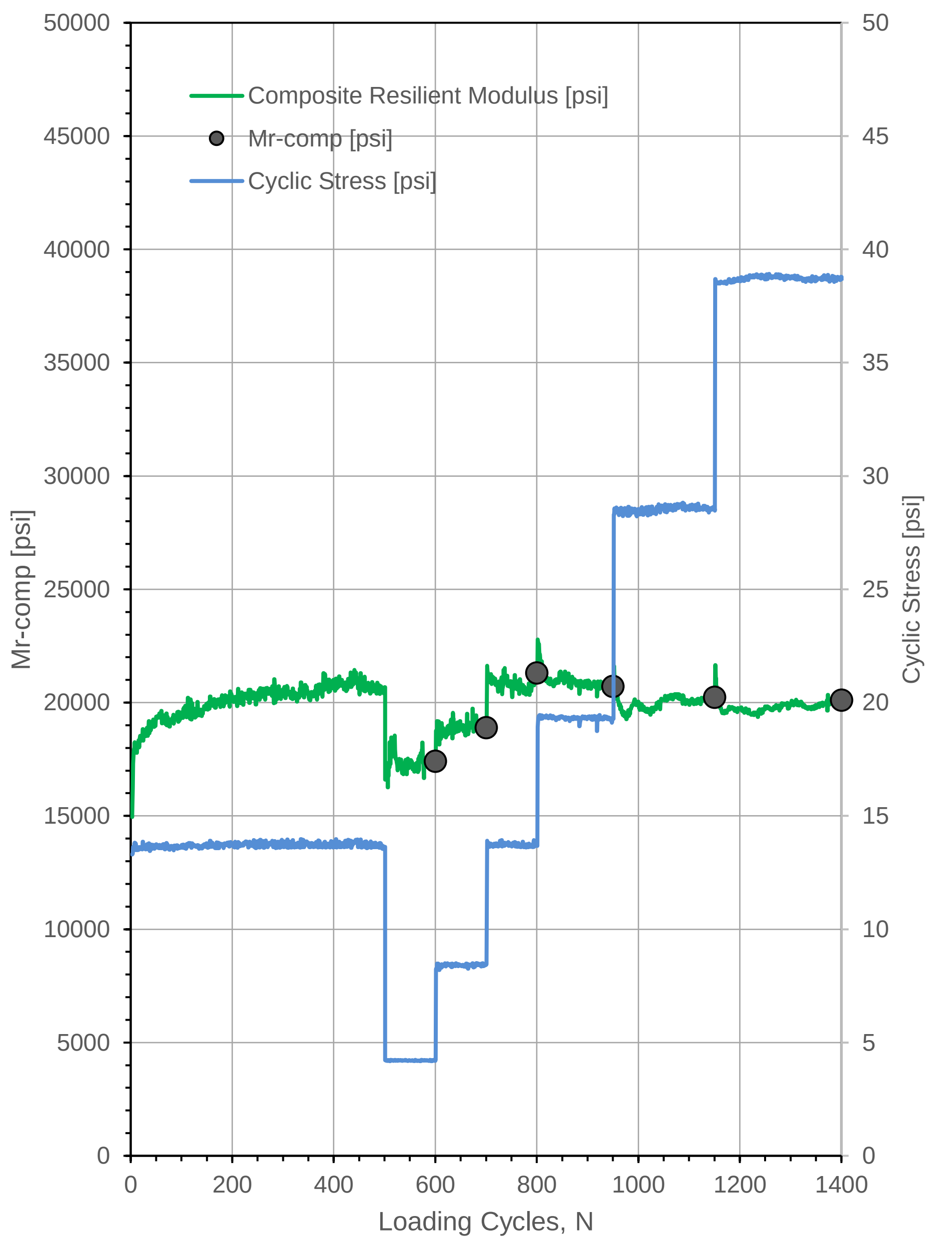
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/19/2017	Time:	12:42:13 PM	Test ID	**Hwy20_12_pt3**
Tested By	DW, JV	Location:	Hwy20 EB Lane	Sta.	NA
Latitude,N:	42.474873	Longitude,W:	95.197968	Elev. (ft):	1345
Comments:	Recyled aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	14,808
3	16,171
4	17,143
5	17,882
6	18,465
7	18,934
8	19,316
9	19,631
10	19,891
11	20,106
12	20,283
13	20,428
14	20,546
15	20,641
16	20,715
17	20,771
18	20,811
21	20,855
22	20,849
23	20,834
24	20,811
25	20,781
26	20,744
27	20,702
28	20,655
29	20,604
30	20,548
31	20,488
32	20,425
33	20,359
34	20,291
35	20,219
36	20,146
37	20,071
38	19,993
39	19,915
40	19,834



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #2)

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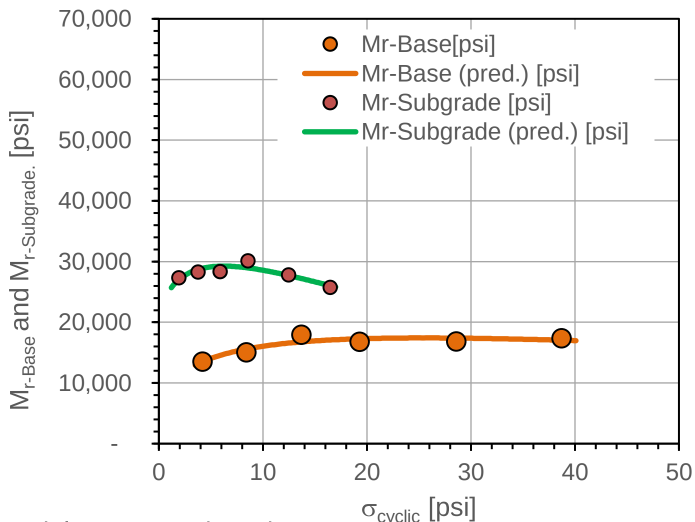
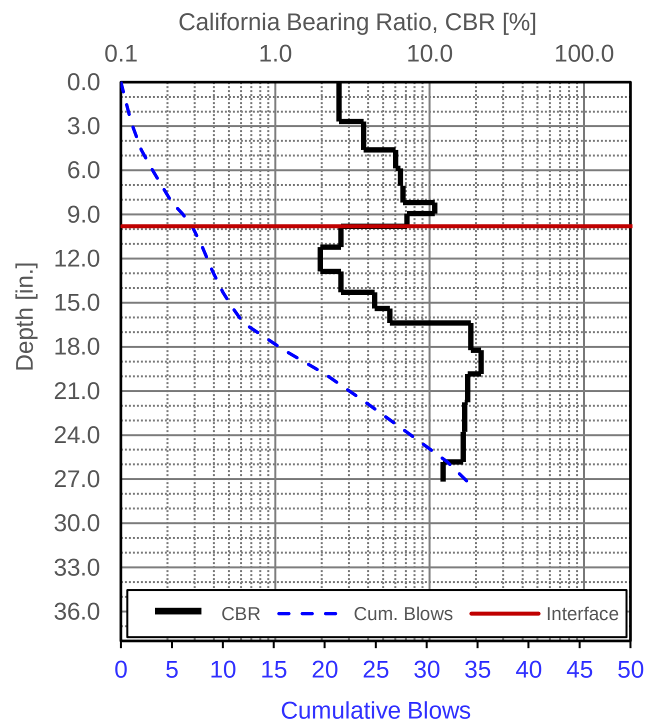
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/19/2017	Time:	12:42:13 PM	Test ID	**Hwy20_12_pt3**
Tested By	DW, JV	Location:	Hwy20 EB Lane	Sta.	NA
Latitude:	42.474873	Longitude:	95.197968	Elev. (ft):	1345
Comments:	Recyled aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	13.71	---	---	---	---	---	---
1	100	4.21	13,550	13,494	1.92	27,331	27,004	0.50
2	100	8.42	15,057	15,585	3.78	28,315	28,712	0.53
3	100	13.71	17,944	16,763	5.92	28,339	29,245	0.63
4	100	19.31	16,831	17,278	8.58	30,166	28,956	0.56
5	100	28.59	16,872	17,392	12.46	27,811	27,710	0.61
6	100	38.72	17,366	17,044	16.46	25,746	26,037	0.67

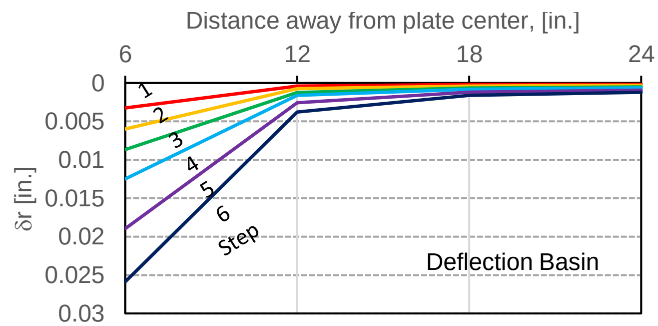




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\ (Base)}$	1095.7	1.21E-06
$k^*_{2\ (Base)}$	0.290	6.82E-02
$k^*_{3\ (Base)}$	-1.359	1.67E-01
Adj. R^2	0.792	
Std. Error [psi]	685	
$k^*_{1\ (Subgrade)}$	2592.5	4.97E-06
$k^*_{2\ (Subgrade)}$	0.250	6.99E-02
$k^*_{3\ (Subgrade)}$	-2.655	5.62E-02
Adj. R^2	0.684	
Std. Error [psi]	706	



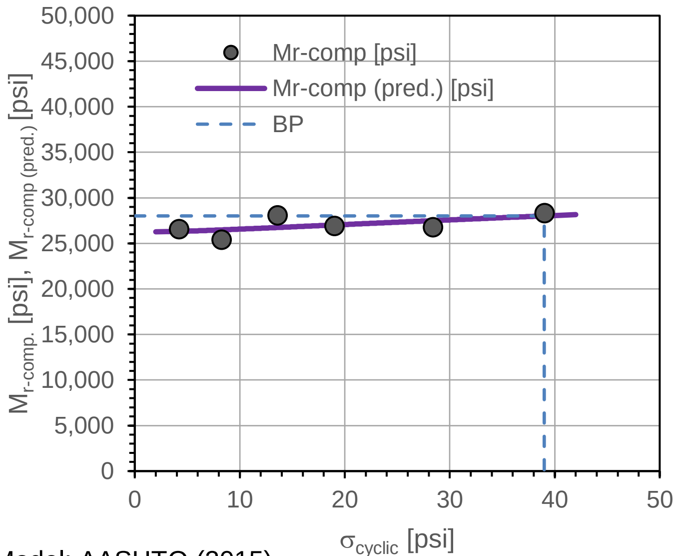
In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

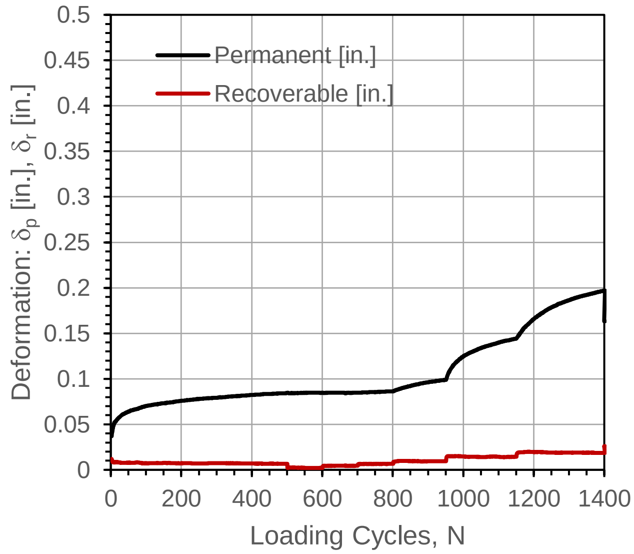
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #2)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/19/2017	Time:	1:19:39 PM	Test ID	**Hwy20_12_pt4**
Tested By	DW, JV	Location:	Hwy20 EB Lane	Sta.	NA
Latitude,N:	42.474865	Longitude,W:	95.197655	Elev. (ft):	1344
Comments:	Recyled aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.60	---	---	0.0844	---	0.128	---
1	100	4.22	26,577	26,314	0.0847	0.0003	0.266	Y
2	100	8.27	25,425	26,481	0.0848	0.0004	0.023	Y
3	100	13.60	28,092	26,743	0.0863	0.0019	0.572	Y
4	150	19.03	26,914	27,020	0.0988	0.0144	0.769	N
5	200	28.41	26,801	27,495	0.1442	0.0598	0.654	N
6	250	39.03	28,325	28,015	0.1969	0.1125	0.775	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	1,767.1	4.88E-07
k^*_2	-0.005	9.52E-01
k^*_3	0.245	7.07E-01
Adj. R^2	0.205	
Std. Error [psi]	575	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	28,013
$\sigma_{cyclic\text{-}BP}$ [psi]	39.0

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #2)

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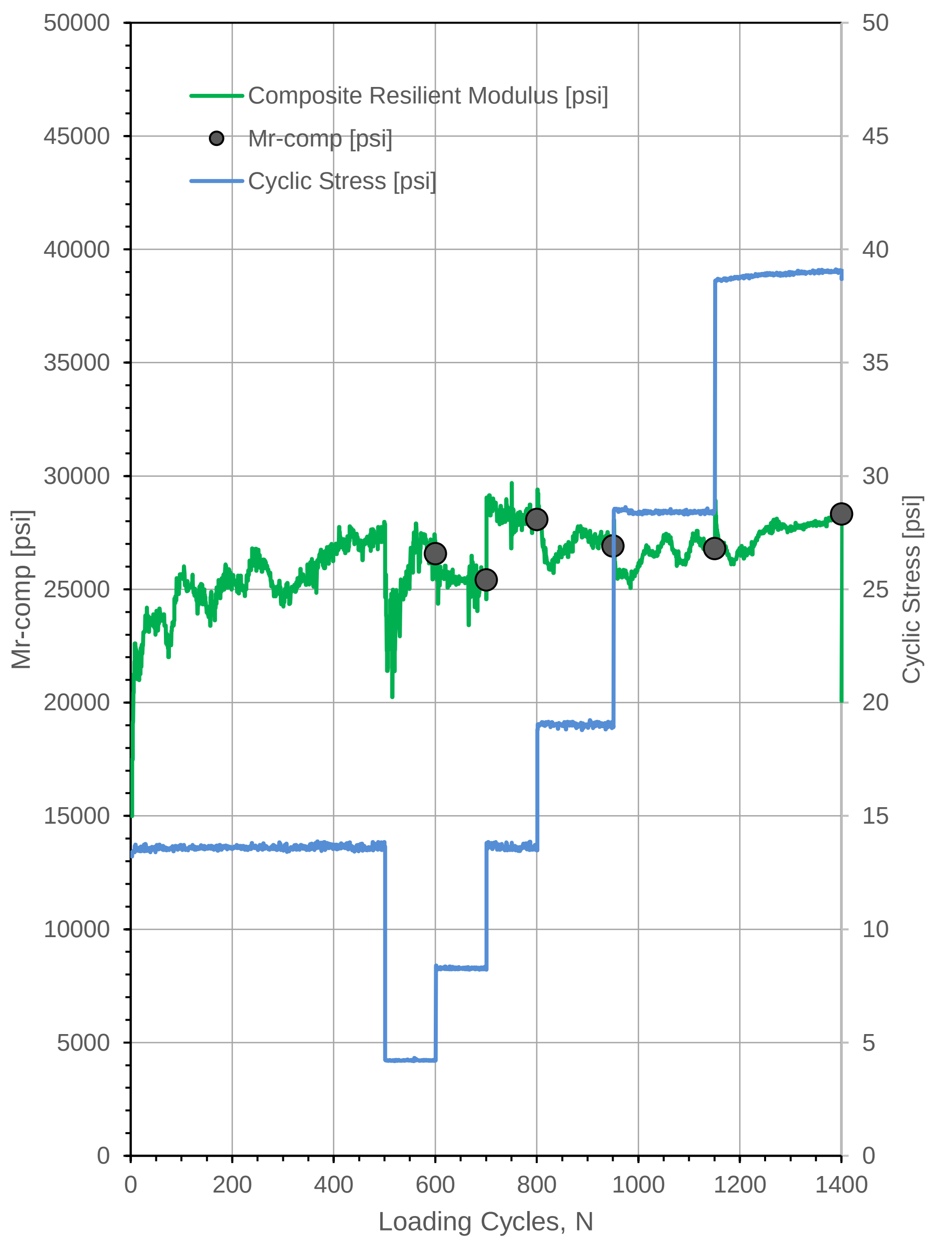
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/19/2017	Time:	1:19:39 PM	Test ID	**Hwy20_12_pt4**
Tested By	DW, JV	Location:	Hwy20 EB Lane	Sta.	NA
Latitude,N:	42.474865	Longitude,W:	95.197655	Elev. (ft):	1344
Comments:	Recyled aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

σ_{cyclic} [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]
2	26,271
3	26,281
4	26,307
5	26,341
6	26,381
7	26,423
8	26,469
9	26,515
10	26,564
11	26,613
12	26,662
13	26,712
14	26,763
15	26,814
16	26,865
17	26,916
18	26,967
21	27,120
22	27,171
23	27,222
24	27,273
25	27,324
26	27,374
27	27,424
28	27,474
29	27,524
30	27,574
31	27,624
32	27,673
33	27,722
34	27,771
35	27,820
36	27,869
37	27,917
38	27,965
39	28,013
40	28,061



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #2)

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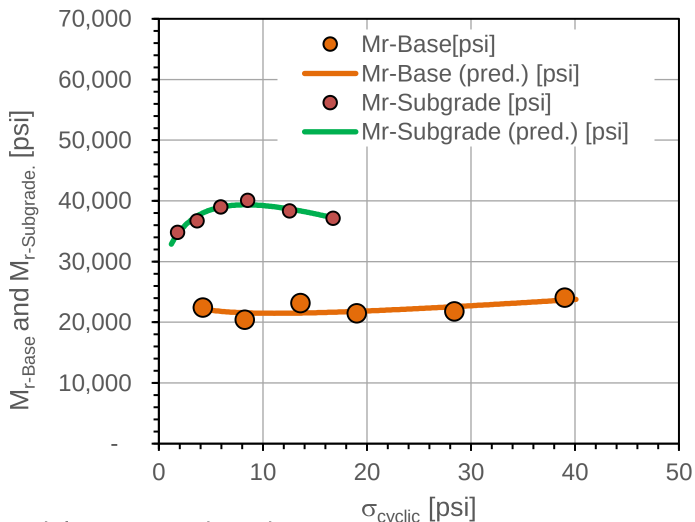
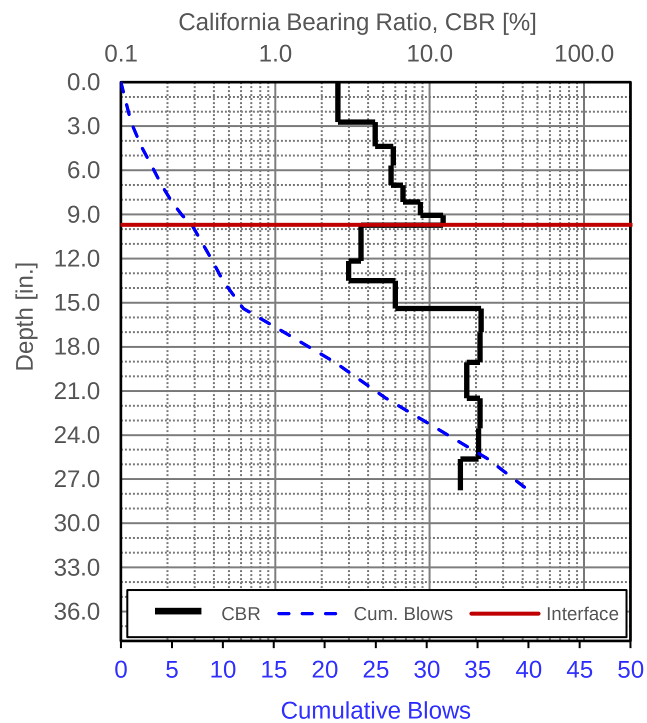
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/19/2017	Time:	1:19:39 PM	Test ID	**Hwy20_12_pt4**
Tested By	DW, JV	Location:	Hwy20 EB Lane	Sta.	NA
Latitude:	42.474865	Longitude:	95.197655	Elev. (ft):	1344
Comments:	Recyled aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-Base}}$[psi]	$M_{r\text{-Base (pred.)}}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-Subgrade}}$ [psi]	$M_{r\text{-Subgrade (pred.)}}$ [psi]	Modulus Ratio
Conditioning	500	13.60	---	---	---	---	---	---
1	100	4.22	22,471	22,211	1.81	34,855	34,548	0.64
2	100	8.27	20,452	21,565	3.68	36,763	37,499	0.56
3	100	13.60	23,162	21,522	5.95	38,971	38,976	0.59
4	100	19.03	21,502	21,799	8.53	40,138	39,354	0.54
5	100	28.41	21,793	22,577	12.57	38,373	38,664	0.57
6	100	39.03	24,060	23,655	16.76	37,171	37,210	0.65

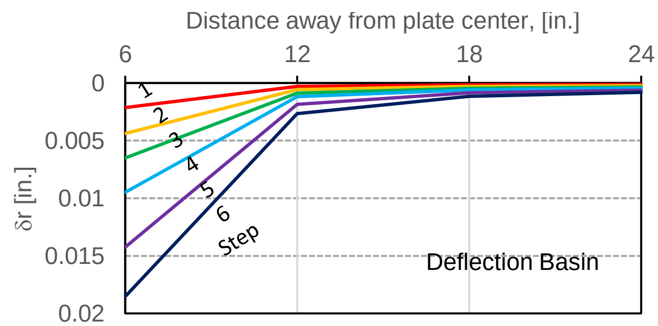




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\text{ (Base)}}$	1392.1	1.55E-06
$k^*_{2\text{ (Base)}}$	-0.101	4.55E-01
$k^*_{3\text{ (Base)}}$	0.942	3.45E-01
Adj. R^2	0.255	
Std. Error [psi]	699	
$k^*_{1\text{ (Subgrade)}}$	3290.6	6.18E-07
$k^*_{2\text{ (Subgrade)}}$	0.255	1.14E-02
$k^*_{3\text{ (Subgrade)}}$	-2.140	1.72E-02
Adj. R^2	0.904	
Std. Error [psi]	547	



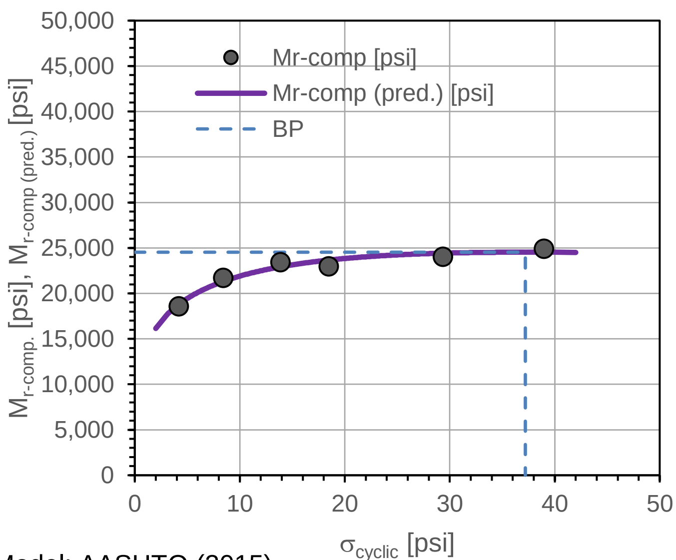
In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

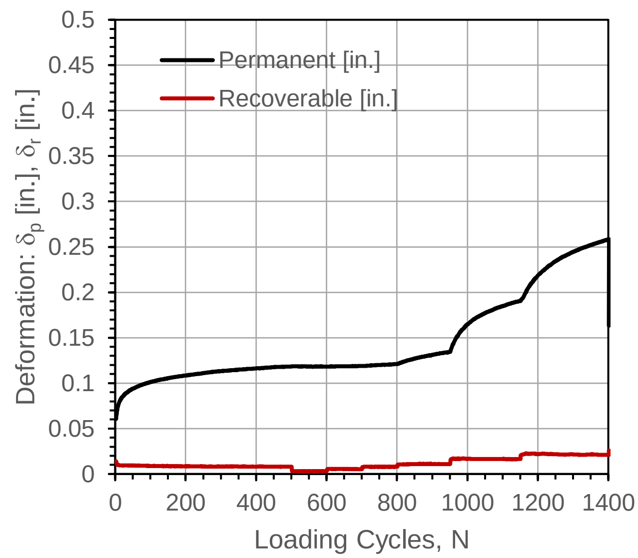
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #2)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/19/2017	Time:	1:56:24 PM	Test ID	**Hwy20_12_pt5**
Tested By	DW, JV	Location:	Hwy20 EB Lane	Sta.	NA
Latitude,N:	42.474869	Longitude,W:	95.197319	Elev. (ft):	1347
Comments:	Recyled aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.88	---	---	0.1184	---	0.108	---
1	100	4.20	18,588	18,797	0.1183	-0.0001	-0.106	Y
2	100	8.43	21,715	21,321	0.1189	0.0006	0.381	Y
3	100	13.88	23,447	22,923	0.1209	0.0025	0.724	N
4	150	18.49	22,983	23,667	0.1343	0.0159	0.834	N
5	200	29.35	24,034	24,423	0.1905	0.0721	0.695	N
6	250	38.98	24,913	24,527	0.2581	0.1398	0.802	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	1,454.3	1.66E-07
k^*_2	0.230	2.63E-02
k^*_3	-0.808	1.37E-01
Adj. R^2	0.938	
Std. Error [psi]	548	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	24,531
$\sigma_{cyclic\text{-}BP}$ [psi]	37.2

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC

Project ID: SIA-00001

Location: Hwy 20, Eastbound near Early, IA (Project #2)

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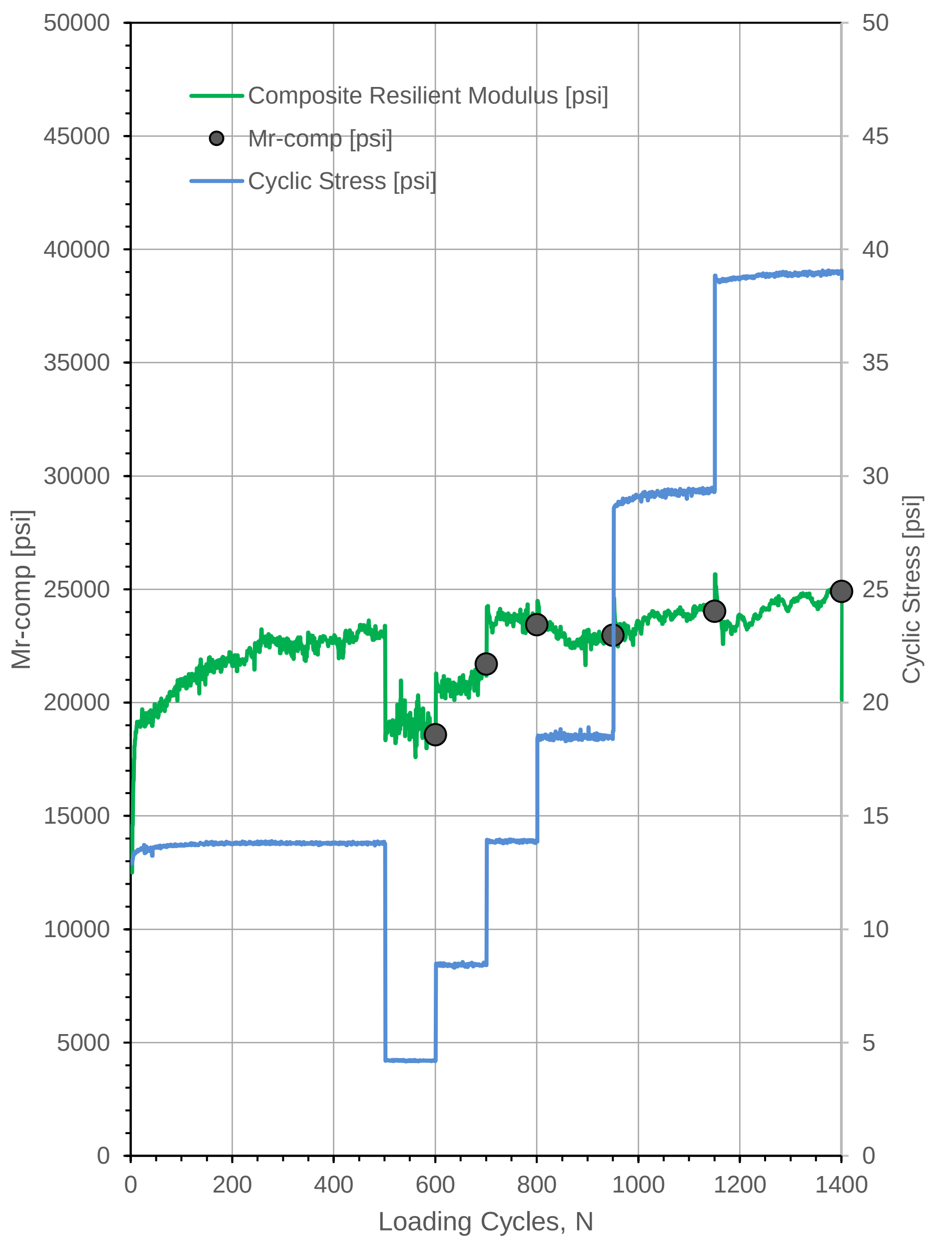
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/19/2017	Time:	1:56:24 PM	Test ID	**Hwy20_12_pt5**
Tested By	DW, JV	Location:	Hwy20 EB Lane	Sta.	NA
Latitude,N:	42.474869	Longitude,W:	95.197319	Elev. (ft):	1347
Comments:	Recyled aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

σ_{cyclic} [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]
2	16,146
3	17,574
4	18,619
5	19,438
6	20,105
7	20,662
8	21,136
9	21,545
10	21,901
11	22,212
12	22,487
13	22,731
14	22,947
15	23,140
16	23,313
17	23,467
18	23,605
21	23,937
22	24,025
23	24,103
24	24,173
25	24,234
26	24,288
27	24,335
28	24,376
29	24,411
30	24,441
31	24,466
32	24,487
33	24,503
34	24,515
35	24,524
36	24,529
37	24,531
38	24,530
39	24,526
40	24,520



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #2)

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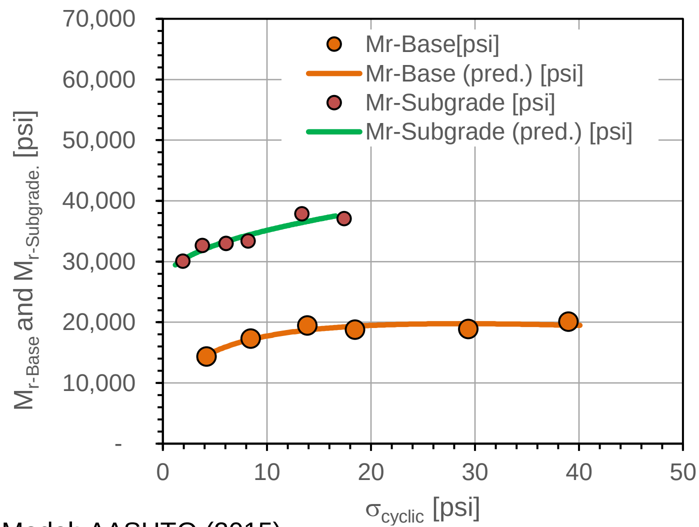
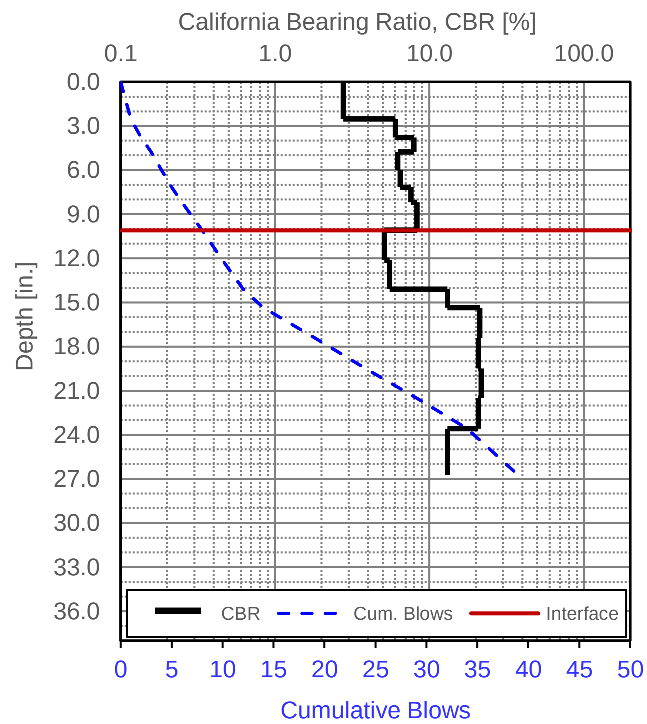
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/19/2017	Time:	1:56:24 PM	Test ID	**Hwy20_12_pt5**
Tested By	DW, JV	Location:	Hwy20 EB Lane	Sta.	NA
Latitude:	42.474869	Longitude:	95.197319	Elev. (ft):	1347
Comments:	Recyled aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade}$ (pred.) [psi]	Modulus Ratio
Conditioning	500	13.88	---	---	---	---	---	---
1	100	4.20	14,400	14,565	1.93	30,112	30,307	0.48
2	100	8.43	17,320	17,147	3.79	32,658	31,891	0.53
3	100	13.88	19,494	18,709	6.09	32,942	33,305	0.59
4	100	18.49	18,833	19,353	8.19	33,399	34,355	0.56
5	100	29.35	18,938	19,763	13.37	37,915	36,431	0.50
6	100	38.98	20,118	19,521	17.43	37,110	37,787	0.54

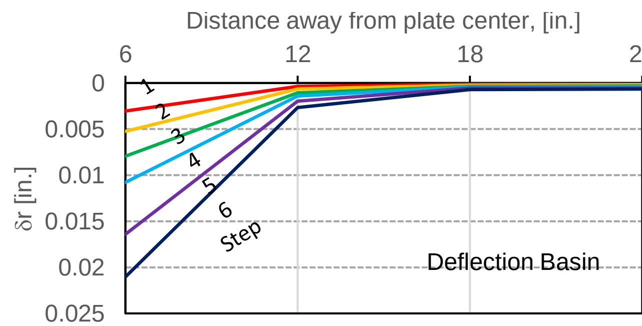




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\ (Base)}$	1195.4	6.31E-07
$k^*_{2\ (Base)}$	0.316	3.41E-02
$k^*_{3\ (Base)}$	-1.353	1.13E-01
Adj. R^2	0.885	
Std. Error [psi]	679	
$k^*_{1\ (Subgrade)}$	2198.9	4.85E-06
$k^*_{2\ (Subgrade)}$	0.082	4.32E-01
$k^*_{3\ (Subgrade)}$	0.328	7.22E-01
Adj. R^2	0.875	
Std. Error [psi]	986	



In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #2)

Automated Plate Load Test [APLT]

Test:	In-Situ Static Plate Load Test: Two Loading Cycles.				
Date:	10/19/2017	Time:	3:25:49 PM	Test ID	**Hwy20_2_30Static_6_Subbase**
Tested By	DW, JV	Location:	Hwy20 EB Lane	Sta.	NA
Latitude:	42.4748617	Longitude:	95.1969800	Elev. (ft):	1361
Comments:	Recyled aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.				

Cycle	Stage	Load Step	Target Applied Load (lbs)	Target Applied Stress (psi)	Actual Applied Stress (psi)	Deformation (in.) Sensor 1	Sensor 2	Sensor 3	Average Def. (in.)
0	Seating	0	707	1	*1.41*	0.0343	0.0097	0.0736	**0.0392**
Zero load and deformation sensors after applying the seating stress.									
1	Seating	0	0	0	*0.00*	*0.0000*	*0.0000*	*0.0000*	**0.0000**
1	Load	1	1767	2.5	*2.44*	*0.0425*	*0.0293*	*0.0551*	**0.0423**
1	Load	2	3534	5	*4.96*	*0.0671*	*0.0524*	*0.0853*	**0.0683**
1	Load	3	5301	7.5	*7.41*	*0.0901*	*0.0704*	*0.1099*	**0.0901**
1	Load	4	7069	10	*9.92*	*0.1131*	*0.0891*	*0.1336*	**0.1120**
1	Load	5	8836	12.5	*12.37*	*0.1254*	*0.1021*	*0.1524*	**0.1266**
1	Load	6	10603	15	*14.52*	*0.1426*	*0.1151*	*0.1719*	**0.1432**
1	Unload	7	7069	10	*9.80*	*0.1369*	*0.1108*	*0.1669*	**0.1382**
1	Unload	8	3534	5	*4.85*	*0.1291*	*0.1051*	*0.1589*	**0.1310**
1	Unload	9	1767	2.5	*2.72*	*0.1232*	*0.1006*	*0.1524*	**0.1254**
2	Load	10	3534	5	*4.95*	*0.1261*	*0.1036*	*0.1567*	**0.1288**
2	Load	11	7069	10	*10.03*	*0.1354*	*0.1101*	*0.1647*	**0.1367**
2	Load	12	10603	15	*14.61*	*0.1455*	*0.1180*	*0.1748*	**0.1461**
2	Unload	13	1767	2.5	*2.14*	*0.1254*	*0.1021*	*0.1553*	**0.1276**
2	Unload	14	0	0	*0.00*	*0.1210*	*0.0978*	*0.1459*	**0.1216**

Plate Diameter:	*30.0*	in.
Shape factor:	**2.67**	
Material Type:	*B*	A = Cohesive, B = Granular, C = Intermediate
Poisson's ratio:	*0.35*	
Design Stress:	*10.0*	psi
Target Deformation:	*0.05*	in.

AASHTO T222 Method
PCA Design Criteria

k_{u1} (pci) @ design stress:	**91**
k_u (pci) @ δ = 0.05 in.:	**76**

Modulus at target deformation

Stress @ δ = 0.05 in. (psi	**3.8**
E_1 (psi)	**2,664**
k'_u (pci)	**76**
k_u (pci)	**76**

Plate Bending Correction for

$$k'_u \geq 100 \text{ and } 1{,}000\ pci$$

$$k_u = -39.9178 + 5.5076\,[k'_u]^{0.7019}$$

Modulus at target/design applied stress

First Loading Cycle

δ_1 (in.)	**0.1100**
E_1 (psi)	**3,190**
k'_{u1} (pci)	**91**
k_{u1} (pci)	**91**

Second Loading Cycle

δ_2 (in.)	**0.0144**
E_2 (psi)	**17,676**
k'_{u2} (pci)	**694**
k_{u2} (pci)	**504**
E_2 / E_1 or k_2 / k_1 Ratio	**5.5**

In-situ Modulus of Subgrade Reaction (k) and Elastic Modulus

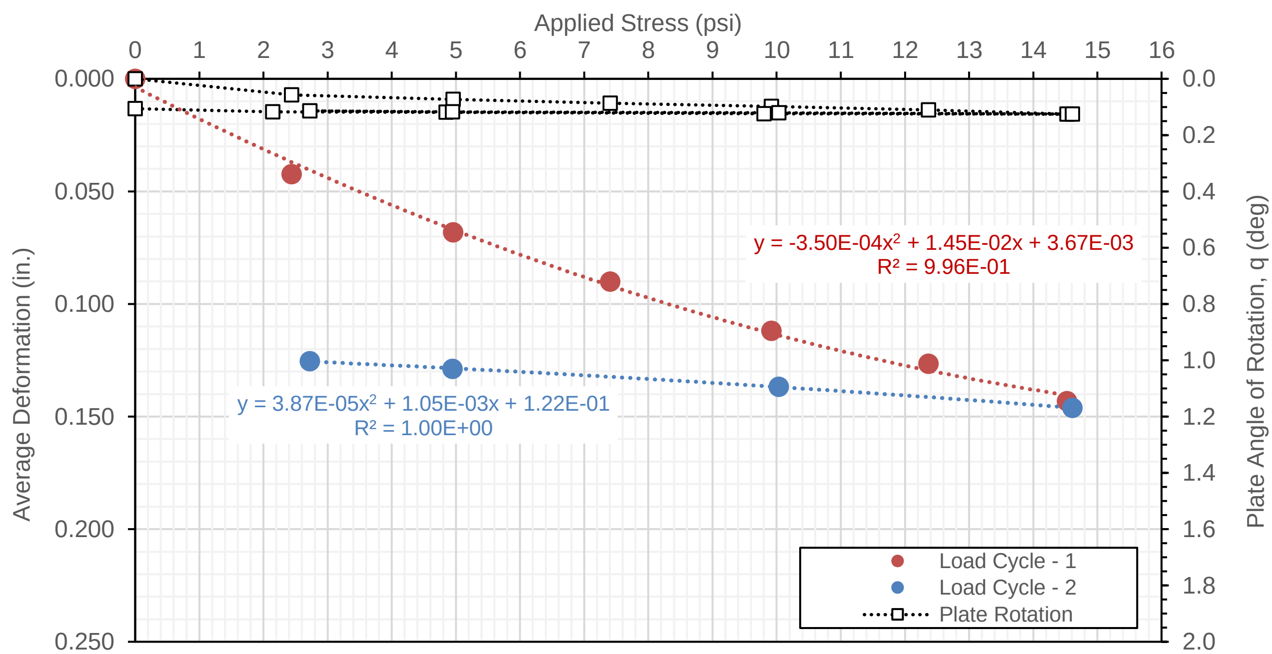
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #2)

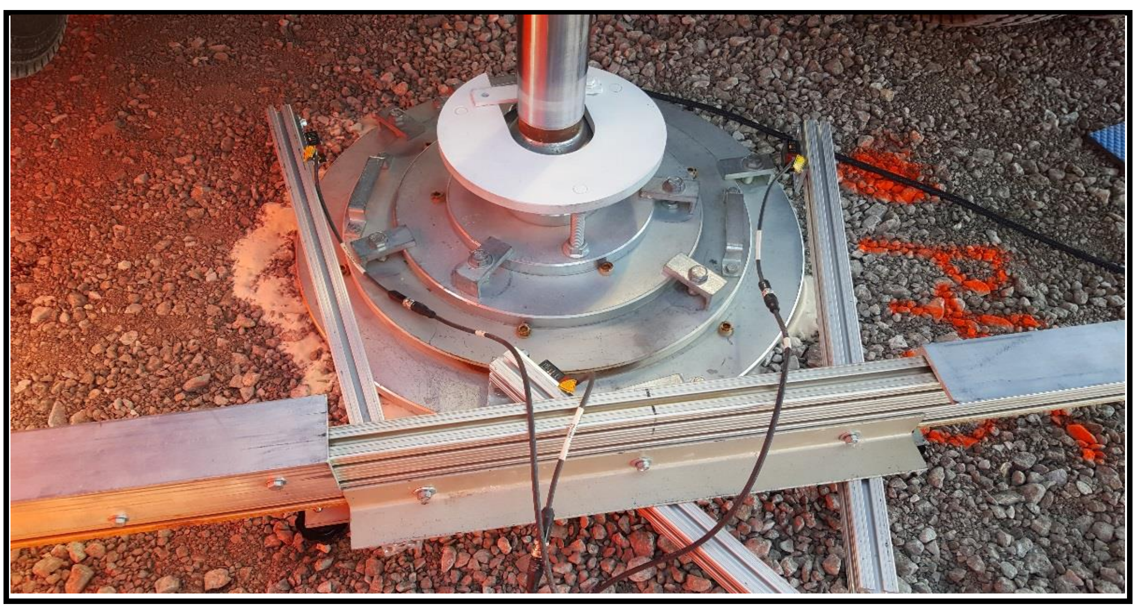
ingios GEOTECHNICS

Polynomial Fit Parameters

First Cycle		*Second Cycle*			
a_1	-3.50E-04	a_1	3.87E-05	θ_{max} (deg)	0.1252
a_2	1.45E-02	a_2	1.05E-03		
R^2	1.00	R^2	1.00		

NOTES:
1. Test performed per AASHTO T222/ASTM D1196.
2. k-value determined using:
(a) calculated stress at 0.05 in. plate deformation (d) for first loading cycle, per PCA design guidelines, and
(b) for a defined target stress and calculating corresponding plate deformations using polynomial fit parameters.





Automated Plate Load Test [APLT]

Test:	In-Situ Static Plate Load Test: Two Loading Cycles.				
Date:	10/19/2017	Time:	4:40:32 PM	Test ID	**Hwy20_2_30Static_7_Subgrade**
Tested By	DW, JV	Location:	Hwy20 EB Lane	Sta.	NA
Latitude:	42.4748217	Longitude:	95.1966633	Elev. (ft):	1337
Comments:	Testing performed directly on the subgrade by excavating the recycled aggregate subbase layer.				

Cycle	Stage	Load Step	Target Applied Load (lbs)	Target Applied Stress (psi)	Actual Applied Stress (psi)	Deformation (in.) Sensor 1	Sensor 2	Sensor 3	Average Def. (in.)
0	Seating	0	707	1	*1.37*	0.0242	0.0178	0.0177	**0.0199**
Zero load and deformation sensors after applying the seating stress.									
1	Seating	0	0	0	*0.00*	*0.0000*	*0.0000*	*0.0000*	**0.0000**
1	Load	1	1767	2.5	*2.51*	*0.0324*	*0.0347*	*0.0282*	**0.0318**
1	Load	2	3534	5	*4.99*	*0.0604*	*0.0647*	*0.0513*	**0.0588**
1	Load	3	5301	7.5	*7.47*	*0.0823*	*0.0880*	*0.0709*	**0.0804**
1	Load	4	7069	10	*9.95*	*0.1024*	*0.1082*	*0.0880*	**0.0996**
1	Load	5	8836	12.5	*12.41*	*0.1277*	*0.1324*	*0.1090*	**0.1230**
1	Load	6	10603	15	*14.53*	*0.1421*	*0.1457*	*0.1217*	**0.1365**
1	Unload	7	7069	10	*9.81*	*0.1341*	*0.1384*	*0.1139*	**0.1288**
1	Unload	8	3534	5	*4.82*	*0.1202*	*0.1253*	*0.1006*	**0.1154**
1	Unload	9	1767	2.5	*2.51*	*0.1118*	*0.1170*	*0.0938*	**0.1076**
2	Load	10	3534	5	*4.98*	*0.1161*	*0.1212*	*0.0974*	**0.1116**
2	Load	11	7069	10	*9.95*	*0.1291*	*0.1334*	*0.1088*	**0.1238**
2	Load	12	10603	15	*14.55*	*0.1437*	*0.1471*	*0.1222*	**0.1377**
2	Unload	13	1767	2.5	*2.30*	*0.1119*	*0.1175*	*0.0930*	**0.1075**
2	Unload	14	0	0	*0.00*	*0.0997*	*0.1056*	*0.0822*	**0.0958**

Plate Diameter:	*30.0*	in.
Shape factor:	**1.57**	
Material Type:	*A*	A = Cohesive, B = Granular, C = Intermediate
Poisson's ratio:	*0.35*	
Design Stress:	*10.0*	psi
Target Deformation:	*0.05*	in.

AASHTO T222 Method
PCA Design Criteria

k_{u1} (pci) @ design stress:	**98**
k_u (pci) @ δ = 0.05 in.:	**89**

Modulus at target deformation

Stress @ δ = 0.05 in. (psi	**4.4**
E_1 (psi)	**1,838**
k'_u (pci)	**89**
k_u (pci)	**89**

Plate Bending Correction for

$k'_u \geq 100$ *and* $1{,}000$ *pci*

$$k_u = -39.9178 + 5.5076\,[k'_u]^{0.7019}$$

Modulus at target/design applied stress

First Loading Cycle

δ_1 (in.)	**0.1017**
E_1 (psi)	**2,034**
k'_{u1} (pci)	**98**
k_{u1} (pci)	**98**

Second Loading Cycle

δ_2 (in.)	**0.0198**
E_2 (psi)	**8,154**
k'_{u2} (pci)	**504**
k_{u2} (pci)	**394**
E_2 / E_1 or k_2 / k_1 Ratio	**4.0**

In-situ Modulus of Subgrade Reaction (k) and Elastic Modulus

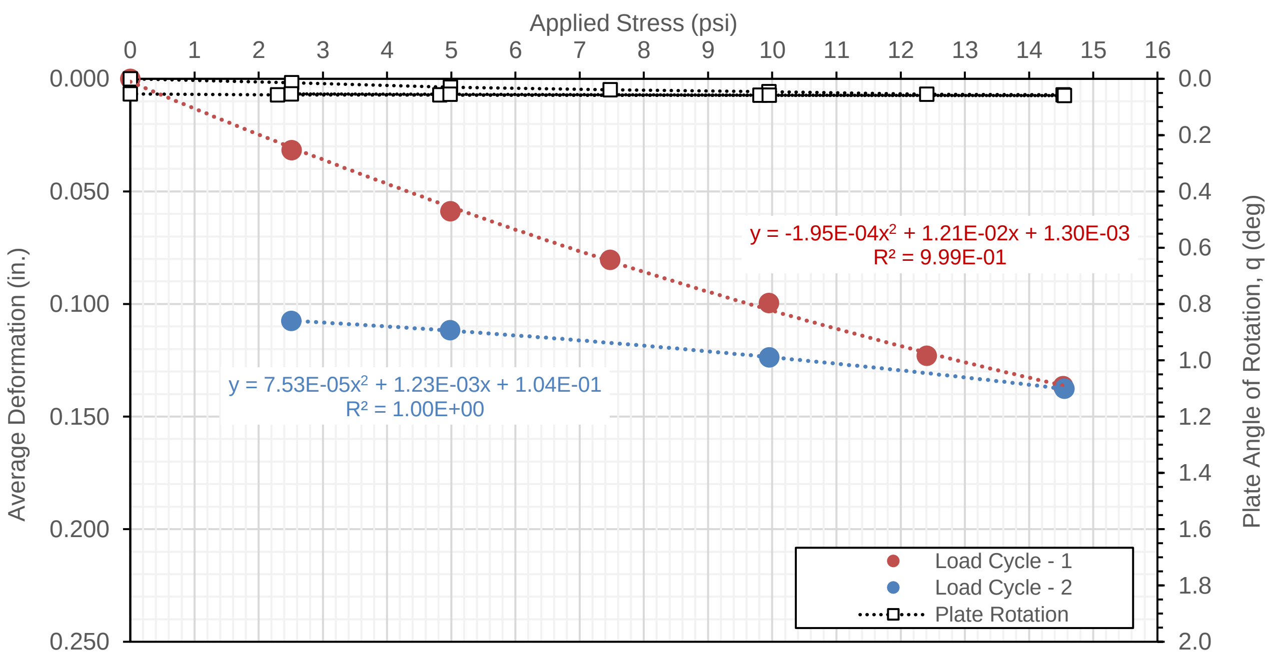
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, Eastbound near Early, IA (Project #2)

ingios GEOTECHNICS

Polynomial Fit Parameters

	First Cycle		*Second Cycle*		
a_1	-1.95E-04	a_1	7.53E-05	θ_{max} (deg)	0.0597
a_2	1.21E-02	a_2	1.23E-03		
R^2	1.00	R^2	1.00		

NOTES:
1. Test performed per AASHTO T222/ASTM D1196.
2. k-value determined using:
   (a) calculated stress at 0.05 in. plate deformation (d) for first loading cycle, per PCA design guidelines, and
   (b) for a defined target stress and calculating corresponding plate deformations using polynomial fit parameters.



Date of Test	10/19/2017	Test ID	Pt1	Operator	DW, JV	ASTM	D6951
Latitude	42.4748540	Longitude		95.1987300		Elevation (ft)	1365
Location	Hwy20 EB Lane	Station		NA			
Comments	Recyled aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	26.7	7.4	9.2	2,059
Avg. Subgrade Layer (top 12 in.)	22.9	6.6	8.5	1,906
Ratio of Avg. Top/Bottom Layer	1.2	1.1	1.1	1.1
Std.Dev.Subbase Layer	25.1	3.8	6.0	1,324
Std. Dev. Subgrade Layer (top 12 in.)	16.4	6.2	8.2	1,832

NOTES:

Subgrade is classified as CL

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

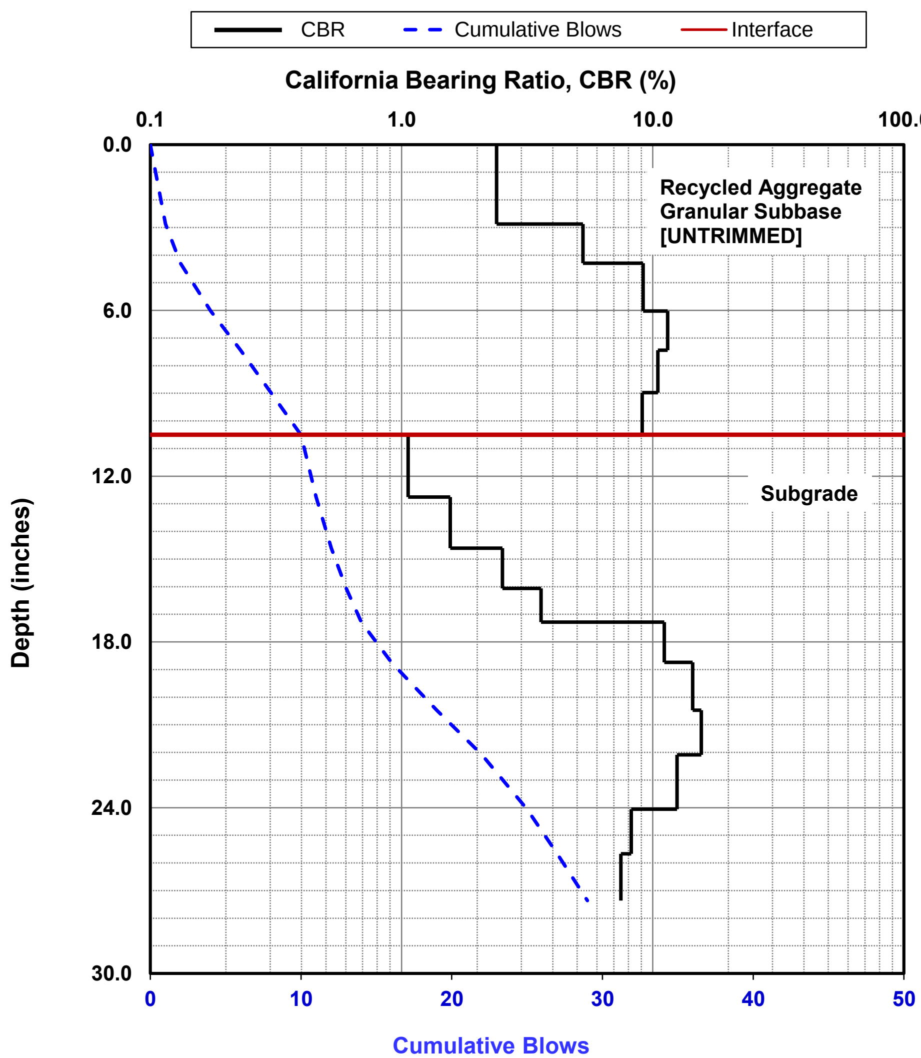
[2]E (ksi) = $(17.6\ CBR^{0.64}) \times 0.1450377$

[3]S_u (psf) = $(3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name: Iowa DOT STIC

Project ID: SIA-00001

Location: Hwy 20, Eastbound near Early, IA (Project #2)

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Date of Test	10/19/2017	Test ID	Pt2	Operator	DW, JV	ASTM	D6951
Latitude	42.4748800	Longitude		95.1983640		Elevation (ft)	1350
Location	Hwy20 EB Lane	Station		NA			
Comments	Recyled aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	39.3	4.8	7.0	1,545
Avg. Subgrade Layer (top 12 in.)	22.2	7.0	8.9	1,988
Ratio of Avg. Top/Bottom Layer	1.8	0.7	0.8	0.8
Std.Dev.Subbase Layer	24.4	3.6	5.8	1,285
Std. Dev. Subgrade Layer (top 12 in.)	13.3	8.7	10.2	2,292

NOTES:

Subgrade is classified as CL

[1] $CBR = 292/DPI^{1.12}$

[1] $CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

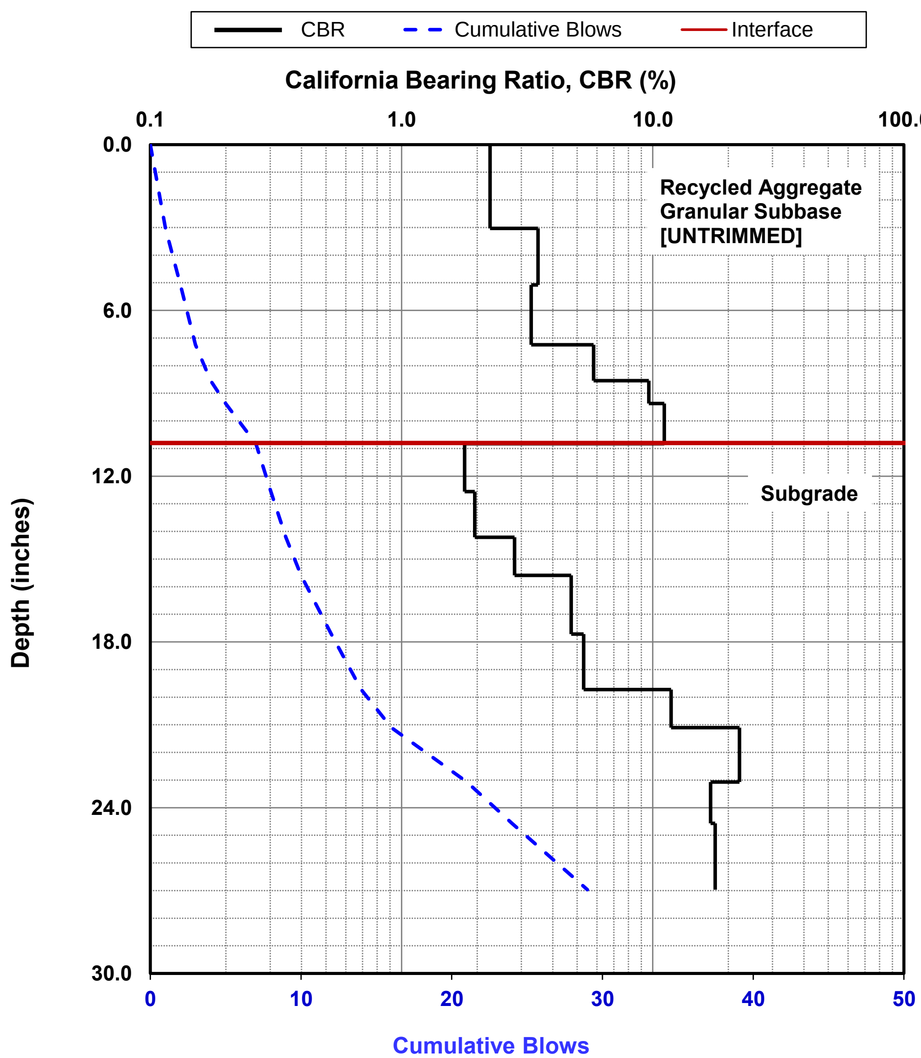
[2] $E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3] $S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2] Powell et al. (1986)

[3] Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Eastbound near Early, IA (Project #2)

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Date of Test	10/19/2017	Test ID	Pt3	Operator	DW, JV	ASTM	D6951
Latitude	42.4748730	Longitude	95.1979680	Elevation (ft)	1352		
Location	Hwy20 EB Lane	Station	NA				
Comments	Recyled aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	35.6	5.3	7.5	1,663
Avg. Subgrade Layer (top 12 in.)	17.9	11.6	12.2	2,774
Ratio of Avg. Top/Bottom Layer	2.0	0.5	0.6	0.6
Std.Dev.Subbase Layer	19.6	2.8	4.9	1,070
Std. Dev. Subgrade Layer (top 12 in.)	12.5	8.3	9.9	2,230

NOTES:

Subgrade is classified as CL

[1] $CBR = 292/DPI^{1.12}$

[1] $CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

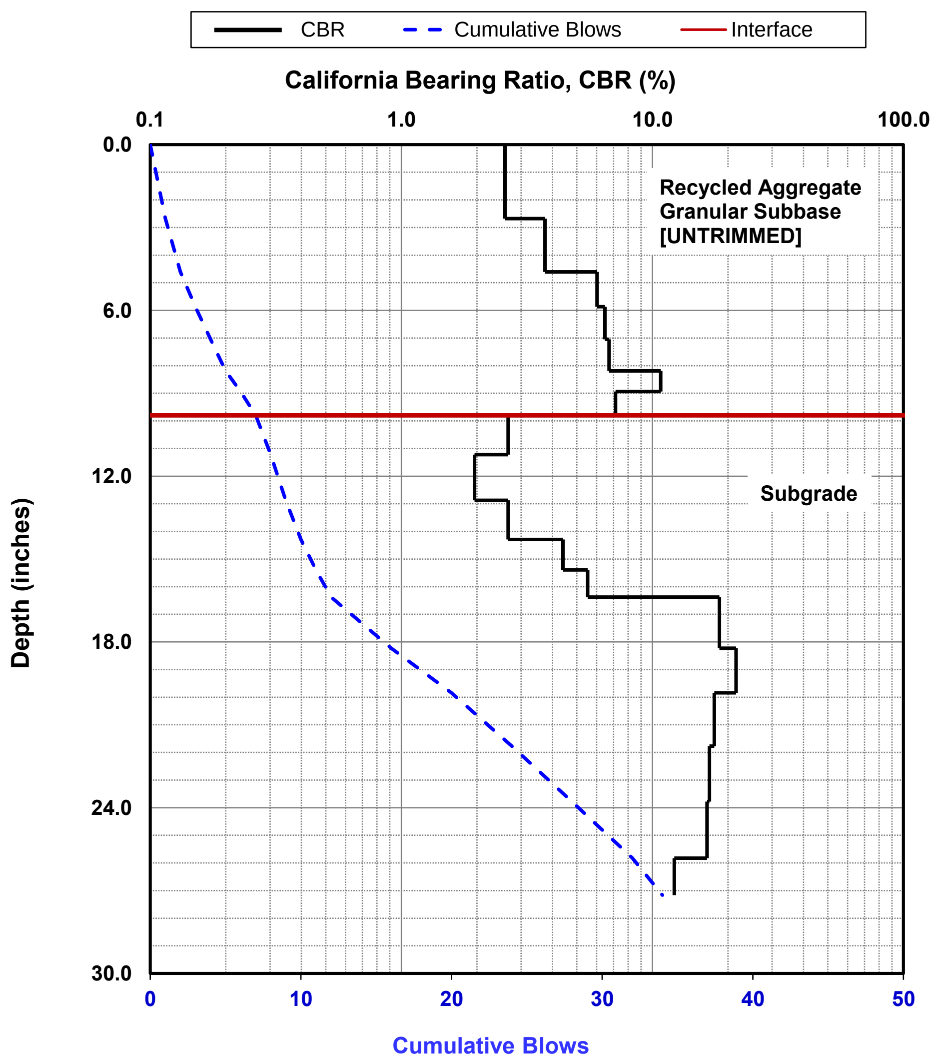
[2] $E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3] $S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2] Powell et al. (1986)

[3] Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Eastbound near Early, IA (Project #2)

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Date of Test	10/19/2017	Test ID	Pt4	Operator	DW, JV	ASTM	D6951
Latitude	42.4748650		Longitude	95.1976550		Elevation (ft)	1351
Location	Hwy20 EB Lane		Station	NA			
Comments	Recyled aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	35.3	5.4	7.5	1,673
Avg. Subgrade Layer (top 12 in.)	15.7	13.3	13.4	3,050
Ratio of Avg. Top/Bottom Layer	2.2	0.4	0.6	0.5
Std.Dev.Subbase Layer	19.7	3.2	5.4	1,190
Std. Dev. Subgrade Layer (top 12 in.)	10.7	8.9	10.3	2,327

NOTES:

Subgrade is classified as CL

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

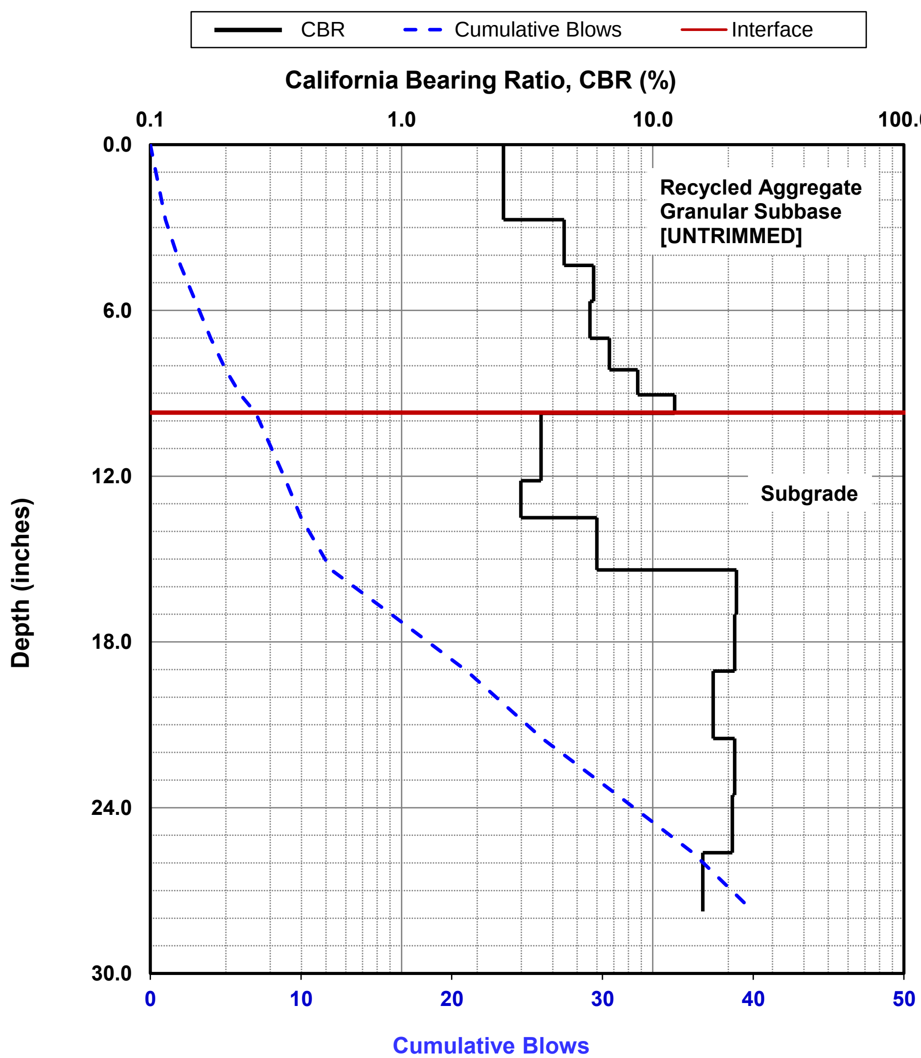
[2]$E\text{ (ksi)} = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\text{ (psf)} = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Eastbound near Early, IA (Project #2)

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Date of Test	10/19/2017	Test ID	Pt5	Operator	DW, JV	ASTM	D6951
Latitude	42.4748690	Longitude		95.1973190		Elevation (ft)	1354
Location	Hwy20 EB Lane	Station		NA			
Comments	Recyled aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	32.0	6.0	8.1	1,799
Avg. Subgrade Layer (top 12 in.)	13.8	15.4	14.7	3,362
Ratio of Avg. Top/Bottom Layer	2.3	0.4	0.5	0.5
Std.Dev.Subbase Layer	16.4	2.2	4.2	912
Std. Dev. Subgrade Layer (top 12 in.)	7.4	7.8	9.5	2,141

NOTES:

Subgrade is classified as CL

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

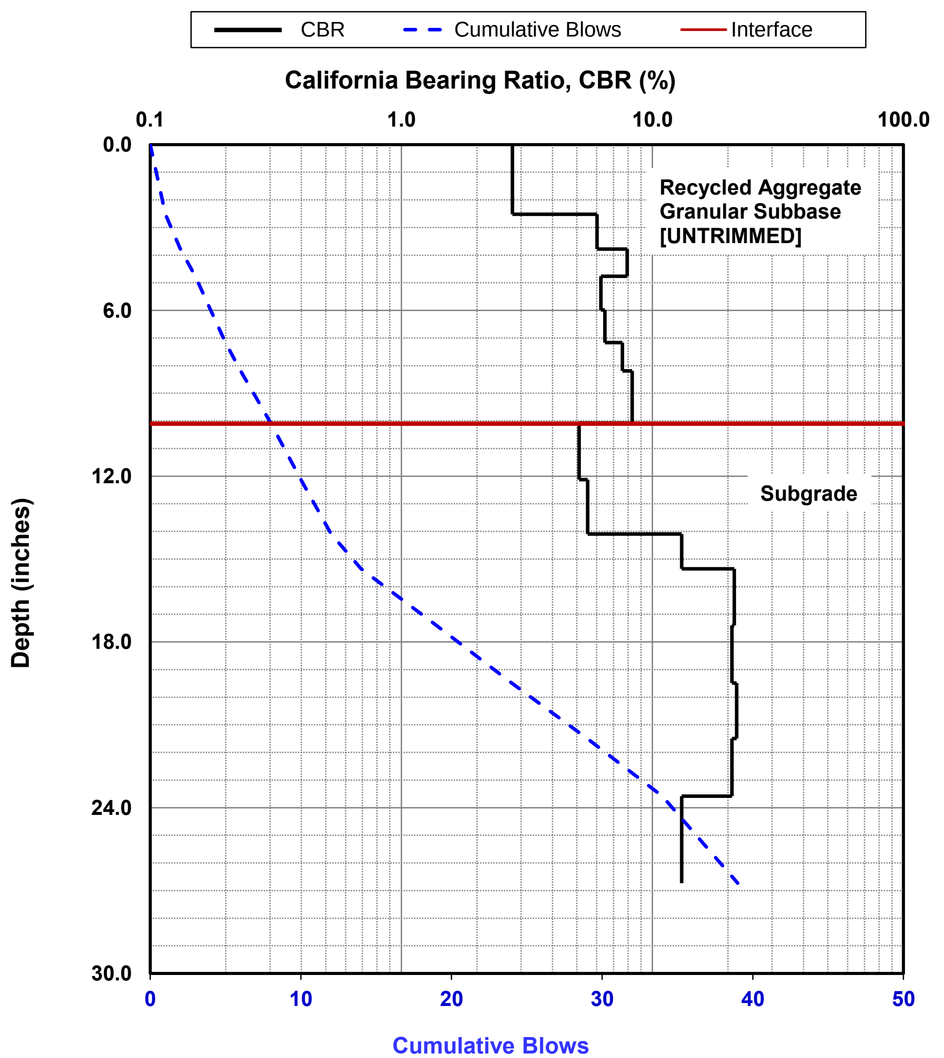
[2]$E \text{ (ksi)} = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u \text{ (psf)} = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name: Iowa DOT STIC

Project ID: SIA-00001

Location: Hwy 20, Eastbound near Early, IA (Project #2)

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Date of Test	10/19/2017	Test ID	Pt6	Operator	DW, JV	ASTM	D6951
Latitude	42.4748617		Longitude	95.1969800		Elevation (ft)	1361
Location	Hwy20 EB Lane		Station	NA			
Comments	Recyled aggregate base over select subgrade (glacial till). Testing completed after two roller passes and prior to trimming.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	21.5	9.4	10.7	2,422
Avg. Subgrade Layer (top 12 in.)	14.2	14.9	14.4	3,286
Ratio of Avg. Top/Bottom Layer	1.5	0.6	0.7	0.7
Std.Dev.Subbase Layer	10.1	3.2	5.4	1,192
Std. Dev. Subgrade Layer (top 12 in.)	11.6	7.6	9.4	2,102

NOTES:

Subgrade is classified as CL

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

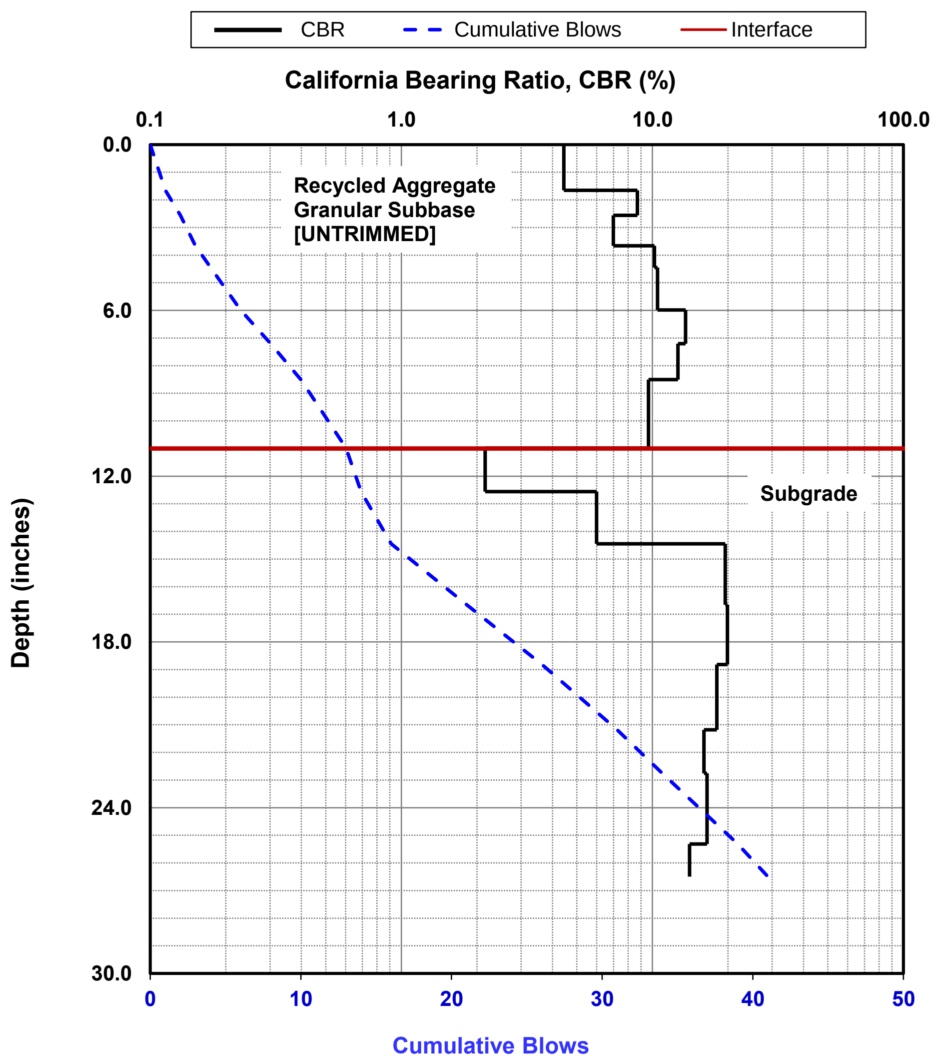
[2]$E\text{ (ksi)} = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\text{ (psf)} = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Eastbound near Early, IA (Project #2)

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Date of Test	10/19/2017	Test ID	Pt6	Operator	DW, JV	ASTM	D6951
Latitude	42.4748690	Longitude	95.1966633	Elevation (ft)	1337		
Location	Hwy20 EB Lane	Station	NA				
Comments	Testing completed on compacted subgrade.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	NA	NA	NA	NA
Avg. Subgrade Layer (top 12 in.)	17.7	11.7	12.3	2,791
Ratio of Avg. Top/Bottom Layer	NA	NA	NA	NA
Std.Dev.Subbase Layer	NA	NA	NA	NA
Std. Dev. Subgrade Layer (top 12 in.)	12.0	7.4	9.2	2,068

NOTES:

Subgrade is classified as CL

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

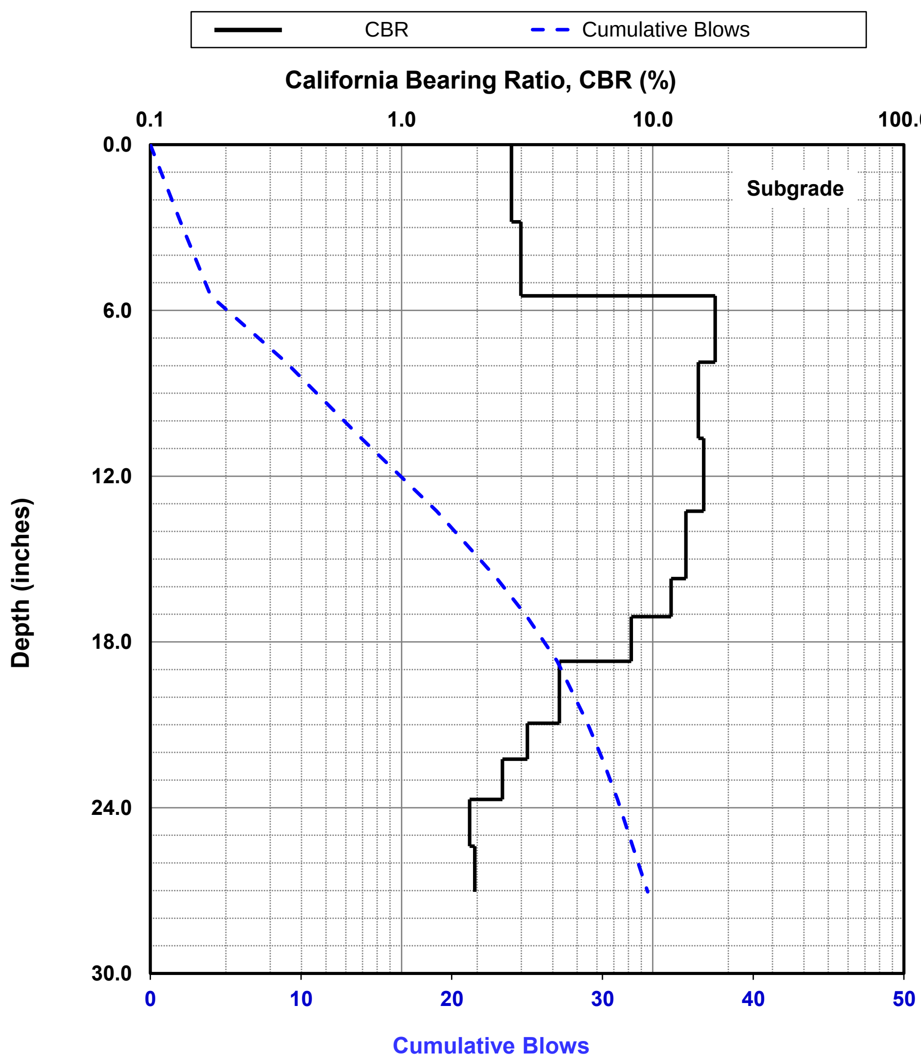
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name: Iowa DOT STIC

Project ID: SIA-00001

Location: Hwy 20, Eastbound near Early, IA (Project #2)

Field Project # 3

I-35NB to US30EB Ramp, Ames, Story County, IA

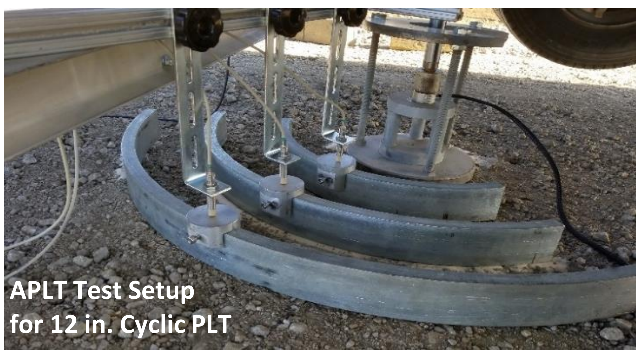
10/28/2017

Modified subbase (recycled concrete) over select subgrade

Project Location and Test Locations

Test Locations	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

Site Conditions and Pictures



Pictures

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

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Summary of Test Results

Summary of Cyclic APLT Test Results

Point #	4 psi cyclic stress @ surface $M_{r\text{-Comp}}$ (psi)	$M_{r\text{-Base}}$ (psi)	$M_{r\text{-SG}}$ (psi)	$\Delta\delta_p$ ([in.)	8 psi plate cyclic stress @ surface $M_{r\text{-Comp}}$ (psi)	$M_{r\text{-Base}}$ (psi)	$M_{r\text{-SG}}$ (psi)	$\Delta\delta_p$ ([in.)
Untrimmed1	27,247	29,637	23,606	0.0004	26,845	28,346	24,407	0.0004
Untrimmed2	27,267	30,909	21,461	0.0002	21,354	21,885	20,158	0.0001
Untrimmed3	9,977	21,652	3,698	-0.0001	9,132	20,359	3,329	0.0004
Trimmed4	28,192	46,145	14,645	0.0000	22,108	32,743	12,828	0.0000
Trimmed5	38,407	58,461	22,521	0.0000	32,067	44,679	20,610	0.0001
Trimmed6	25,433	30,742	18,391	-0.0001	23,596	29,404	16,507	-0.0002
AVG	**26,087**	**36,258**	**17,387**	**0.0001**	**22,517**	**29,569**	**16,307**	**0.0001**
COV	35%	37%	43%	277%	34%	30%	46%	178%

Point #	13 psi cyclic stress @ surface $M_{r\text{-Comp}}$ (psi)	$M_{r\text{-Base}}$ (psi)	$M_{r\text{-SG}}$ (psi)	$\Delta\delta_p$ ([in.)	18 psi plate cyclic stress @ surface $M_{r\text{-Comp}}$ (psi)	$M_{r\text{-Base}}$ (psi)	$M_{r\text{-SG}}$ (psi)	$\Delta\delta_p$ ([in.)
Untrimmed1	29,233	31,533	25,734	0.0008	31,618	37,192	24,957	0.0043
Untrimmed2	22,075	23,526	19,708	0.0005	23,520	26,562	18,994	0.0073
Untrimmed3	8,762	20,971	3,016	0.0019	7,436	17,869	2,551	0.0348
Trimmed4	19,605	28,517	11,640	0.0005	16,561	23,806	9,939	0.0075
Trimmed5	29,712	41,743	19,039	0.0000	27,330	38,159	17,620	0.0043
Trimmed6	24,575	33,696	15,114	0.0002	22,674	31,420	13,858	0.0049
AVG	**22,327**	**29,998**	**15,709**	**0.0006**	**21,523**	**29,168**	**14,653**	**0.0105**
COV	35%	25%	50%	103%	40%	27%	53%	114%

Point #	28 psi cyclic stress @ surface $M_{r\text{-Comp}}$ (psi)	$M_{r\text{-Base}}$ (psi)	$M_{r\text{-SG}}$ (psi)	$\Delta\delta_p$ ([in.)	38 psi plate cyclic stress @ surface $M_{r\text{-Comp}}$ (psi)	$M_{r\text{-Base}}$ (psi)	$M_{r\text{-SG}}$ (psi)	$\Delta\delta_p$ ([in.)
Untrimmed1	30,699	33,936	26,179	0.0153	34,064	40,434	26,242	0.0268
Untrimmed2	22,947	26,609	17,834	0.0303	23,821	29,641	16,639	0.0569
Untrimmed3	6,368	16,216	2,070	0.1596	5,608	15,436	1,718	0.3101
Trimmed4	13,792	20,530	7,981	0.0357	11,679	17,299	6,762	0.0689
Trimmed5	25,254	37,648	15,181	0.0173	24,524	38,223	14,024	0.0309
Trimmed6	22,212	34,358	11,912	0.0220	20,875	33,449	10,764	0.0404
AVG	**20,212**	**28,216**	**13,526**	**0.0467**	**20,095**	**29,080**	**12,691**	**0.0890**
COV	43%	30%	61%	120%	50%	36%	67%	123%

Summary of Test Results

Summary of AASHTO (2015) universal model parameters

Point #	$k^*_{1(Comp)}$	$k^*_{2(Comp)}$	$k^*_{3(Comp)}$	$M_{r\text{-}Comp}$ R^2(Adj.)	Std. Error (psi)	$M_{r\text{-}Comp(pred)\text{-}BP}$ (psi)	$\sigma_{cyclic\text{-}BP}$ (psi)
Untrimmed1	1,790.6	0.017	0.622	0.822	1,075	33,750	39.0
Untrimmed2	1,477.6	-0.335	2.071	0.598	1,033	33,331	2.0
Untrimmed3	759.4	0.011	-2.082	0.982	222	10,550	2.0
Trimmed4	1,899.9	-0.262	-1.114	0.993	498	36,835	2.0
Trimmed5	2,369.5	-0.304	0.576	0.997	303	49,981	2.0
Trimmed6	1,759.7	-0.008	-0.551	0.835	626	25,812	2.0
AVG	**1,676.1**	**(0.147)**	**-0.080**	**0.871**	**626**	**31,710**	**8.2**
COV	32%	-116%	-18.509	18%	58%	41%	185%

Point #	$k^*_{1(Base)}$	$k^*_{2(Base(}$	$k^*_{3(Base)}$	$M_{r\text{-}Base}$ R^2(Adj.)	Std. Error (psi)
Untrimmed1	1,875.3	-0.003	1.066	0.701	2,214
Untrimmed2	1,446.3	-0.515	3.714	0.621	1,780
Untrimmed3	1,593.7	0.021	-1.377	0.901	784
Trimmed4	2,776.6	-0.465	0.022	0.990	1,036
Trimmed5	3,132.0	-0.528	2.228	0.991	764
Trimmed6	2,053.0	0.037	0.151	0.405	1,095
AVG	**2,146.2**	**(0.242)**	**0.967**	**0.768**	**1,279**
COV	31%	-118%	1.860	30%	46%

Point #	$k^*_{1(SG)}$	$k^*_{2(SG)}$	$k^*_{3(SG)}$	$M_{r\text{-}SG}$ R^2(Adj.)	Std. Error (psi)
Untrimmed1	1,805.7	0.091	-0.371	0.857	376
Untrimmed2	1,534.7	-0.006	-1.742	0.989	183
Untrimmed3	496.2	0.187	-16.069	0.998	32
Trimmed4	1,106.7	-0.055	-5.749	0.993	241
Trimmed5	1,596.8	-0.054	-3.389	0.995	219
Trimmed6	1,298.3	-0.094	-3.858	0.997	155
AVG	**1,306.4**	**0.011**	**-5.196**	**0.972**	**201**
COV	36%	941%	-1.084	6%	56%

Summary of Test Results

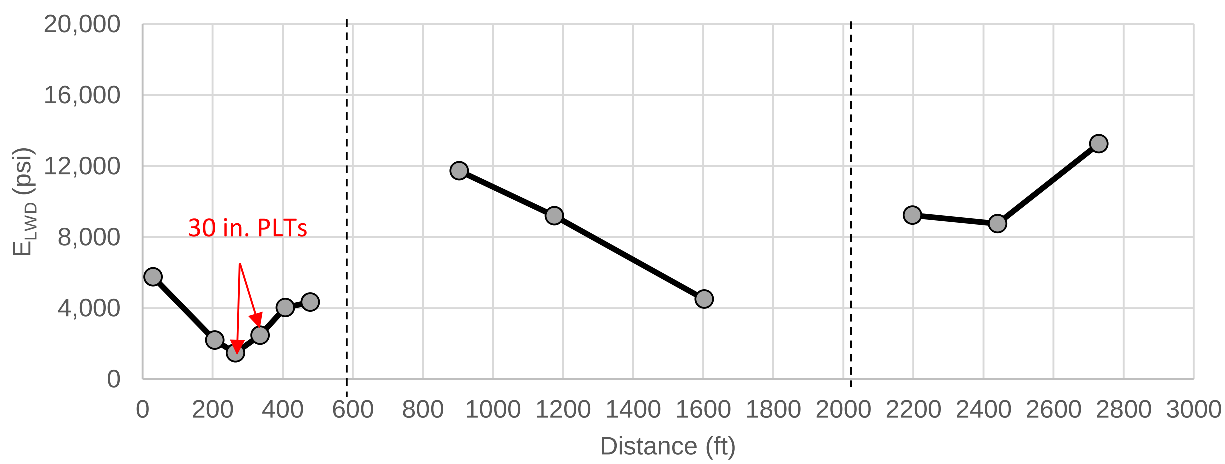
Summary of Static PLT results

Point #	k_u (pci) at δ = 0.05 in.[a]	k_{u1} (pci) at 10 psi[b]	k_{u2} (pci) at 10 psi	Ratio of k_{u2}/k_{u1}
	30 in. static PLT			
Subgrade1	37	36	213	5.9
Subgrade2	43	36	195	5.5

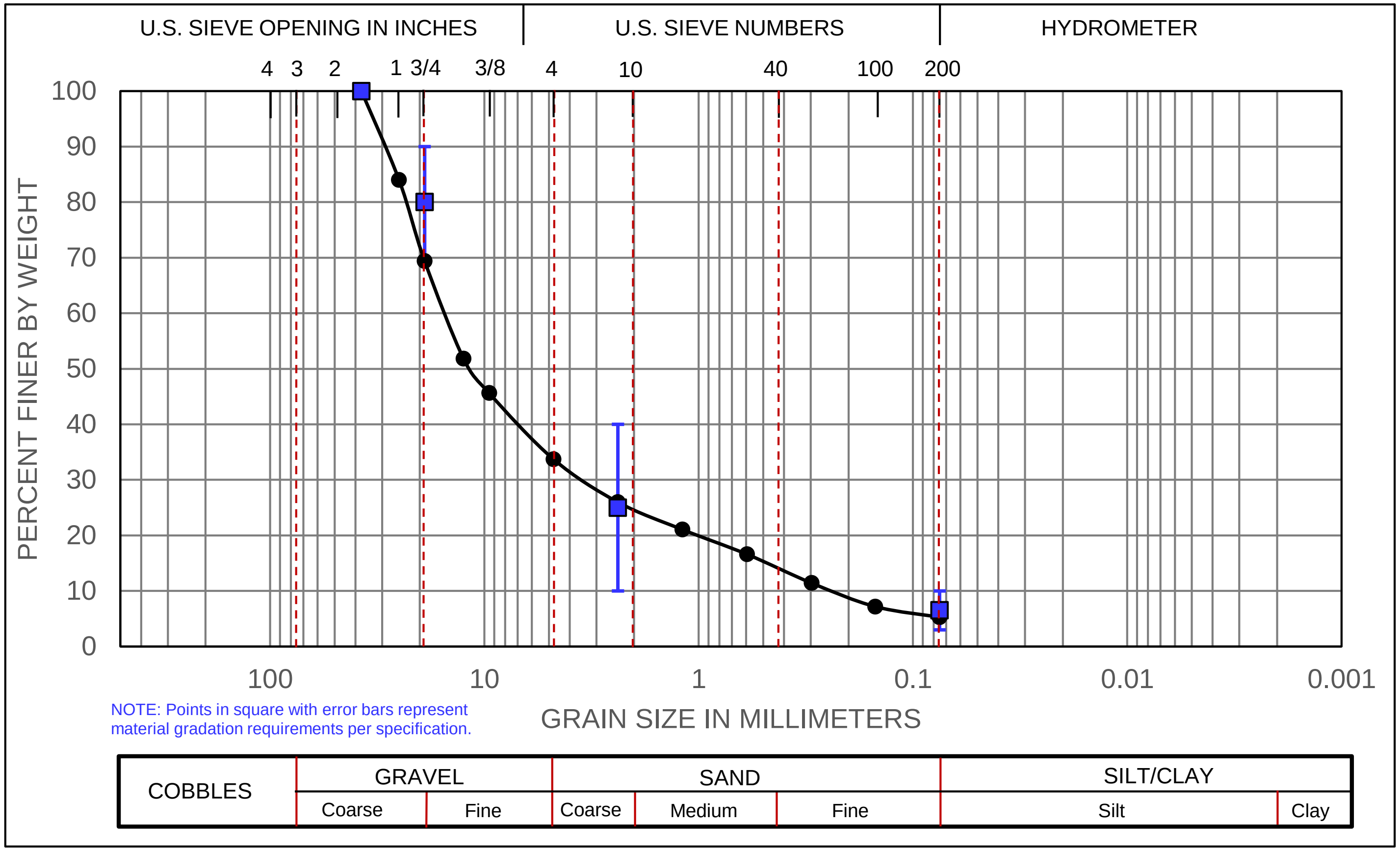
[a]per PCA design critera
[b]per AASHTO T222

Summary of DCP and LWD test results

Point #	Subbase Layer Thickness, H_1 (in.)	Subbase Layer Avg. CBR (%)	Subbase Layer St. Dev CBR (%)	Subgrade Layer Thickness, H_2 (in.)	Subgrade Layer Avg. CBR (%)	Subgrade Layer St. Dev CBR (%)	Ratio CBR_1/ CBR_2	E_{LWD} (psi)
SubgradeA	NA	NA	NA	NA	NA	NA	NA	5,760
SubgradeB	NA	NA	NA	NA	NA	NA	NA	2,199
Subgrade1	NA	NA	NA	12.0	11.8	4.8	NA	1,475
Subgrade2	NA	NA	NA	12.0	5.9	3.8	NA	2,467
SubgradeC	NA	NA	NA	NA	NA	NA	NA	4,025
SubgradeD	NA	NA	NA	NA	NA	NA	NA	4,337
AVG	**NA**	**NA**	**NA**	**12.0**	**8.9**	**4.3**	**NA**	**3,185**
COV	**NA**	**NA**	**NA**	**0%**	**47%**	**16%**	**NA**	**60%**
Untrimmed1	10.4	26.5	10.7	12.0	39.5	16.4	0.7	11,733
Untrimmed2	11.3	17.1	8.8	12.0	19.5	4.0	0.9	9,206
Untrimmed3	11.1	16.5	9.9	12.0	6.7	10.8	2.5	4,515
Trimmed4	10.6	23.0	11.0	12.0	8.6	8.0	2.7	9,236
Trimmed5	10.0	37.0	7.2	12.0	15.0	12.3	2.5	8,749
Trimmed6	11.1	33.0	13.9	12.0	21.9	7.9	1.5	13,255
AVG	**10.8**	**25.5**	**10.3**	**12.0**	**18.5**	**9.9**	**1.8**	**9,449**
COV	5%	33%	22%	0%	64%	43%	50%	32%



GRAIN SIZE DISTRIBUTION
ASTM D422/C136



Gradation Summary

% Gravel	66.3
% Sand	28.4
% Fines	5.3
D_{10} (mm)	0.248
D_{30} (mm)	3.616
D_{50} (mm)	11.630
D_{60} (mm)	15.533
D_{85} (mm)	25.801
C_u	62.7
C_c	3.4

Atterberg Limits

LL	NP
PL	NP
PI	NP

Classification

AASHTO:	A-1-a
USCS:	GP

MATERIAL: Gray Crushed Recycled PCC - Untrimmed (Iowa DOT Gradation 4123 - Modified Subbase)

LOCATION: I35NB Ramp to Hwy30 EB near Ames, IA (Project #3) **TESTED BY:** PV/DW

SAMPLE DATE: 10/28/2017 **TEST DATE:** 11/28/2017

Gradation and Soil Classification Test Results

Project Name: Iowa DOT STIC

Project ID: SIA-00001

Location: I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

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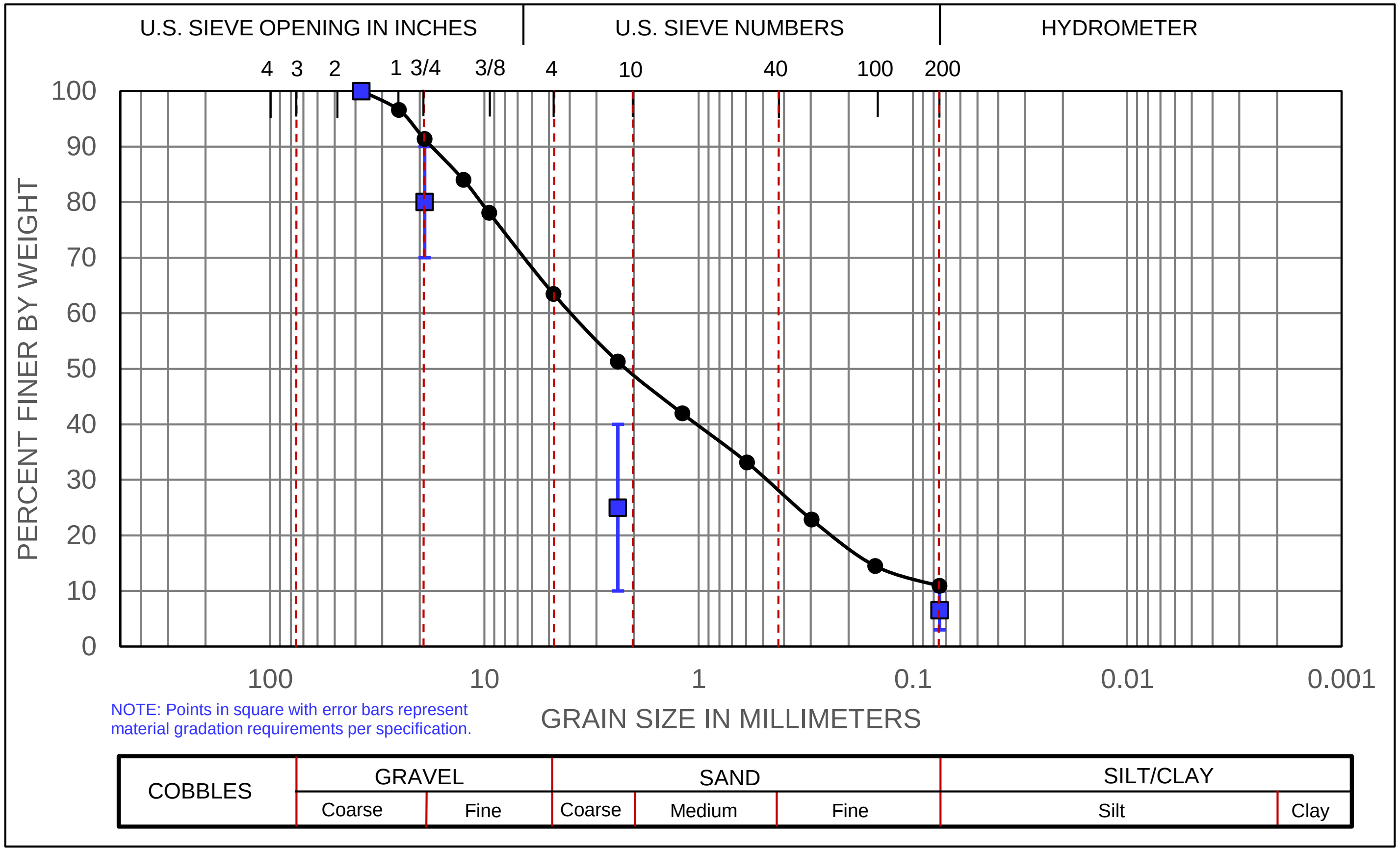
GRAIN SIZE DISTRIBUTION
ASTM D422/C136



Gradation Summary

% Gravel	36.6
% Sand	52.6
% Fines	10.9
D_{10} (mm)	0.057
D_{30} (mm)	0.504
D_{50} (mm)	2.217
D_{60} (mm)	4.079
D_{85} (mm)	13.385
C_u	72.0
C_c	1.1

Atterberg Limits

LL	NP
PL	NP
PI	NP

Classification

AASHTO:	A-1-a
USCS:	SW

MATERIAL: Gray Crushed Recycled PCC - Trimmed (Iowa DOT Gradation 4123 - Modified Subbase)

LOCATION: I35NB Ramp to Hwy30 EB near Ames, IA (Project #3) **TESTED BY:** PV/DW

SAMPLE DATE: 10/28/2017 **TEST DATE:** 11/28/2017

Gradation and Soil Classification Test Results

Project Name: Iowa DOT STIC

Project ID: SIA-00001

Location: I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

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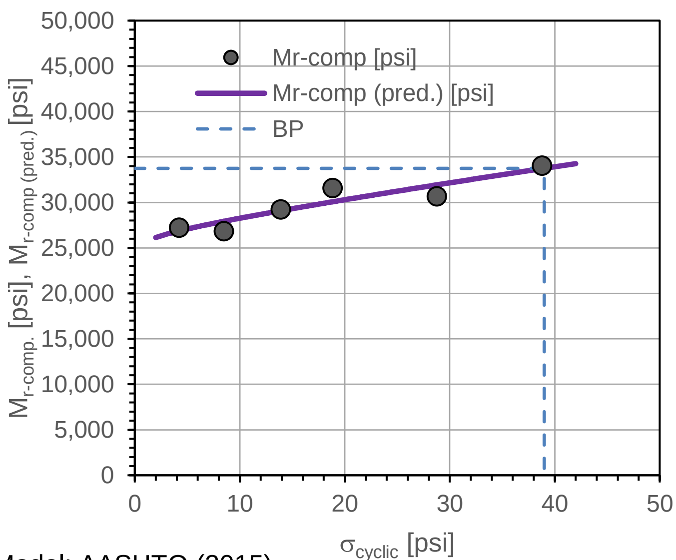
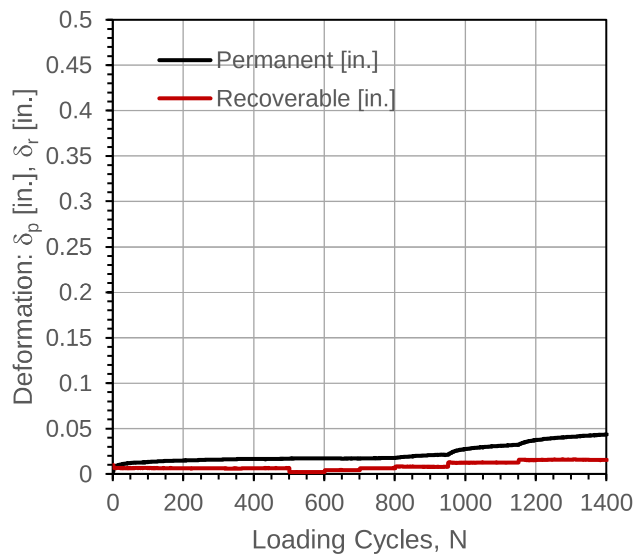
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/28/2017	Time:	2:44:30 PM	Test ID	**Untrimmed1**
Tested By	PV, JV	Location:	I35NB R./Hwy 30 EB	Sta.	NA
Latitude,N:	42.005829	Longitude,W:	93.569458	Elev. (ft):	899
Comments:	Recyled aggregate subbase. Testing on untrimmed subbase.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.91	---	---	0.0167	---	0.170	---
1	100	4.23	27,247	26,871	0.0171	0.0004	0.123	Y
2	100	8.49	26,845	27,929	0.0171	0.0004	-0.067	Y
3	100	13.91	29,233	29,091	0.0175	0.0008	0.470	Y
4	150	18.84	31,618	30,073	0.0210	0.0043	0.587	N
5	200	28.78	30,699	31,937	0.0320	0.0153	0.564	N
6	250	38.80	34,064	33,716	0.0435	0.0268	0.616	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	1,790.6	6.41E-07
k^*_2	0.017	8.60E-01
k^*_3	0.622	4.09E-01
Adj. R^2	0.822	
Std. Error [psi]	1,075	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	33,750
$\sigma_{cyclic\text{-}BP}$ [psi]	39.0

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

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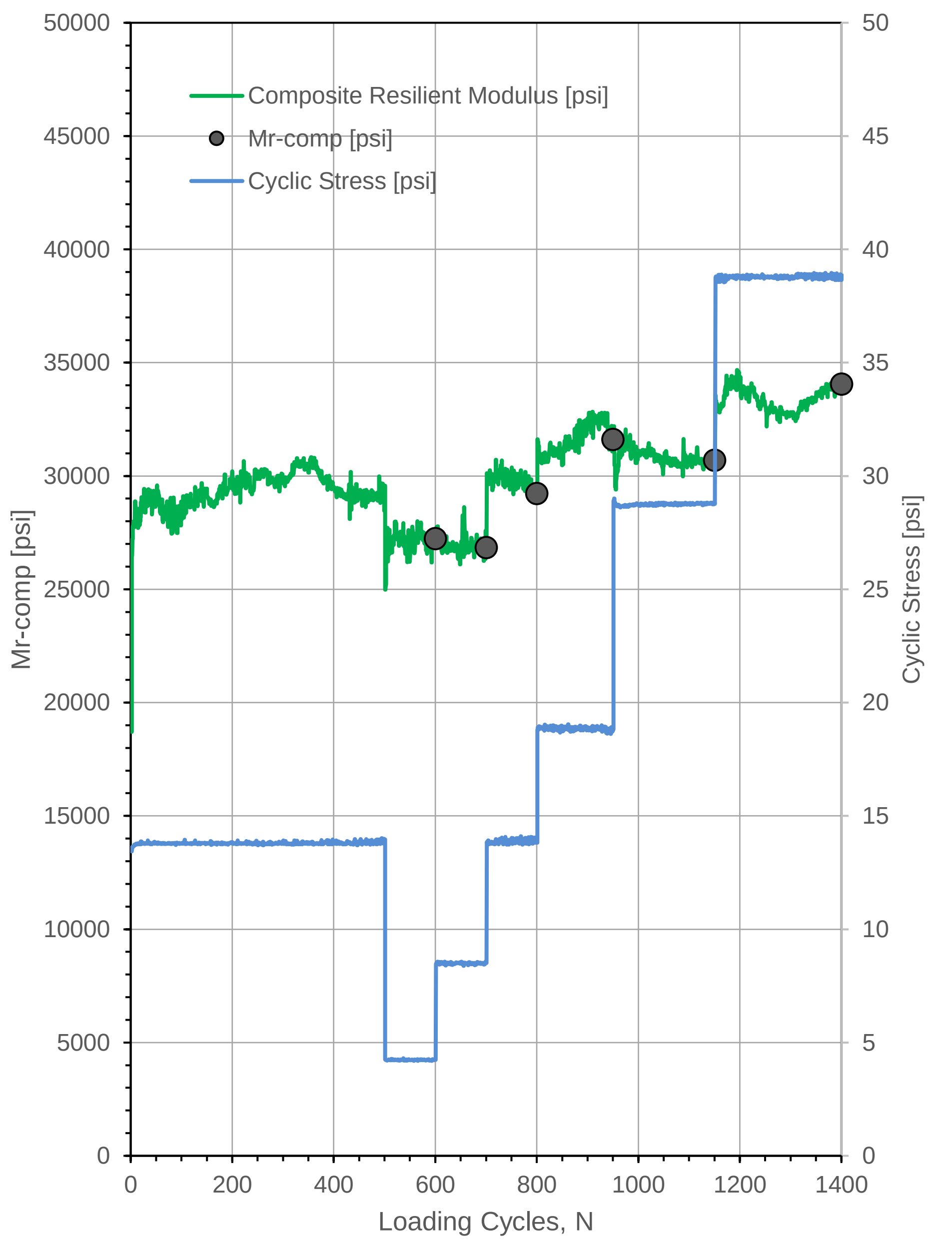
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/28/2017	Time:	2:44:30 PM	Test ID	**Untrimmed1**
Tested By	DV, JV	Location:	I35NB R./Hwy 30 EB	Sta.	NA
Latitude,N:	42.005829	Longitude,W:	93.569458	Elev. (ft):	899
Comments:	Recyled aggregate subbase. Testing on untrimmed subbase.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	26,145
3	26,501
4	26,805
5	27,081
6	27,338
7	27,582
8	27,817
9	28,044
10	28,266
11	28,483
12	28,695
13	28,904
14	29,110
15	29,314
16	29,514
17	29,713
18	29,910
21	30,490
22	30,680
23	30,869
24	31,056
25	31,242
26	31,428
27	31,612
28	31,795
29	31,977
30	32,158
31	32,338
32	32,517
33	32,696
34	32,873
35	33,050
36	33,226
37	33,402
38	33,576
39	33,750
40	33,923



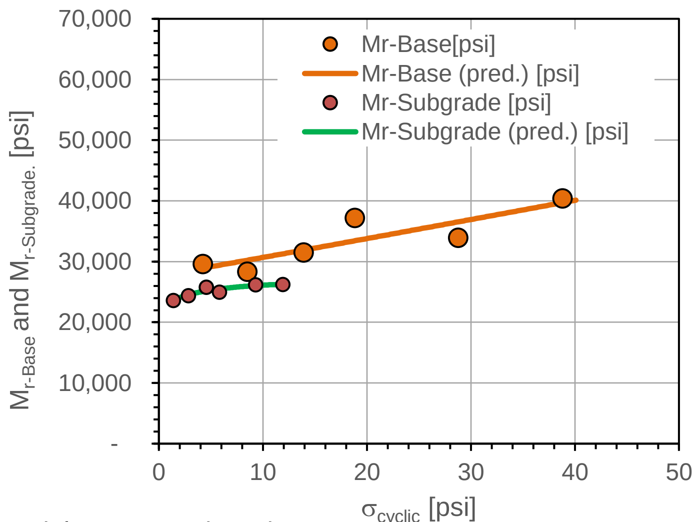
In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

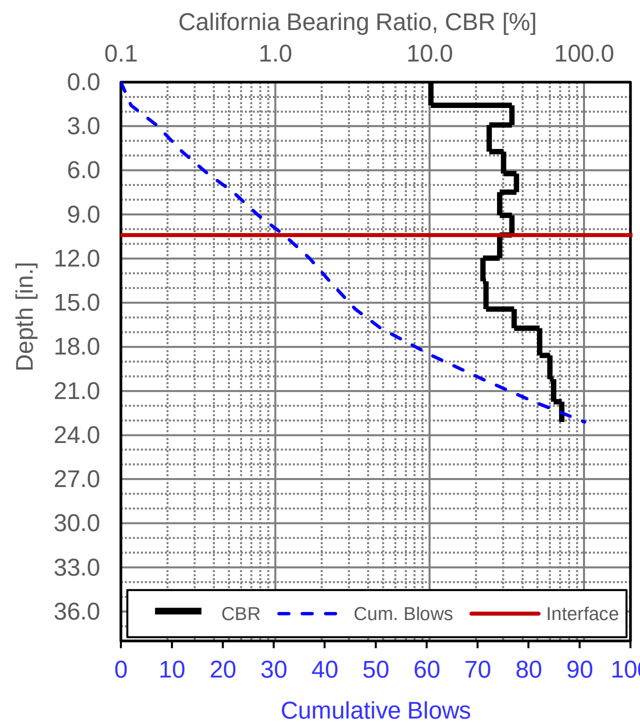
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/28/2017	Time:	2:44:30 PM	Test ID	**Untrimmed1**
Tested By	PV, JV	Location:	I35NB R./Hwy 30 EB	Sta.	NA
Latitude:	42.005829	Longitude:	93.569458	Elev. (ft):	899
Comments:	Recyled aggregate subbase. Testing on untrimmed subbase.				

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	13.91	---	---	---	---	---	---
1	100	4.23	29,637	28,930	1.38	23,606	23,608	1.26
2	100	8.49	28,346	30,218	2.84	24,407	24,525	1.16
3	100	13.91	31,533	31,888	4.57	25,734	25,176	1.23
4	100	18.84	37,192	33,422	5.84	24,957	25,498	1.49
5	100	28.78	33,936	36,542	9.31	26,179	26,041	1.30
6	100	38.80	40,434	39,709	11.91	26,242	26,264	1.54

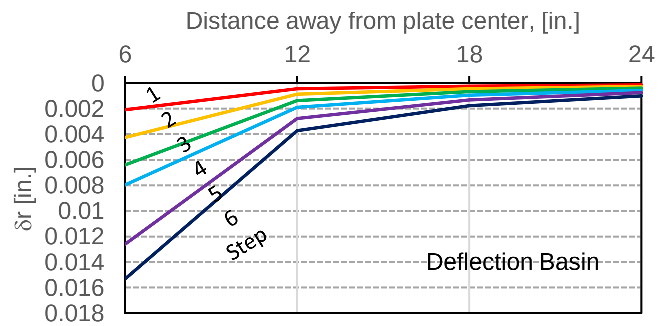




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\ (Base)}$	1875.3	4.46E-06
$k^*_{2\ (Base)}$	-0.003	9.89E-01
$k^*_{3\ (Base)}$	1.066	4.56E-01
Adj. R^2	0.701	
Std. Error [psi]	2214	
$k^*_{1\ (Subgrade)}$	1805.7	2.13E-06
$k^*_{2\ (Subgrade)}$	0.091	1.95E-01
$k^*_{3\ (Subgrade)}$	-0.371	6.16E-01
Adj. R^2	0.857	
Std. Error [psi]	376	



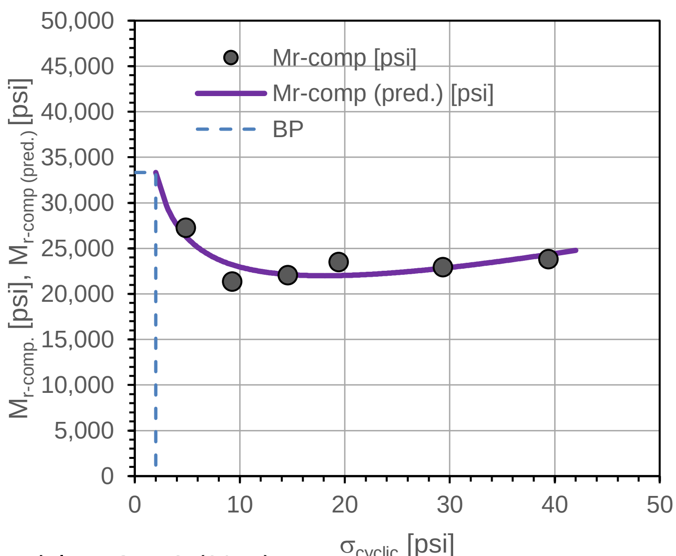
In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

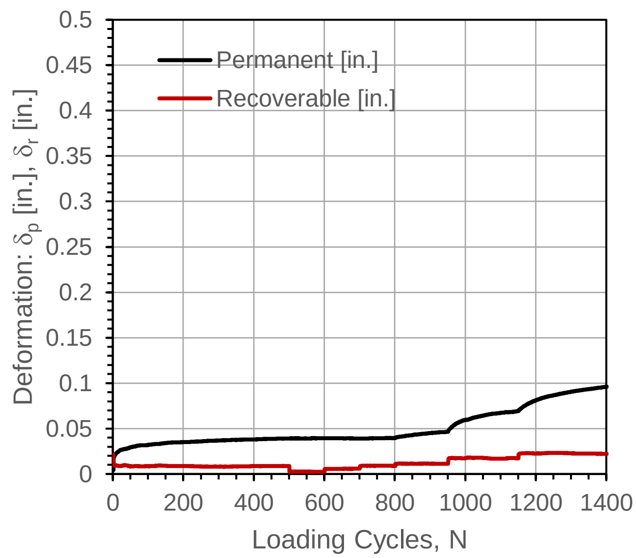
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/28/2017	Time:	3:42:49 PM	Test ID	**Untrimmed2**
Tested By	PV, JV	Location:	I35NB R./Hwy 30 EB	Sta.	NA
Latitude,N:	42.006432	Longitude,W:	93.568863	Elev. (ft):	901
Comments:	Recyled aggregate subbase. Testing on untrimmed subbase.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	14.57	---	---	0.0390	---	0.170	---
1	100	4.85	27,267	26,320	0.0393	0.0002	0.123	Y
2	100	9.29	21,354	23,200	0.0391	0.0001	-0.067	Y
3	100	14.57	22,075	22,133	0.0395	0.0005	0.470	Y
4	150	19.41	23,520	22,013	0.0463	0.0073	0.587	N
5	200	29.36	22,947	22,824	0.0693	0.0303	0.564	N
6	250	39.41	23,821	24,335	0.0959	0.0569	0.616	N





Model: AASHTO (2015)

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

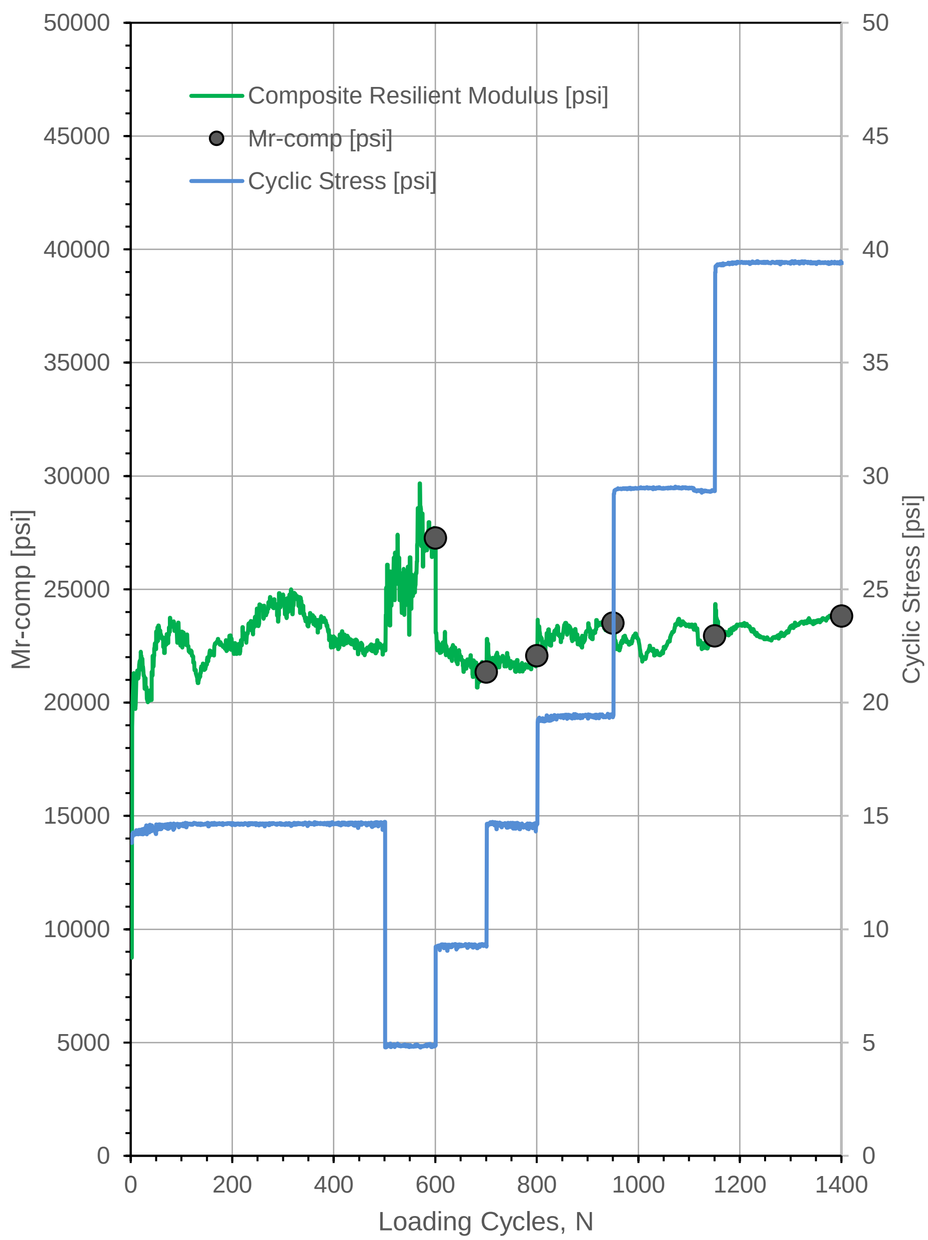
Parameter	Value	P-Value
k^*_1	1,477.6	2.04E-06
k^*_2	-0.335	1.11E-01
k^*_3	2.071	1.35E-01
Adj. R^2	0.598	
Std. Error [psi]	1,033	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	33,331
$\sigma_{cyclic\text{-}BP}$ [psi]	2.0

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/28/2017	Time:	3:42:49 PM	Test ID	**Untrimmed2**
Tested By	PV, JV	Location:	I35NB R./Hwy 30 EB	Sta.	NA
Latitude,N:	42.006432	Longitude,W:	93.568863	Elev. (ft):	901
Comments:	Recyled aggregate subbase. Testing on untrimmed subbase.				

σ_{cyclic} [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]
2	33,331
3	29,731
4	27,581
5	26,141
6	25,111
7	24,346
8	23,763
9	23,312
10	22,960
11	22,685
12	22,472
13	22,309
14	22,187
15	22,099
16	22,041
17	22,008
18	21,997
21	22,070
22	22,123
23	22,189
24	22,265
25	22,351
26	22,447
27	22,550
28	22,661
29	22,780
30	22,905
31	23,036
32	23,173
33	23,315
34	23,462
35	23,614
36	23,771
37	23,932
38	24,097
39	24,265
40	24,438



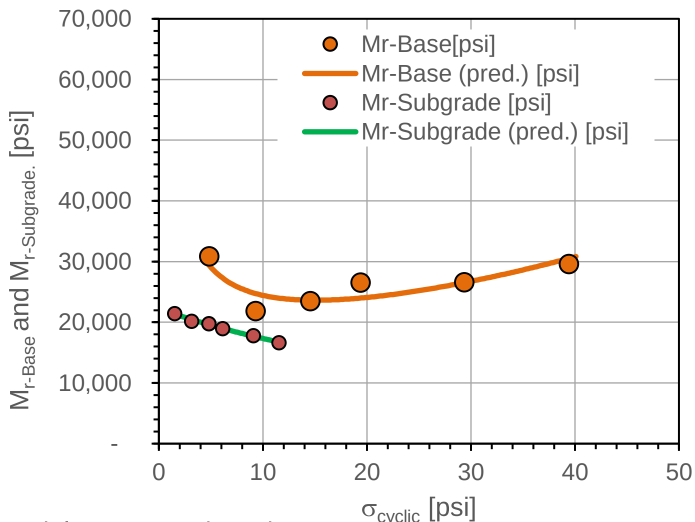
In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

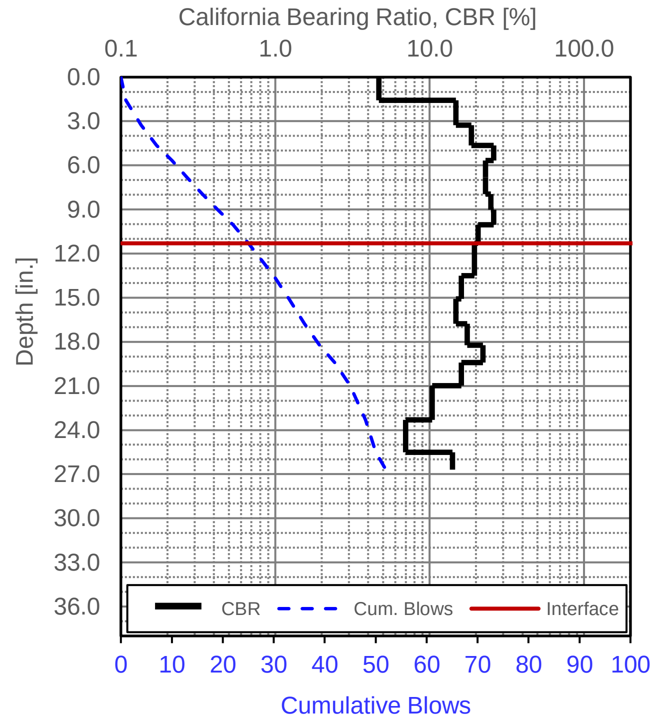
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/28/2017	Time:	3:42:49 PM	Test ID	**Untrimmed2**
Tested By	PV, JV	Location:	I35NB R./Hwy 30 EB	Sta.	NA
Latitude:	42.006432	Longitude:	93.568863	Elev. (ft):	901
Comments:	Recyled aggregate subbase. Testing on untrimmed subbase.				

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade}$ (pred.) [psi]	Modulus Ratio
Conditioning	500	14.57	---	---	---	---	---	---
1	100	4.85	30,909	29,340	1.52	21,461	21,347	1.44
2	100	9.29	21,885	24,743	3.16	20,158	20,438	1.09
3	100	14.57	23,526	23,637	4.83	19,708	19,595	1.19
4	100	19.41	26,562	23,993	6.14	18,994	18,976	1.40
5	100	29.36	26,609	26,529	9.10	17,834	17,693	1.49
6	100	39.41	29,641	30,525	11.55	16,639	16,741	1.78

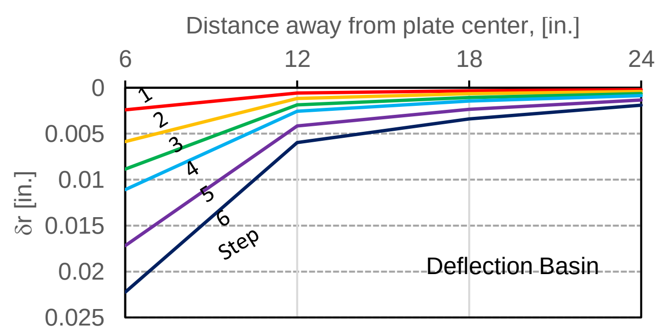




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\ (Base)}$	1446.3	6.87E-06
$k^*_{2\ (Base)}$	-0.515	1.05E-01
$k^*_{3\ (Base)}$	3.714	9.29E-02
Adj. R^2	0.621	
Std. Error [psi]	1780	
$k^*_{1\ (Subgrade)}$	1534.7	6.36E-07
$k^*_{2\ (Subgrade)}$	-0.006	8.80E-01
$k^*_{3\ (Subgrade)}$	-1.742	2.89E-02
Adj. R^2	0.989	
Std. Error [psi]	183	



In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

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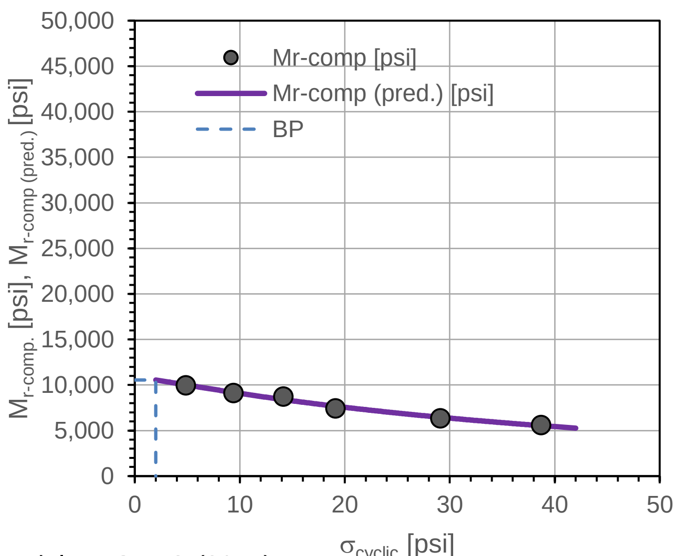
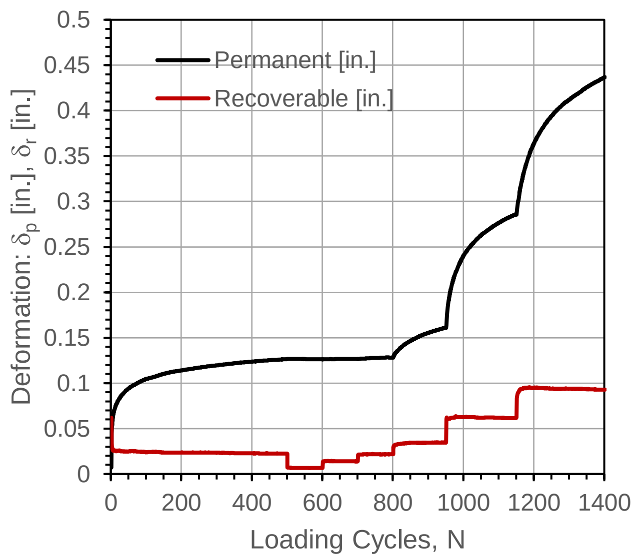
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/28/2017	Time:	4:43:11 PM	Test ID	**Untrimmed3**
Tested By	PV, JV	Location:	I35NB R./Hwy 30 EB	Sta.	NA
Latitude,N:	42.007236	Longitude,W:	93.567726	Elev. (ft):	903
Comments:	Recyled aggregate subbase. Testing on untrimmed subbase.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	14.14	---	---	0.1263	---	0.168	---
1	100	4.85	9,977	10,019	0.1262	-0.0001	-0.334	Y
2	100	9.42	9,132	9,183	0.1267	0.0004	0.287	Y
3	100	14.14	8,762	8,401	0.1282	0.0019	0.615	N
4	150	19.13	7,436	7,670	0.1610	0.0348	0.705	N
5	200	29.12	6,368	6,457	0.2859	0.1596	0.650	N
6	250	38.70	5,608	5,538	0.4363	0.3101	0.666	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	759.4	3.34E-07
k^*_2	0.011	8.93E-01
k^*_3	-2.082	2.67E-02
Adj. R^2	0.982	
Std. Error [psi]	222	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	10,550
$\sigma_{cyclic\text{-}BP}$ [psi]	2.0

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

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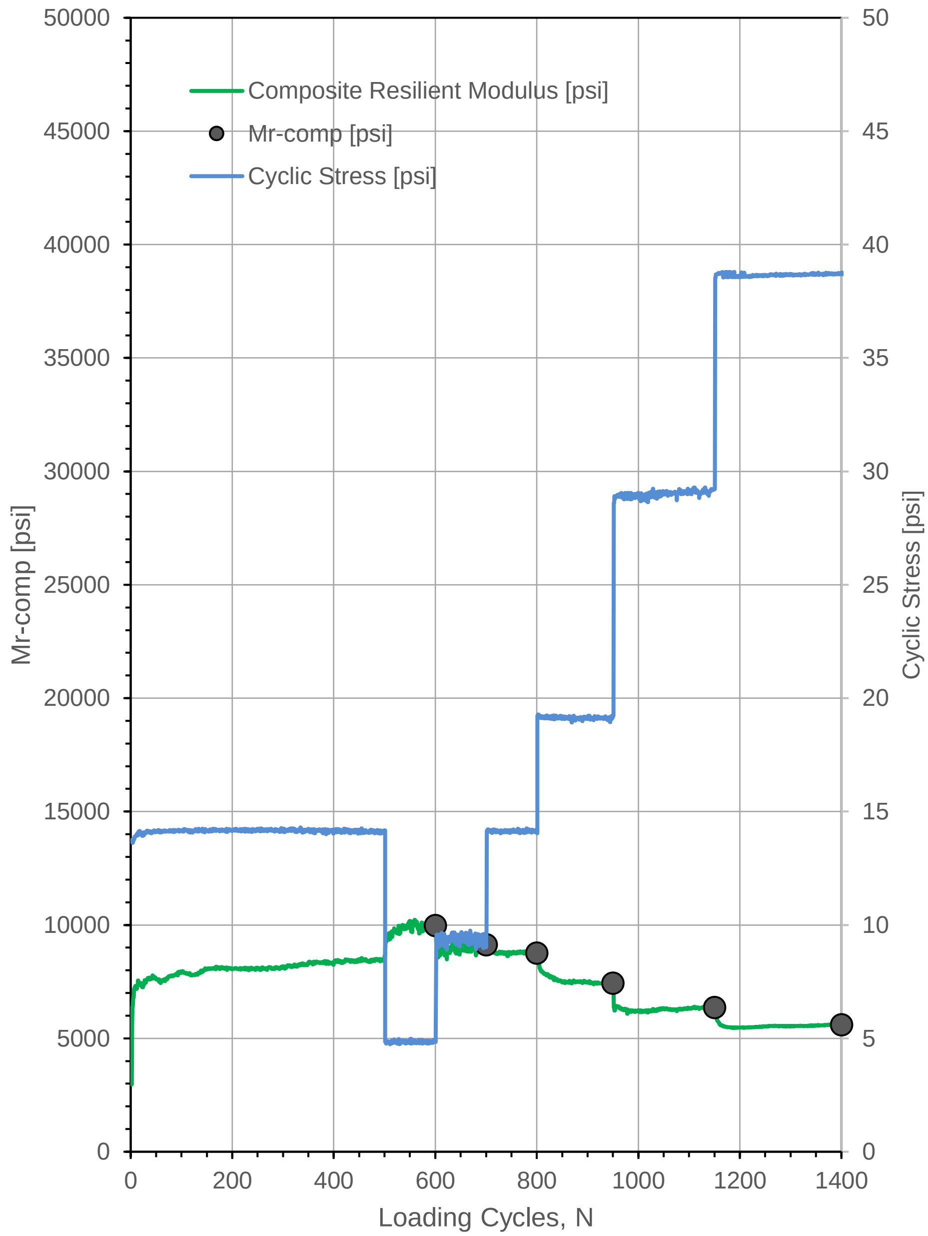
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/28/2017	Time:	4:43:11 PM	Test ID	**Untrimmed3**
Tested By	PV, JV	Location:	I35NB R./Hwy 30 EB	Sta.	NA
Latitude,N:	42.007236	Longitude,W:	93.567726	Elev. (ft):	903
Comments:	Recyled aggregate subbase. Testing on untrimmed subbase.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	10,550
3	10,369
4	10,181
5	9,991
6	9,803
7	9,617
8	9,435
9	9,256
10	9,081
11	8,911
12	8,744
13	8,582
14	8,423
15	8,269
16	8,118
17	7,971
18	7,828
21	7,420
22	7,290
23	7,164
24	7,041
25	6,921
26	6,804
27	6,690
28	6,578
29	6,469
30	6,363
31	6,260
32	6,158
33	6,059
34	5,963
35	5,869
36	5,776
37	5,686
38	5,598
39	5,512
40	5,428



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

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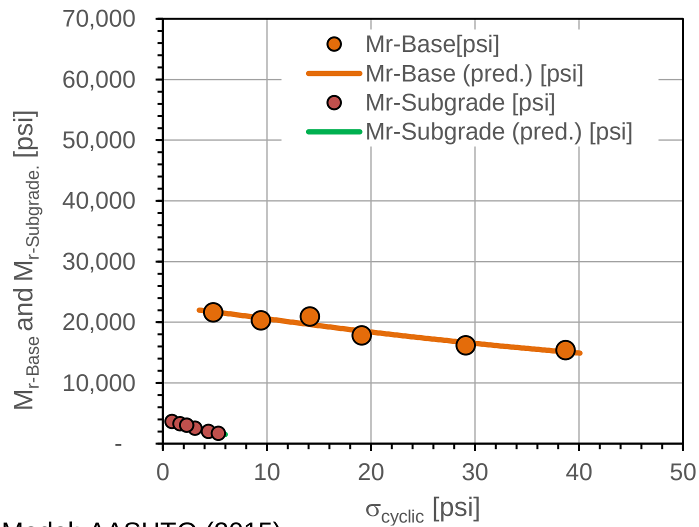
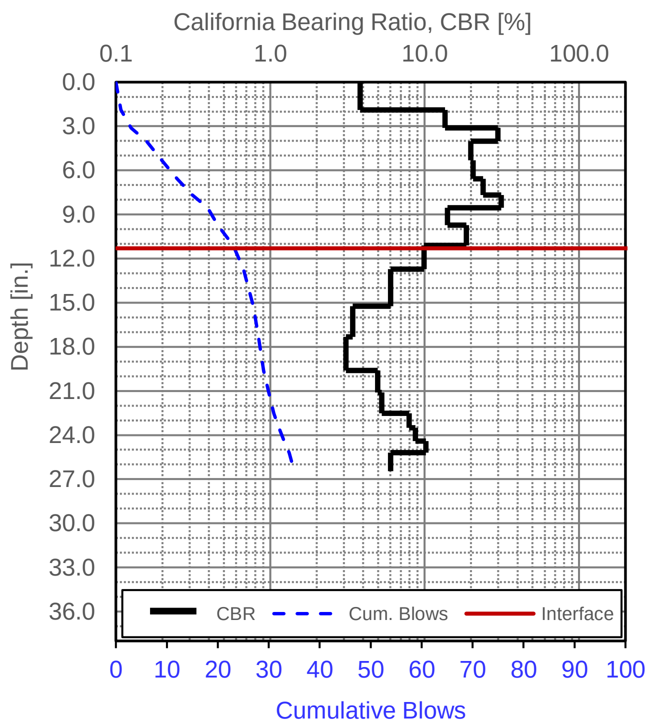
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/28/2017	Time:	4:43:11 PM	Test ID	**Untrimmed3**
Tested By	PV, JV	Location:	I35NB R./Hwy 30 EB	Sta.	NA
Latitude:	42.007236	Longitude:	93.567726	Elev. (ft):	903
Comments:	Recyled aggregate subbase. Testing on untrimmed subbase.				

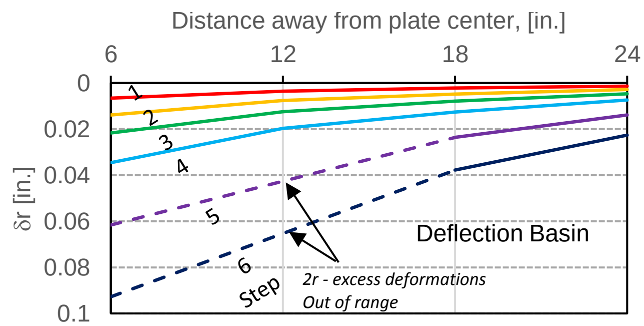
Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	14.14	---	---	---	---	---	---
1	100	4.85	21,652	21,729	0.87	3,698	3,708	5.86
2	100	9.42	20,359	20,706	1.64	3,329	3,318	6.11
3	100	14.14	20,971	19,636	2.29	3,016	2,984	6.95
4	100	19.13	17,869	18,569	3.09	2,551	2,599	7.01
5	100	29.12	16,216	16,669	4.39	2,070	2,051	7.83
6	100	38.70	15,436	15,121	5.33	1,718	1,722	8.98





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
$k^*_{1\ (Base)}$	1593.7	8.65E-07
$k^*_{2\ (Base)}$	0.021	8.63E-01
$k^*_{3\ (Base)}$	-1.377	1.76E-01
Adj. R^2	0.901	
Std. Error [psi]	784	
$k^*_{1\ (Subgrade)}$	496.2	2.41E-05
$k^*_{2\ (Subgrade)}$	0.187	9.42E-02
$k^*_{3\ (Subgrade)}$	-16.069	1.84E-03
Adj. R^2	0.998	
Std. Error [psi]	32	

In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

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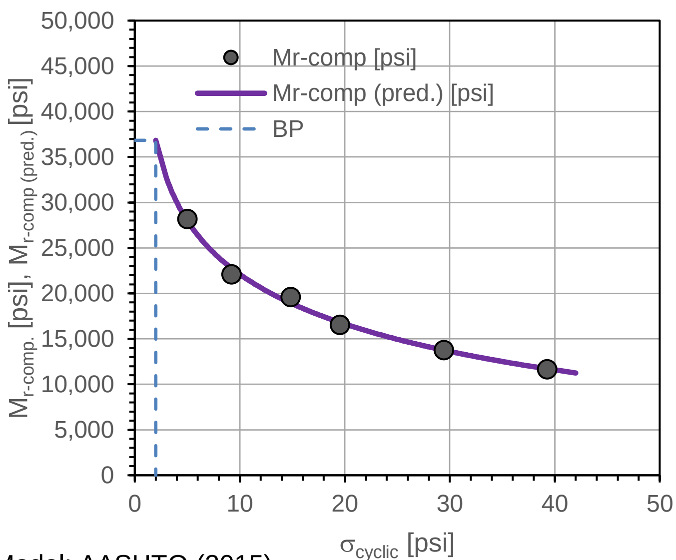
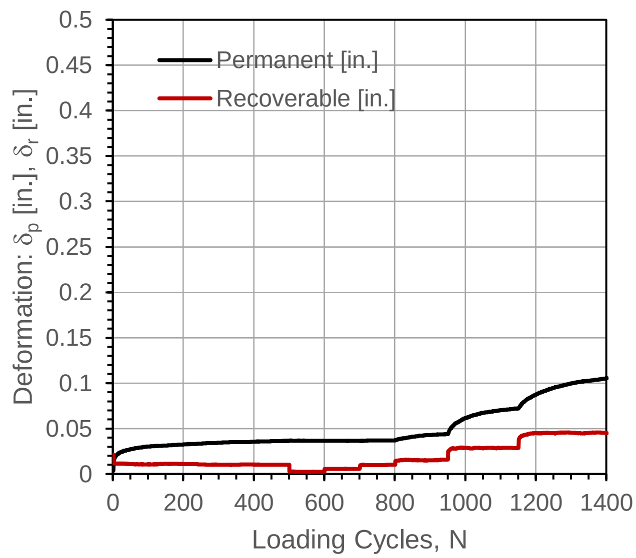
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/28/2017	Time:	5:35:52 PM	Test ID	**Trimmed4**
Tested By	PV, JV	Location:	I35NB R./Hwy 30 EB	Sta.	NA
Latitude,N:	42.007843	Longitude,W:	93.565712	Elev. (ft):	904
Comments:	Recyled aggregate subbase. Testing on trimmed subbase.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	14.84	---	---	0.0365	---	0.157	---
1	100	5.03	28,192	27,941	0.0365	0.0000	-0.014	Y
2	100	9.22	22,108	22,764	0.0365	0.0000	-0.012	Y
3	100	14.84	19,605	18,940	0.0370	0.0005	0.415	Y
4	150	19.54	16,561	16,810	0.0440	0.0075	0.668	N
5	200	29.44	13,792	13,753	0.0722	0.0357	0.577	N
6	250	39.28	11,679	11,704	0.1054	0.0689	0.654	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	1,899.9	1.46E-07
k^*_2	-0.262	2.91E-02
k^*_3	-1.114	8.94E-02
Adj. R^2	0.993	
Std. Error [psi]	498	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	36,835
$\sigma_{cyclic\text{-}BP}$ [psi]	2.0

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

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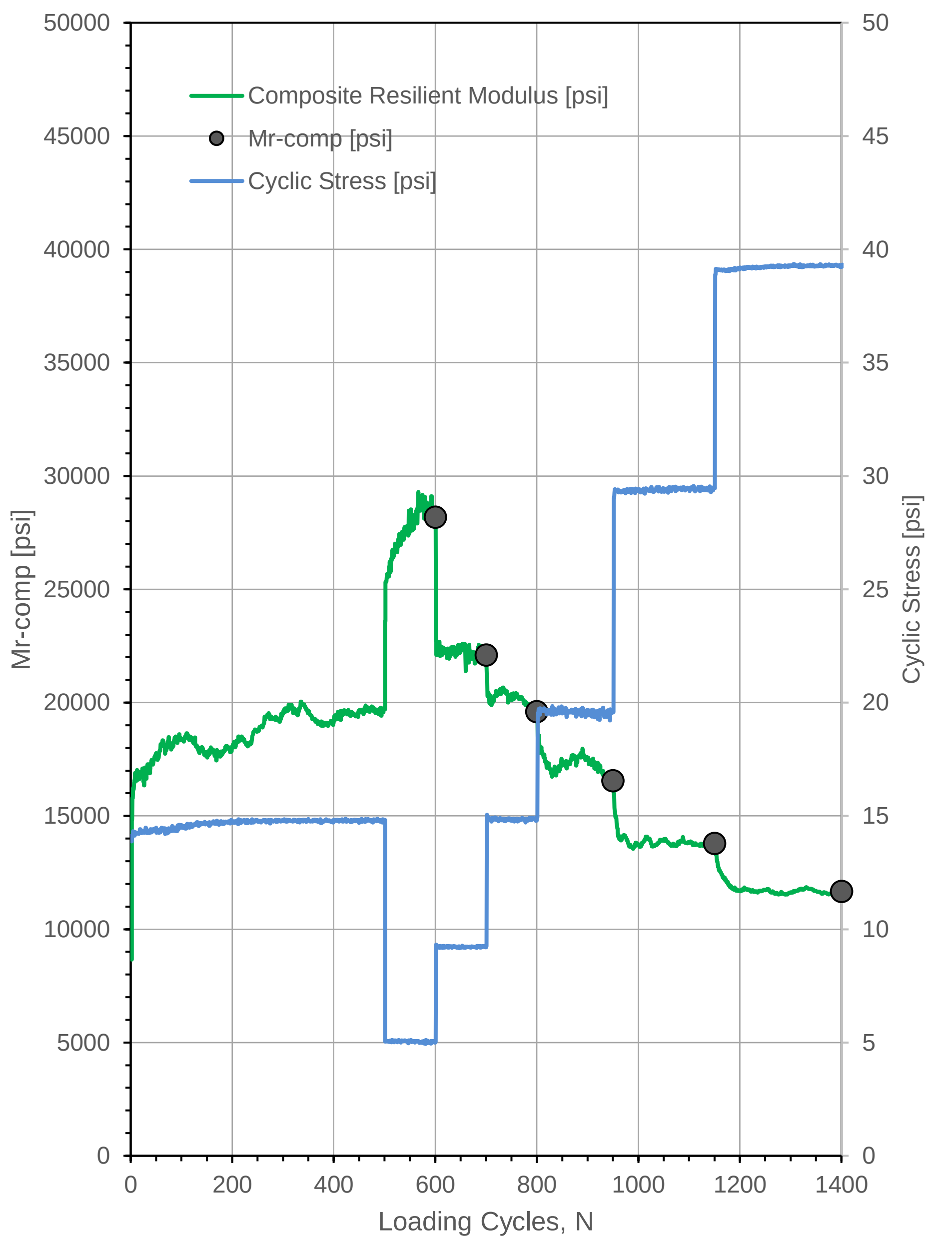
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/28/2017	Time:	5:35:52 PM	Test ID	**Trimmed4**
Tested By	PV, JV	Location:	I35NB R./Hwy 30 EB	Sta.	NA
Latitude,N:	42.007843	Longitude,W:	93.565712	Elev. (ft):	904
Comments:	Recyled aggregate subbase. Testing on trimmed subbase.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	36,835
3	32,743
4	30,021
5	27,998
6	26,395
7	25,070
8	23,943
9	22,964
10	22,099
11	21,325
12	20,625
13	19,986
14	19,399
15	18,857
16	18,352
17	17,881
18	17,440
21	16,262
22	15,911
23	15,576
24	15,258
25	14,954
26	14,663
27	14,385
28	14,118
29	13,862
30	13,616
31	13,379
32	13,150
33	12,930
34	12,717
35	12,512
36	12,313
37	12,121
38	11,935
39	11,754
40	11,579



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC

Project ID: SIA-00001

Location: I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

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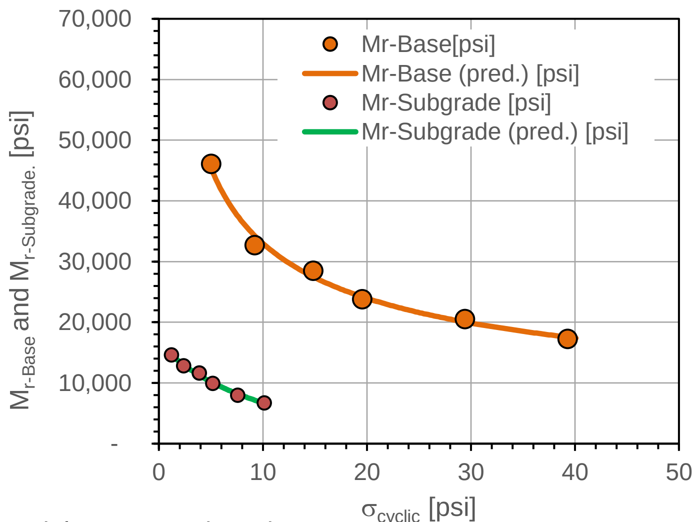
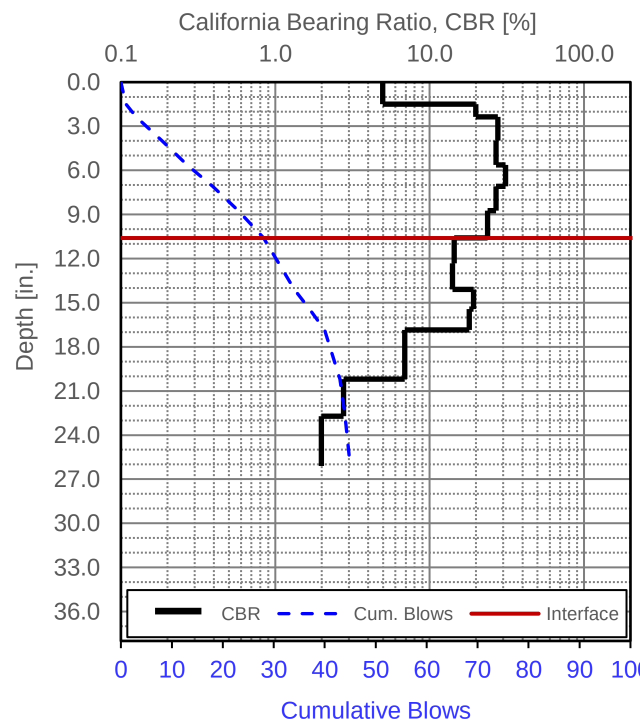
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/28/2017	Time:	5:35:52 PM	Test ID	**Trimmed4**
Tested By	PV, JV	Location:	I35NB R./Hwy 30 EB	Sta.	NA
Latitude:	42.007843	Longitude:	93.565712	Elev. (ft):	904
Comments:	Recyled aggregate subbase. Testing on trimmed subbase.				

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-Base}}$[psi]	$M_{r\text{-Base (pred.)}}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-Subgrade}}$ [psi]	$M_{r\text{-Subgrade (pred.)}}$ [psi]	Modulus Ratio
Conditioning	500	14.84	---	---	---	---	---	---
1	100	5.03	46,145	45,366	1.20	14,645	14,661	3.15
2	100	9.22	32,743	34,261	2.38	12,828	12,975	2.55
3	100	14.84	28,517	27,492	3.89	11,640	11,251	2.45
4	100	19.54	23,806	24,213	5.17	9,939	10,042	2.40
5	100	29.44	20,530	20,050	7.59	7,981	8,185	2.57
6	100	39.28	17,299	17,562	10.14	6,762	6,668	2.56

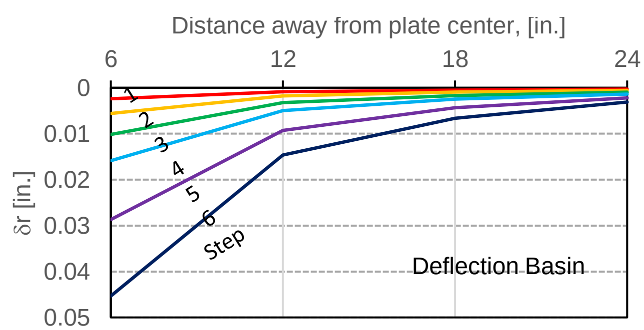




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\,(Base)}$	2776.6	3.59E-07
$k^*_{2\,(Base)}$	-0.465	1.60E-02
$k^*_{3\,(Base)}$	0.022	9.74E-01
Adj. R^2	0.990	
Std. Error [psi]	1036	
$k^*_{1\,(Subgrade)}$	1106.7	1.36E-05
$k^*_{2\,(Subgrade)}$	-0.055	5.72E-01
$k^*_{3\,(Subgrade)}$	-5.749	1.74E-02
Adj. R^2	0.993	
Std. Error [psi]	241	



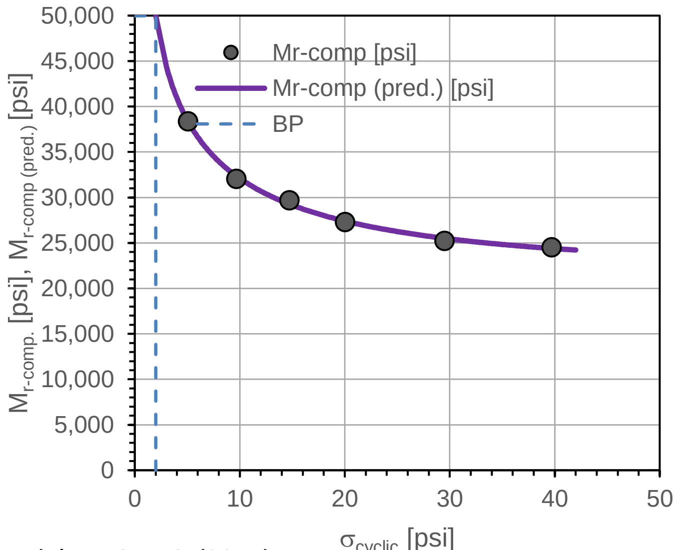
In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

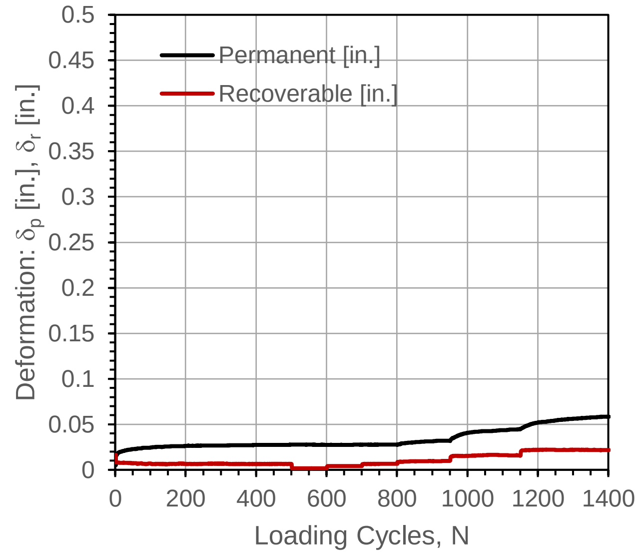
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/28/2017	Time:	6:19:11 PM	Test ID	**Trimmed5**
Tested By	PV, JV	Location:	I35NB R./Hwy 30 EB	Sta.	NA
Latitude,N:	42.007946	Longitude,W:	93.564842	Elev. (ft):	906
Comments:	Recyled aggregate subbase. Testing on trimmed subbase.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	14.73	---	---	0.0276	---	0.099	---
1	100	5.07	38,407	38,364	0.0275	0.0000	-0.198	Y
2	100	9.67	32,067	32,356	0.0276	0.0001	0.104	Y
3	100	14.73	29,712	29,266	0.0276	0.0000	0.086	Y
4	150	20.04	27,330	27,397	0.0319	0.0043	0.580	N
5	200	29.49	25,254	25,508	0.0449	0.0173	0.503	N
6	250	39.71	24,524	24,398	0.0585	0.0309	0.603	N



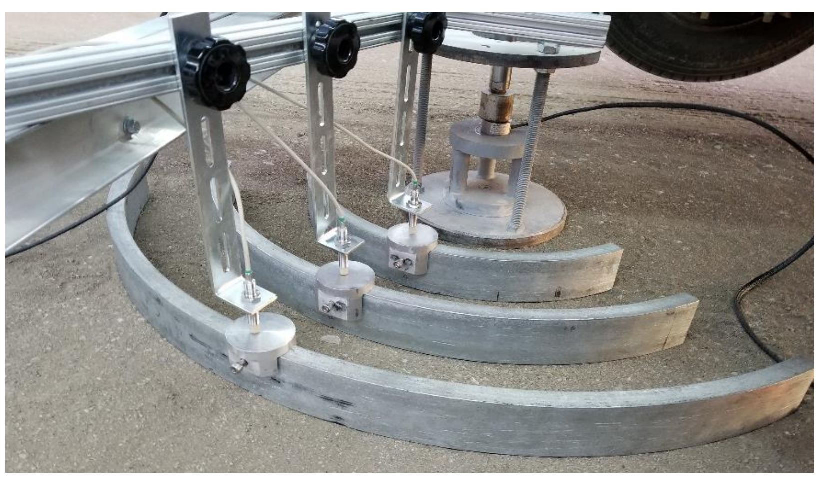


Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	2,369.5	1.03E-08
k^*_2	-0.304	1.78E-03
k^*_3	0.576	5.77E-02
Adj. R^2	0.997	
Std. Error [psi]	303	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	49,981
$\sigma_{cyclic\text{-}BP}$ [psi]	2.0



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

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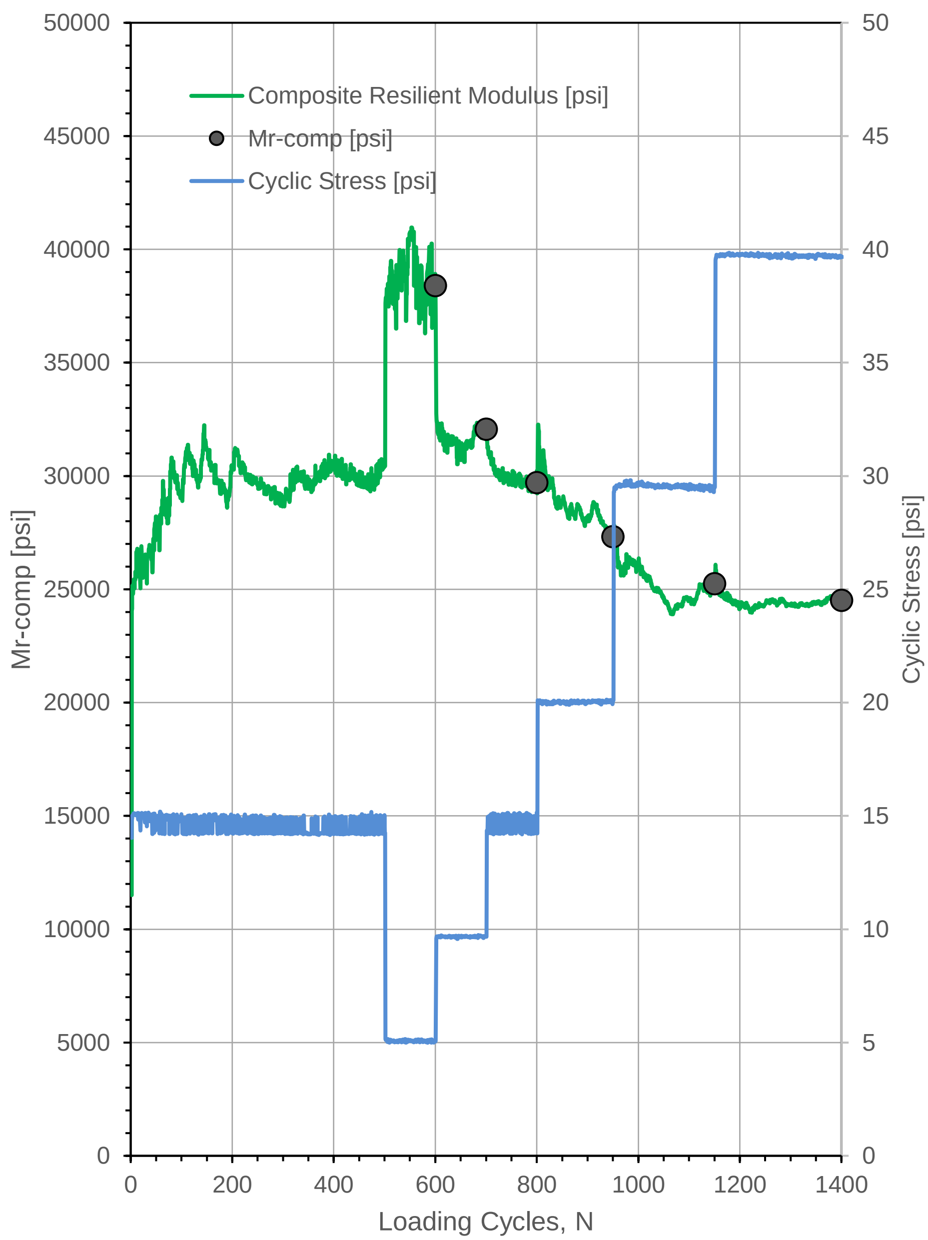
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/28/2017	Time:	6:19:11 PM	Test ID	**Trimmed5**
Tested By	PV, JV	Location:	I35NB R./Hwy 30 EB	Sta.	NA
Latitude,N:	42.007946	Longitude,W:	93.564842	Elev. (ft):	906
Comments:	Recyled aggregate subbase. Testing on trimmed subbase.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	49,981
3	44,449
4	40,968
5	38,506
6	36,641
7	35,165
8	33,959
9	32,950
10	32,090
11	31,346
12	30,695
13	30,120
14	29,608
15	29,148
16	28,733
17	28,356
18	28,013
21	27,142
22	26,895
23	26,666
24	26,453
25	26,254
26	26,069
27	25,895
28	25,732
29	25,580
30	25,436
31	25,301
32	25,174
33	25,053
34	24,940
35	24,832
36	24,731
37	24,634
38	24,543
39	24,456
40	24,374



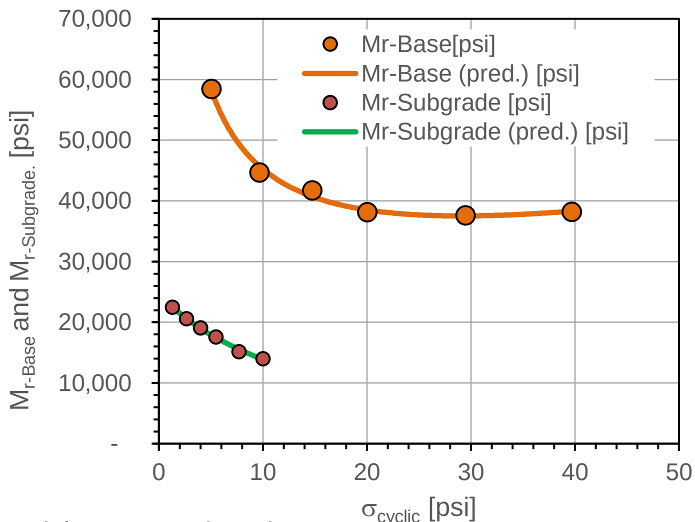
In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

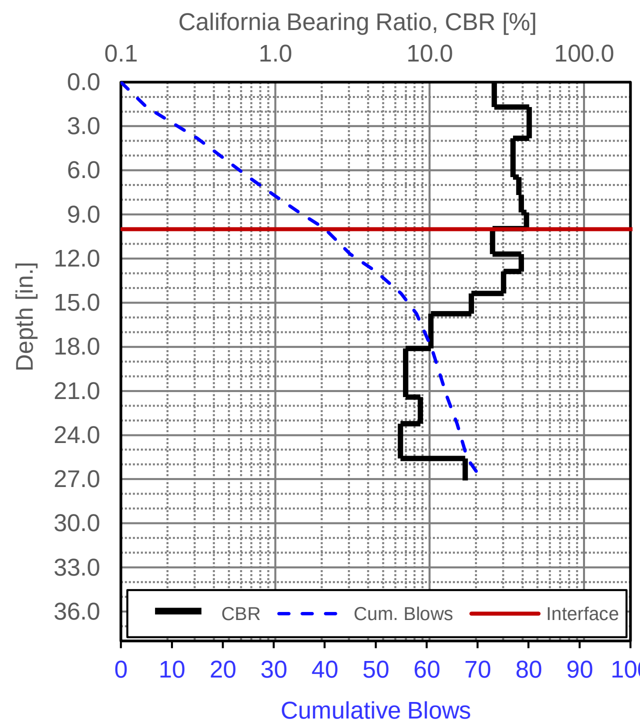
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/28/2017	Time:	6:19:11 PM	Test ID	**Trimmed5**
Tested By	PV, JV	Location:	I35NB R./Hwy 30 EB	Sta.	NA
Latitude:	42.007946	Longitude:	93.564842	Elev. (ft):	906
Comments:	Recyled aggregate subbase. Testing on trimmed subbase.				

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade}$ (pred.) [psi]	Modulus Ratio
Conditioning	500	14.73	---	---	---	---	---	---
1	100	5.07	58,461	58,093	1.30	22,521	22,573	2.60
2	100	9.67	44,679	45,710	2.65	20,610	20,594	2.17
3	100	14.73	41,743	40,723	4.02	19,039	18,958	2.19
4	100	20.04	38,159	38,511	5.50	17,620	17,455	2.17
5	100	29.49	37,648	37,526	7.70	15,181	15,543	2.48
6	100	39.71	38,223	38,310	10.01	14,024	13,865	2.73

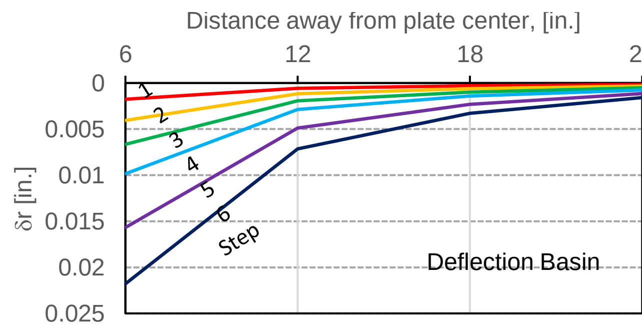




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\ (Base)}$	3132.0	4.53E-08
$k^*_{2\ (Base)}$	-0.528	1.66E-03
$k^*_{3\ (Base)}$	2.228	6.39E-03
Adj. R^2	0.991	
Std. Error [psi]	764	
$k^*_{1\ (Subgrade)}$	1596.8	2.86E-06
$k^*_{2\ (Subgrade)}$	-0.054	4.01E-01
$k^*_{3\ (Subgrade)}$	-3.389	2.07E-02
Adj. R^2	0.995	
Std. Error [psi]	219	



In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

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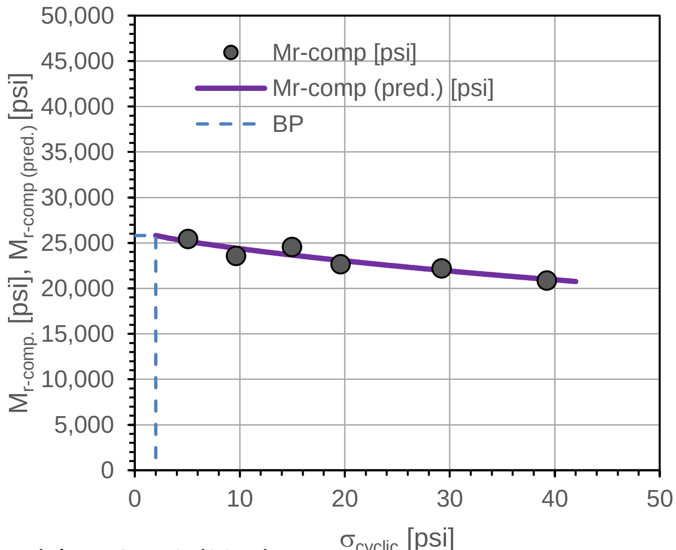
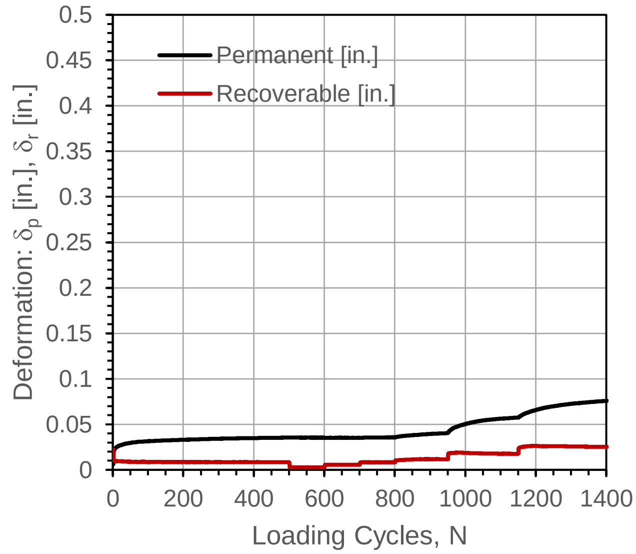
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/28/2017	Time:	7:10:04 PM	Test ID	**Trimmed6**
Tested By	PV, JV	Location:	I35NB R./Hwy 30 EB	Sta.	NA
Latitude,N:	42.008049	Longitude,W:	93.563789	Elev. (ft):	930
Comments:	Recyled aggregate subbase. Testing on trimmed subbase.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	14.98	---	---	0.0354	---	0.099	---
1	100	5.07	25,433	25,172	0.0353	-0.0001	-0.198	Y
2	100	9.64	23,596	24,421	0.0353	-0.0002	0.104	Y
3	100	14.98	24,575	23,665	0.0357	0.0002	0.086	Y
4	150	19.61	22,674	23,075	0.0403	0.0049	0.580	N
5	200	29.24	22,212	21,987	0.0574	0.0220	0.503	N
6	250	39.25	20,875	21,007	0.0758	0.0404	0.603	N





Model: AASHTO (2015)

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

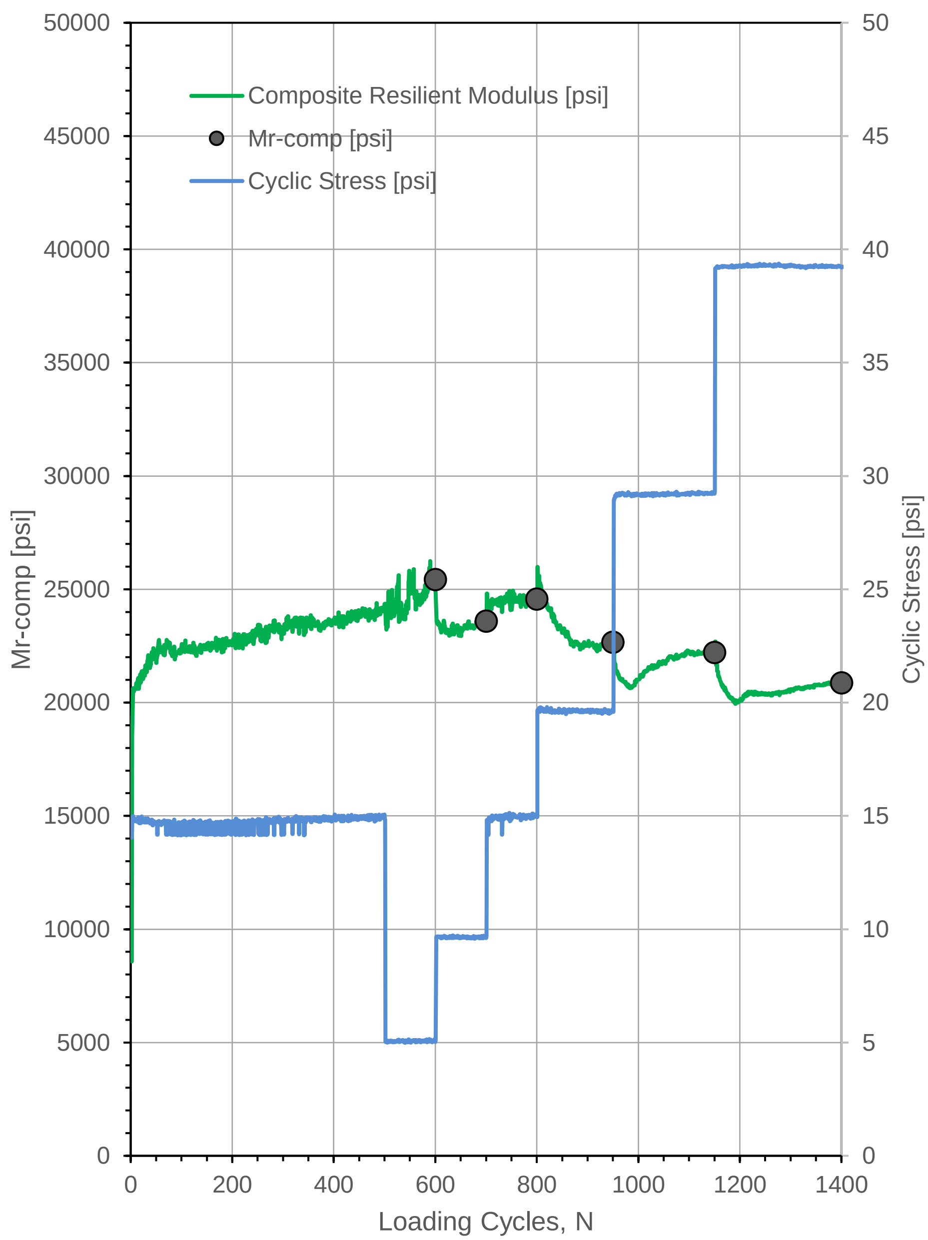
Parameter	Value	P-Value
k^*_1	1,759.7	2.29E-07
k^*_2	-0.008	9.21E-01
k^*_3	-0.551	3.66E-01
Adj. R^2	0.835	
Std. Error [psi]	626	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	25,812
$\sigma_{cyclic\text{-}BP}$ [psi]	2.0

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/28/2017	Time:	7:10:04 PM	Test ID	**Trimmed6**
Tested By	PV, JV	Location:	I35NB R./Hwy 30 EB	Sta.	NA
Latitude,N:	42.008049	Longitude,W:	93.563789	Elev. (ft):	930
Comments:	Recyled aggregate subbase. Testing on trimmed subbase.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	25,812
3	25,579
4	25,373
5	25,185
6	25,007
7	24,838
8	24,676
9	24,519
10	24,367
11	24,219
12	24,075
13	23,934
14	23,797
15	23,662
16	23,531
17	23,401
18	23,275
21	22,907
22	22,789
23	22,673
24	22,559
25	22,446
26	22,335
27	22,226
28	22,118
29	22,012
30	21,908
31	21,805
32	21,703
33	21,603
34	21,504
35	21,407
36	21,311
37	21,216
38	21,122
39	21,030
40	20,938



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

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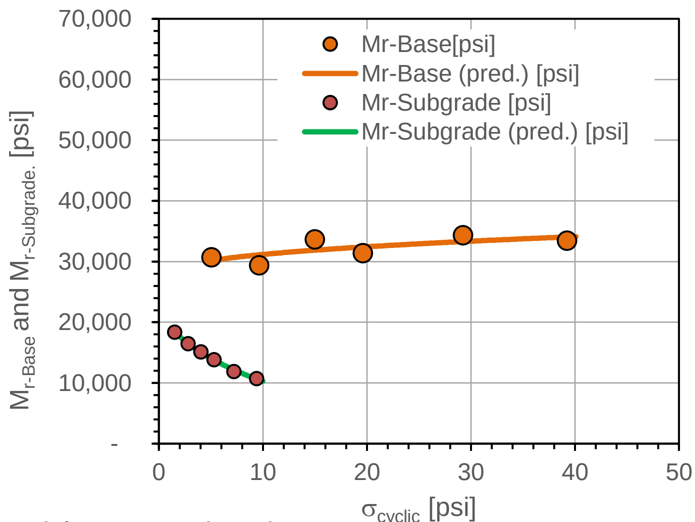
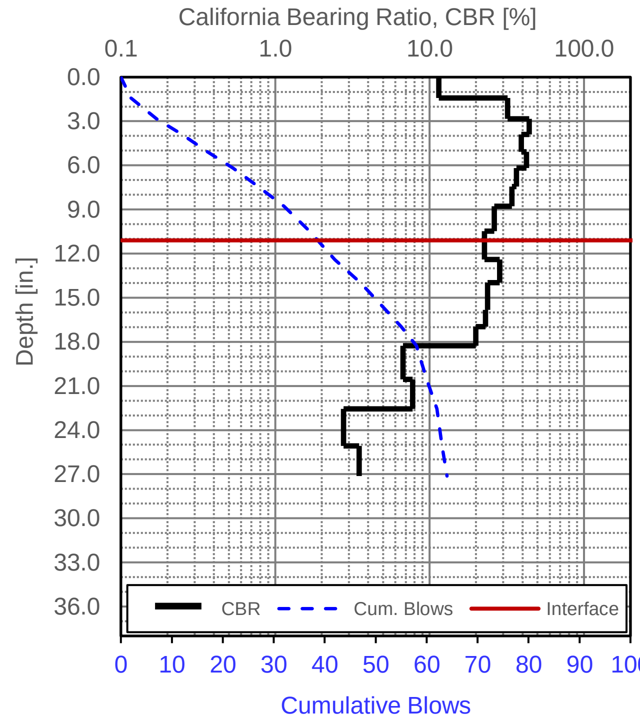
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	10/28/2017	Time:	7:10:04 PM	Test ID	**Trimmed6**
Tested By	PV, JV	Location:	I35NB R./Hwy 30 EB	Sta.	NA
Latitude:	42.008049	Longitude:	93.563789	Elev. (ft):	930
Comments:	Recyled aggregate subbase. Testing on trimmed subbase.				

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	14.98	---	---	---	---	---	---
1	100	5.07	30,742	30,174	1.52	18,391	18,445	1.67
2	100	9.64	29,404	31,119	2.83	16,507	16,485	1.78
3	100	14.98	33,696	31,876	4.07	15,114	15,010	2.23
4	100	19.61	31,420	32,401	5.29	13,858	13,781	2.27
5	100	29.24	34,358	33,294	7.21	11,912	12,166	2.88
6	100	39.25	33,449	34,062	9.40	10,764	10,655	3.11

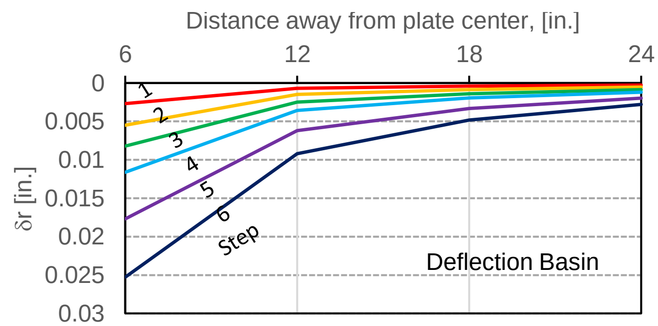




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\ (Base)}$	2053.0	1.02E-06
$k^*_{2\ (Base)}$	0.037	7.91E-01
$k^*_{3\ (Base)}$	0.151	8.74E-01
Adj. R^2	0.405	
Std. Error [psi]	1095	
$k^*_{1\ (Subgrade)}$	1298.3	3.89E-06
$k^*_{2\ (Subgrade)}$	-0.094	2.23E-01
$k^*_{3\ (Subgrade)}$	-3.858	1.86E-02
Adj. R^2	0.997	
Std. Error [psi]	155	



In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

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Automated Plate Load Test [APLT]

Test:	In-Situ Static Plate Load Test: Two Loading Cycles.				
Date:	10/28/2017	Time:	9:58:58 AM	Test ID	**I35 R_3_30Static_1_Subgrade**
Tested By	DW, JV	Location:	I35NB R./Hwy 30 EB	Sta.	NA
Latitude:	42.004163	Longitude:	93.5700433	Elev. (ft):	919
Comments:	Testing performed directly on the subgrade (sandy clay material).				

Cycle	Stage	Load Step	Target Applied Load (lbs)	Target Applied Stress (psi)	Actual Applied Stress (psi)	Deformation (in.) Sensor 1	Sensor 2	Sensor 3	Average Def. (in.)
0	Seating	0	707	1	*1.36*	0.0178	0.0311	0.0319	**0.0269**
Zero load and deformation sensors after applying the seating stress.									
1	Seating	0	0	0	*0.00*	*0.0000*	*0.0000*	*0.0000*	**0.0000**
1	Load	1	1767	2.5	*2.47*	*0.0525*	*0.0669*	*0.0827*	**0.0674**
1	Load	2	3534	5	*4.95*	*0.1174*	*0.1259*	*0.1605*	**0.1346**
1	Load	3	5301	7.5	*7.44*	*0.1859*	*0.1859*	*0.2369*	**0.2029**
1	Load	4	7069	10	*9.90*	*0.2565*	*0.2483*	*0.3133*	**0.2727**
1	Load	5	8836	12.5	*12.41*	*0.3307*	*0.3117*	*0.3911*	**0.3445**
1	Load	6	10603	15	*14.90*	*0.4065*	*0.3773*	*0.4703*	**0.4180**
1	Unload	7	7069	10	*9.92*	*0.3951*	*0.3644*	*0.4593*	**0.4063**
1	Unload	8	3534	5	*4.82*	*0.3705*	*0.3405*	*0.4343*	**0.3818**
1	Unload	9	1767	2.5	*2.55*	*0.3481*	*0.3196*	*0.4087*	**0.3588**
2	Load	10	3534	5	*4.95*	*0.3590*	*0.3305*	*0.4221*	**0.3705**
2	Load	11	7069	10	*9.94*	*0.3848*	*0.3536*	*0.4495*	**0.3960**
2	Load	12	10603	15	*14.70*	*0.4296*	*0.3954*	*0.4955*	**0.4402**
2	Unload	13	1767	2.5	*2.25*	*0.3712*	*0.3384*	*0.4322*	**0.3806**
2	Unload	14	0	0	*0.00*	*0.3373*	*0.3094*	*0.3909*	**0.3459**

Plate Diameter:	*30.0*	in.
Shape factor:	**2.67**	
Material Type:	*B*	A = Cohesive, B = Granular, C = Intermediate
Poisson's ratio:	*0.35*	
Design Stress:	*10.0*	psi
Target Deformation:	*0.05*	in.

AASHTO T222 Method
PCA Design Criteria

k_{u1} (pci) @ design stress:	**36**
k_u (pci) @ δ = 0.05 in.:	**37**

Modulus at target deformation

Stress @ δ = 0.05 in. (psi	**1.9**
E_1 (psi)	**1,314**
k'_u (pci)	**37**
k_u (pci)	**37**

Modulus at target/design applied stress

First Loading Cycle

δ_1 (in.)	**0.2750**
E_1 (psi)	**1,276**
k'_{u1} (pci)	**36**
k_{u1} (pci)	**36**

Second Loading Cycle

δ_2 (in.)	**0.0428**
E_2 (psi)	**7,484**
k'_{u2} (pci)	**234**
k_{u2} (pci)	**213**
E_2 / E_1 or k_2 / k_1 Ratio	**5.9**

Plate Bending Correction for

$$k'_u \geq 100 \text{ and } 1{,}000 \text{ pci}$$

$$k_u = -39.9178 + 5.5076\,[k'_u]^{0.7019}$$

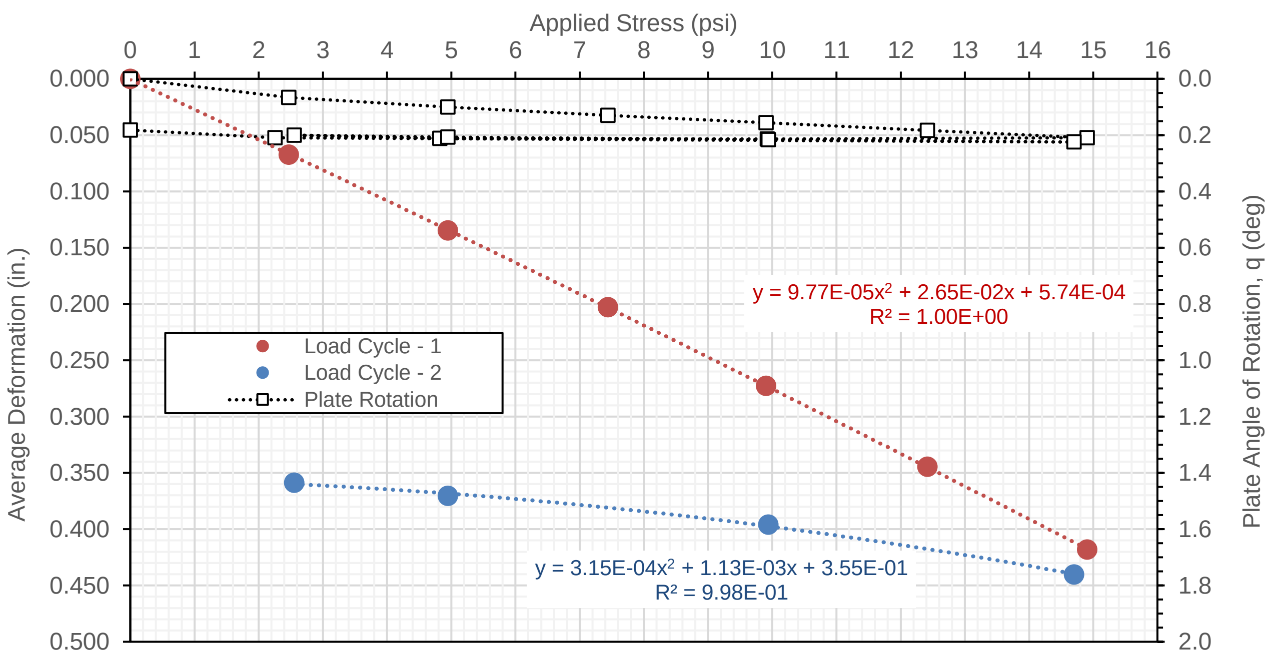
In-situ Modulus of Subgrade Reaction (k) and Elastic Modulus

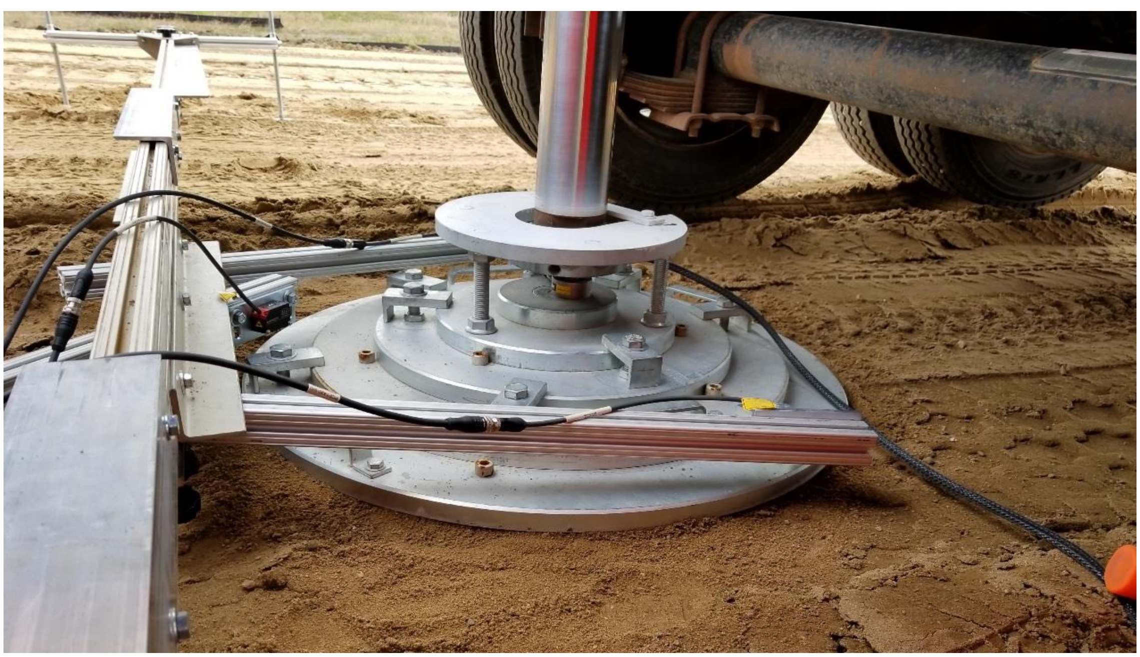
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

Polynomial Fit Parameters

First Cycle		*Second Cycle*			
a_1	9.77E-05	a_1	3.15E-04	θ_{max} (deg)	0.2246
a_2	2.65E-02	a_2	1.13E-03		
R^2	1.00	R^2	1.00		

NOTES:
1. Test performed per AASHTO T222/ASTM D1196.
2. k-value determined using:
   (a) calculated stress at 0.05 in. plate deformation (d) for first loading cycle, per PCA design guidelines, and
   (b) for a defined target stress and calculating corresponding plate deformations using polynomial fit parameters.





Automated Plate Load Test [APLT]

Test:	In-Situ Static Plate Load Test: Two Loading Cycles.				
Date:	10/28/2017	Time:	11:02:20 AM	Test ID	**I35 R_3_30Static_2_Subgrade**
Tested By	DW, JV	Location:	I35NB R./Hwy 30 EB	Sta.	NA
Latitude:	42.0043417	Longitude:	93.5700117	Elev. (ft):	904
Comments:	Testing performed directly on the subgrade (sandy clay material).				

Cycle	Stage	Load Step	Target Applied Load (lbs)	Target Applied Stress (psi)	Actual Applied Stress (psi)	Deformation (in.) Sensor 1	Sensor 2	Sensor 3	Average Def. (in.)
0	Seating	0	707	1	*1.34*	0.0394	0.0023	0.0769	**0.0395**
Zero load and deformation sensors after applying the seating stress.									
1	Seating	0	0	0	*0.00*	*0.0000*	*0.0000*	*0.0000*	**0.0000**
1	Load	1	1767	2.5	*2.48*	*0.0596*	*0.0422*	*0.0799*	**0.0606**
1	Load	2	3534	5	*4.96*	*0.1203*	*0.0963*	*0.1621*	**0.1262**
1	Load	3	5301	7.5	*7.46*	*0.1906*	*0.1596*	*0.2529*	**0.2010**
1	Load	4	7069	10	*9.97*	*0.2676*	*0.2290*	*0.3454*	**0.2807**
1	Load	5	8836	12.5	*12.45*	*0.3506*	*0.3050*	*0.4475*	**0.3677**
1	Load	6	10603	15	*14.93*	*0.4456*	*0.3902*	*0.5633*	**0.4664**
1	Unload	7	7069	10	*9.74*	*0.4312*	*0.3768*	*0.5461*	**0.4514**
1	Unload	8	3534	5	*4.77*	*0.4039*	*0.3475*	*0.5160*	**0.4224**
1	Unload	9	1767	2.5	*2.46*	*0.3765*	*0.3179*	*0.4849*	**0.3931**
2	Load	10	3534	5	*4.98*	*0.3866*	*0.3316*	*0.4977*	**0.4053**
2	Load	11	7069	10	*9.95*	*0.4182*	*0.3618*	*0.5321*	**0.4374**
2	Load	12	10603	15	*14.61*	*0.4744*	*0.4147*	*0.5972*	**0.4954**
2	Unload	13	1767	2.5	*2.19*	*0.4089*	*0.3499*	*0.5250*	**0.4279**
2	Unload	14	0	0	*0.00*	*0.3773*	*0.3114*	*0.4863*	**0.3917**

Plate Diameter:	*30.0*	in.
Shape factor:	**2.67**	
Material Type:	*B*	A = Cohesive, B = Granular, C = Intermediate
Poisson's ratio:	*0.35*	
Design Stress:	*10.0*	psi
Target Deformation:	*0.05*	in.

AASHTO T222 Method
PCA Design Criteria

k_{u1} (pci) @ design stress:	**36**
k_u (pci) @ δ = 0.05 in.:	**43**

Modulus at target deformation

Stress @ δ = 0.05 in. (psi	**2.1**
E_1 (psi)	**1,493**
k'_u (pci)	**43**
k_u (pci)	**43**

Plate Bending Correction for

$k'_u \geq 100$ *and* $1{,}000$ *pci*

$k_u = -39.9178 + 5.5076\,[k'_u]^{0.7019}$

Modulus at target/design applied stress

First Loading Cycle

δ_1 (in.)	**0.2817**
E_1 (psi)	**1,246**
k'_{u1} (pci)	**36**
k_{u1} (pci)	**36**

Second Loading Cycle

δ_2 (in.)	**0.0476**
E_2 (psi)	**6,847**
k'_{u2} (pci)	**210**
k_{u2} (pci)	**195**
E_2 / E_1 or k_2 / k_1 Ratio	**5.5**

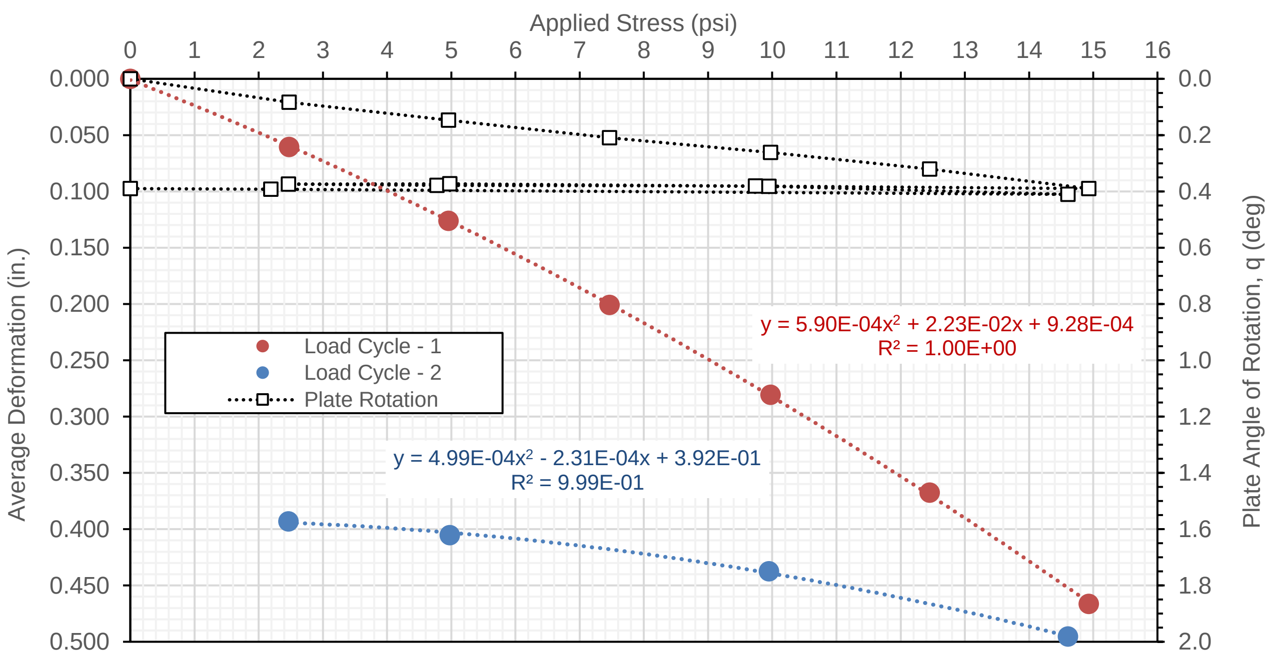
In-situ Modulus of Subgrade Reaction (k) and Elastic Modulus

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

Polynomial Fit Parameters

First Cycle		*Second Cycle*			
a_1	5.90E-04	a_1	4.99E-04	θ_{max} (deg)	0.4105
a_2	2.23E-02	a_2	-2.31E-04		
R^2	1.00	R^2	1.00		

NOTES:
1. Test performed per AASHTO T222/ASTM D1196.
2. k-value determined using:
   (a) calculated stress at 0.05 in. plate deformation (d) for first loading cycle, per PCA design guidelines, and
   (b) for a defined target stress and calculating corresponding plate deformations using polynomial fit parameters.



Date of Test	10/28/2017	Test ID	Subgrade_1	Operator	PV	ASTM	D6951
Latitude	42.0041633	Longitude	93.5700433	Elevation (ft)	926		
Location	I35NB R./Hwy 30 EB	Station	NA				
Comments	Test conducted on subgrade.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg.Top 12 in. of Subgrade	17.5	11.8	12.4	2,815
Avg. Bottom 12 in. of Subgrade	11.7	18.5	16.5	3,795
Ratio of Avg. Top/Bottom Layer	1.5	0.6	0.7	0.7
Std.Dev.Top 12 in. of Subgrade.	9.7	4.8	7.0	1,556
Std. Dev. Bottom 12 in. of Subgrade	7.7	8.7	10.2	2,305

NOTES:

Subgrade is assumed as sandy clay.

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

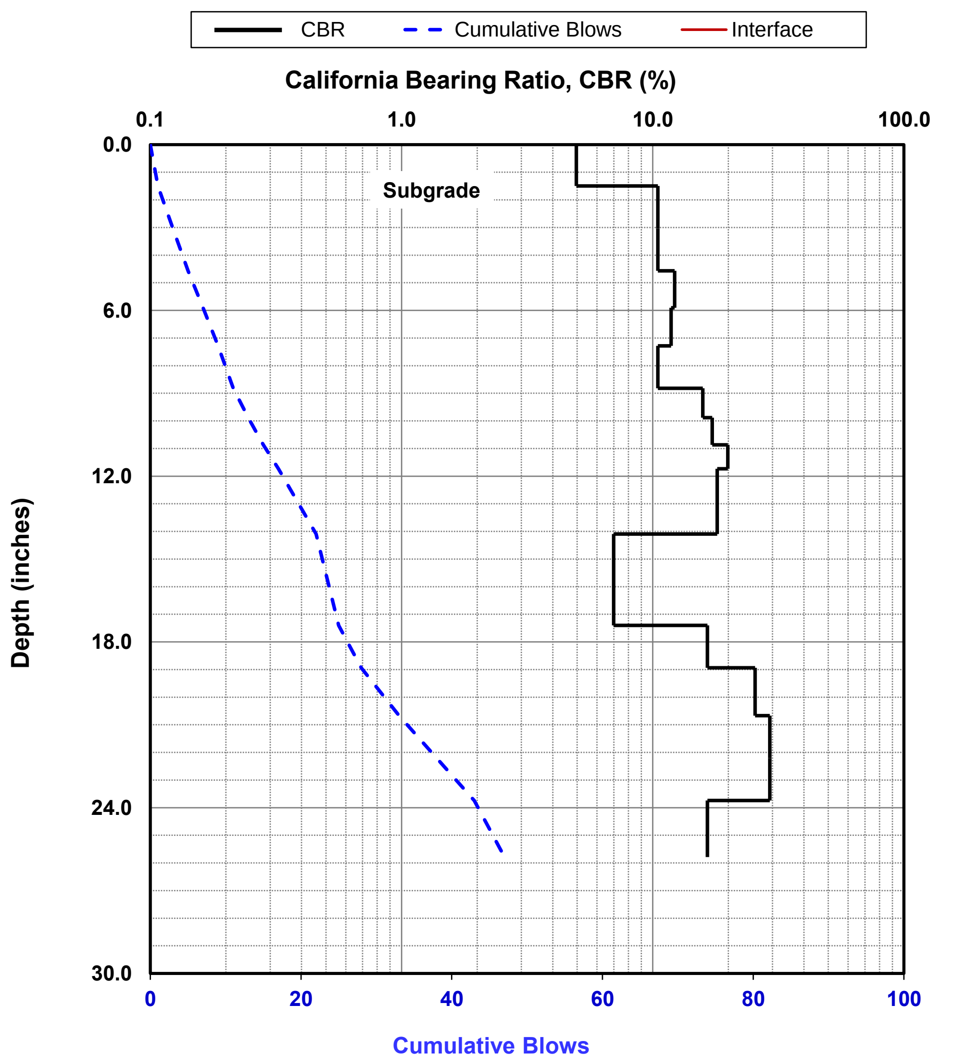
[2]E (ksi) = $(17.6\ CBR^{0.64}) \times 0.1450377$

[3]S_u (psf) = $(3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name: Iowa DOT STIC

Project ID: SIA-00001

Location: I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

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Date of Test	10/28/2017	Test ID	Subgrade_2	Operator	PV	ASTM	D6951
Latitude	42.0043417		Longitude	93.5700117		Elevation (ft)	904
Location	I35NB R./Hwy 30 EB		Station	NA			
Comments	Test conducted on subgrade.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg.Top 12 in. of Subgrade	32.4	5.9	8.0	1,784
Avg. Bottom 12 in. of Subgrade	32.4	3.3	5.5	1,206
Ratio of Avg. Top/Bottom Layer	1.0	1.8	1.5	1.5
Std.Dev.Top 12 in. of Subgrade.	35.7	3.8	6.0	1,336
Std. Dev. Bottom 12 in. of Subgrade	15.6	2.6	4.7	1,028

NOTES:

Subgrade is assumed as sandy clay.

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

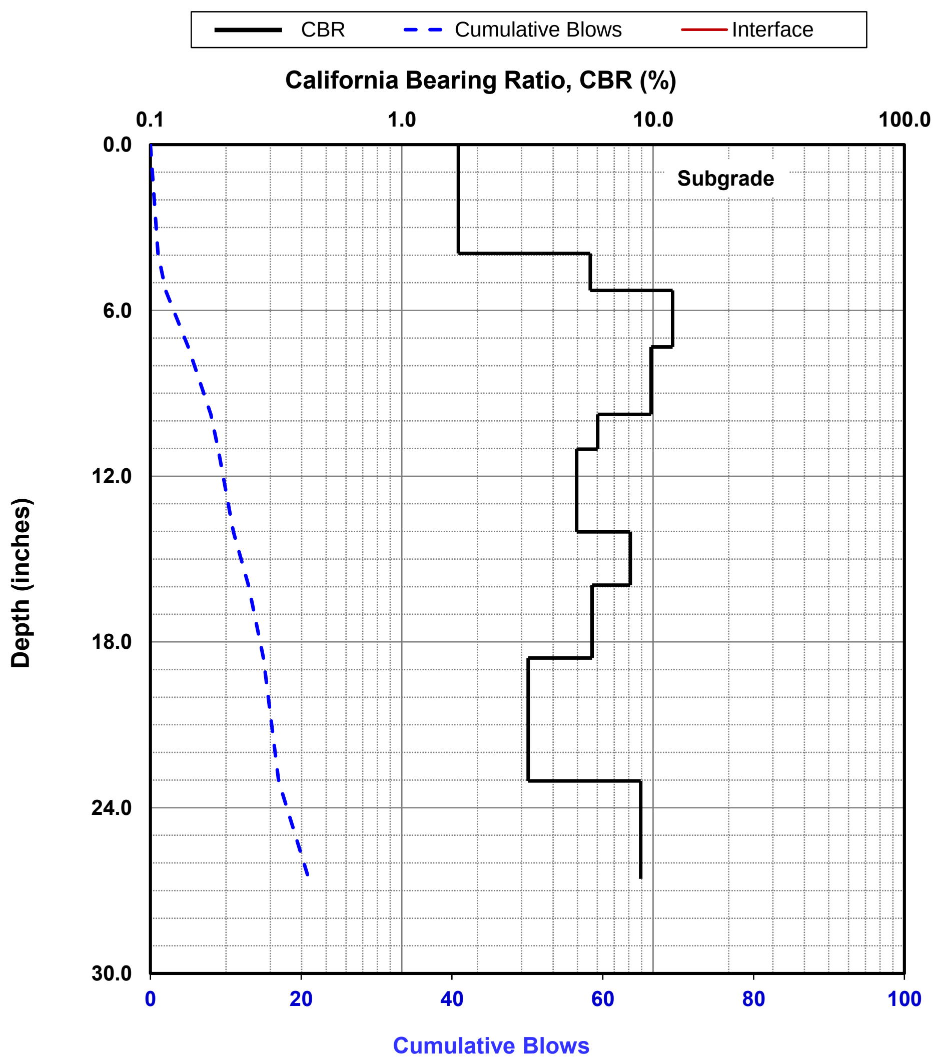
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

ingios GEOTECHNICS

Date of Test	10/28/2017	Test ID	Trimmed_4	Operator	PV	ASTM	D6951
Latitude	42.0078430	Longitude		93.5657120		Elevation (ft)	904
Location	I35NB R./Hwy 30 EB	Station		NA			
Comments	Recyled aggregate subbase. Testing on trimmed subbase.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	9.7	23.0	19.0	4,388
Avg. Subgrade Layer (top 12 in.)	20.0	8.6	10.1	2,279
Ratio of Avg. Top/Bottom Layer	0.5	2.7	1.9	1.9
Std.Dev.Subbase Layer	14.3	11.0	11.9	2,687
Std. Dev. Subgrade Layer (top 12 in.)	28.9	8.0	9.6	2,169

NOTES:

Subgrade is assumed as sandy clay.

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

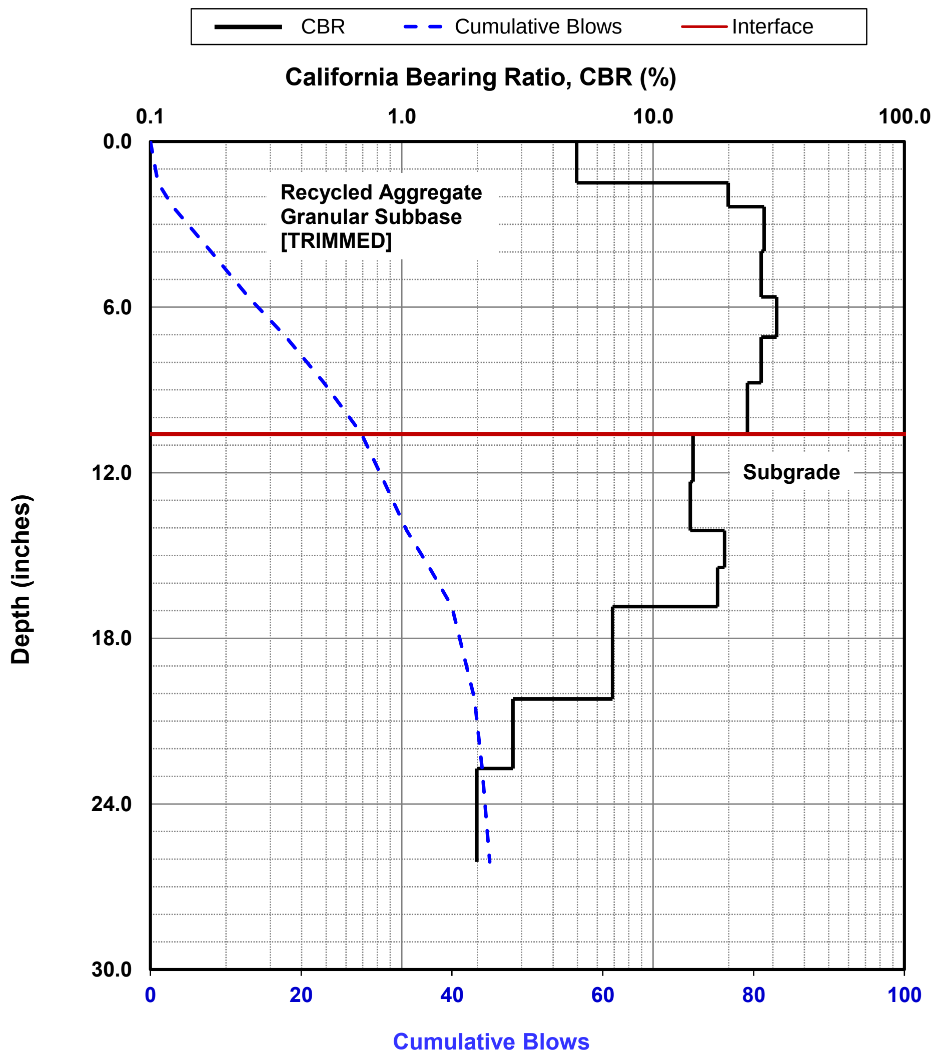
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name: Iowa DOT STIC

Project ID: SIA-00001

Location: I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

Date of Test	10/28/2017	Test ID	Trimmed_5	Operator	PV	ASTM	D6951
Latitude	42.0079460		Longitude	93.5648420		Elevation (ft)	906
Location	I35NB R./Hwy 30 EB		Station	NA			
Comments	Recyled aggregate subbase. Testing on trimmed subbase.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	6.3	37.0	25.7	6,008
Avg. Subgrade Layer (top 12 in.)	14.2	15.0	14.4	3,296
Ratio of Avg. Top/Bottom Layer	0.4	2.5	1.8	1.8
Std.Dev.Subbase Layer	1.3	7.2	9.1	2,033
Std. Dev. Subgrade Layer (top 12 in.)	9.6	12.3	12.7	2,890

NOTES:

Subgrade is assumed as sandy clay.

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

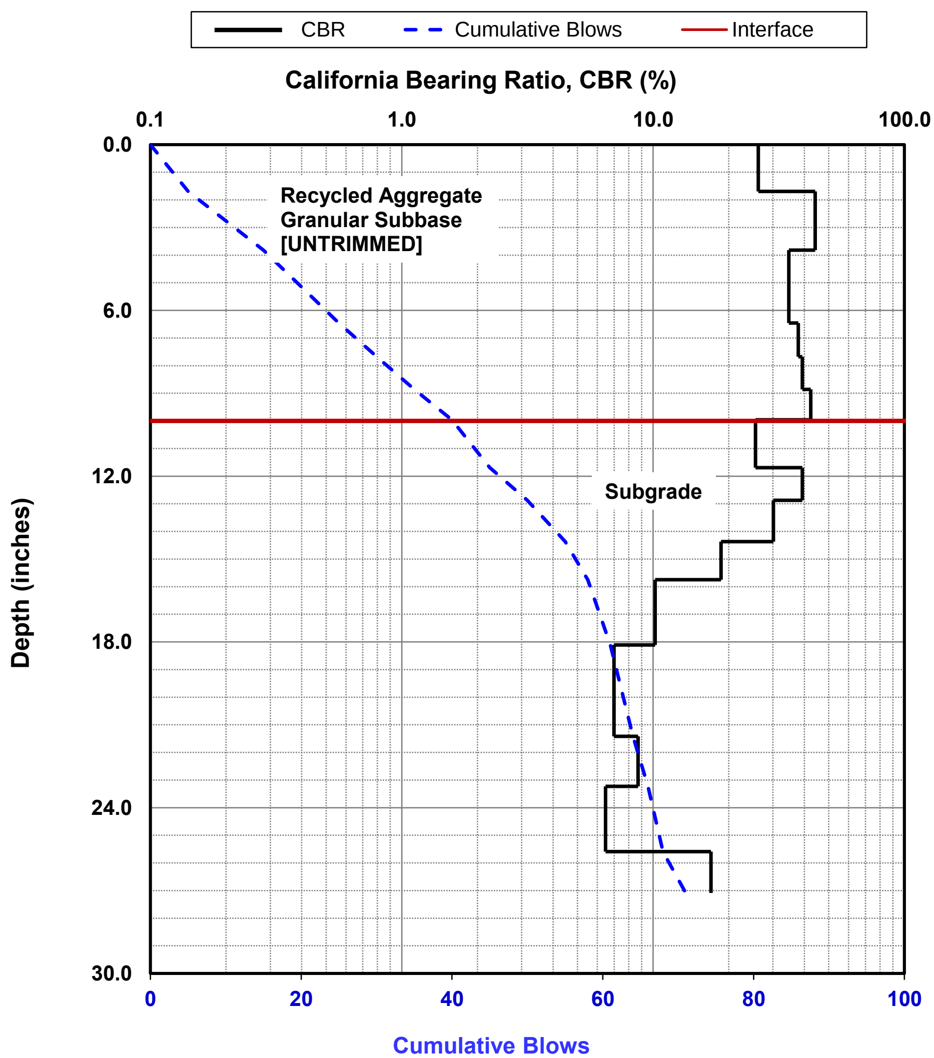
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

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Date of Test	10/28/2017	Test ID	Trimmed_6	Operator	PV	ASTM	D6951
Latitude	42.0080490	Longitude	93.5637890			Elevation (ft)	930
Location	I35NB R./Hwy 30 EB	Station	NA				
Comments	Recyled aggregate subbase. Testing on trimmed subbase.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	7.0	33.0	23.9	5,572
Avg. Subgrade Layer (top 12 in.)	10.1	21.9	18.4	4,245
Ratio of Avg. Top/Bottom Layer	0.7	1.5	1.3	1.3
Std.Dev.Subbase Layer	5.8	13.9	13.8	3,142
Std. Dev. Subgrade Layer (top 12 in.)	7.2	7.9	9.6	2,158

NOTES:

Subgrade is assumed as sandy clay.

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

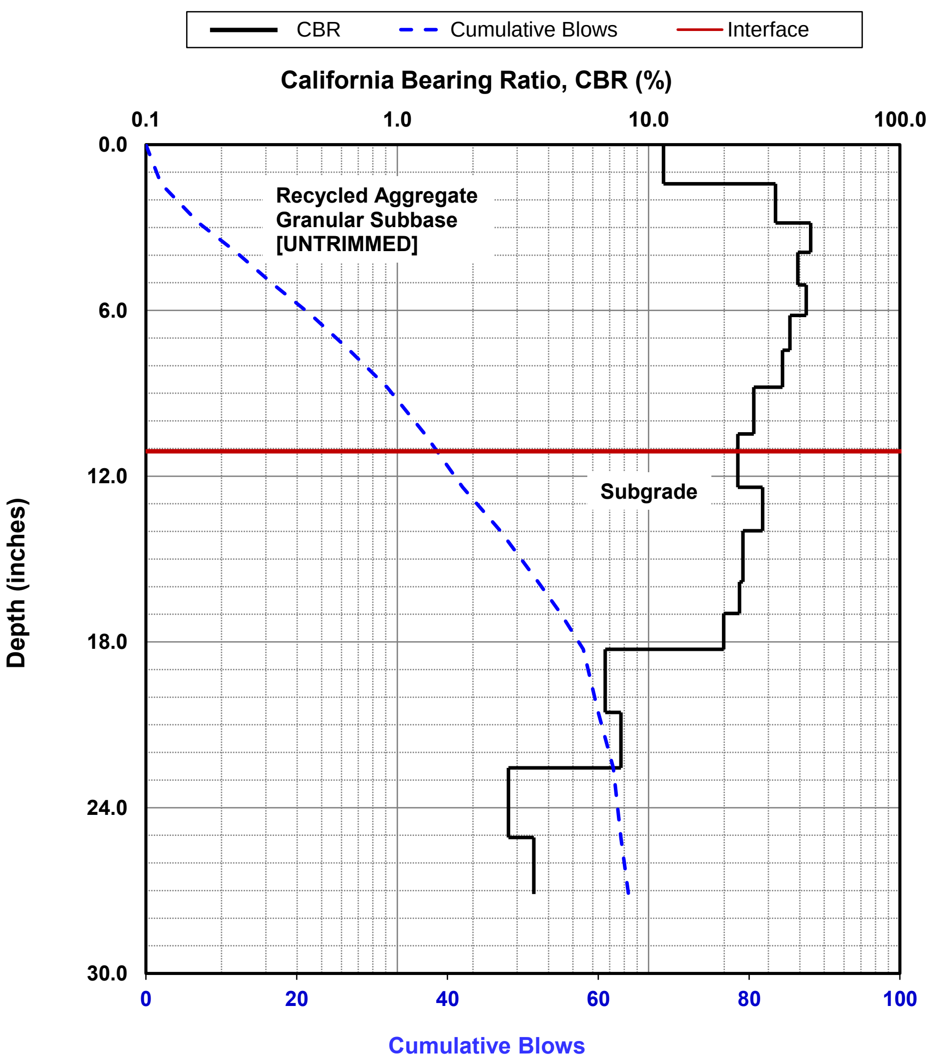
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

Date of Test	10/28/2017	Test ID	Untrimmed_1	Operator	PV	ASTM	D6951
Latitude	42.0058290	Longitude		93.5694580		Elevation (ft)	899
Location	I35NB R./Hwy 30 EB	Station		NA			
Comments	Recyled aggregate subbase. Testing on untrimmed subbase.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	8.5	26.5	20.8	4,815
Avg. Subgrade Layer (top 12 in.)	6.0	39.5	26.9	6,277
Ratio of Avg. Top/Bottom Layer	1.4	0.7	0.8	0.8
Std.Dev.Subbase Layer	6.1	10.7	11.7	2,643
Std. Dev. Subgrade Layer (top 12 in.)	2.4	16.4	15.3	3,503

NOTES:

Subgrade is assumed as sandy clay.

[1] $CBR = 292/DPI^{1.12}$

[1] $CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

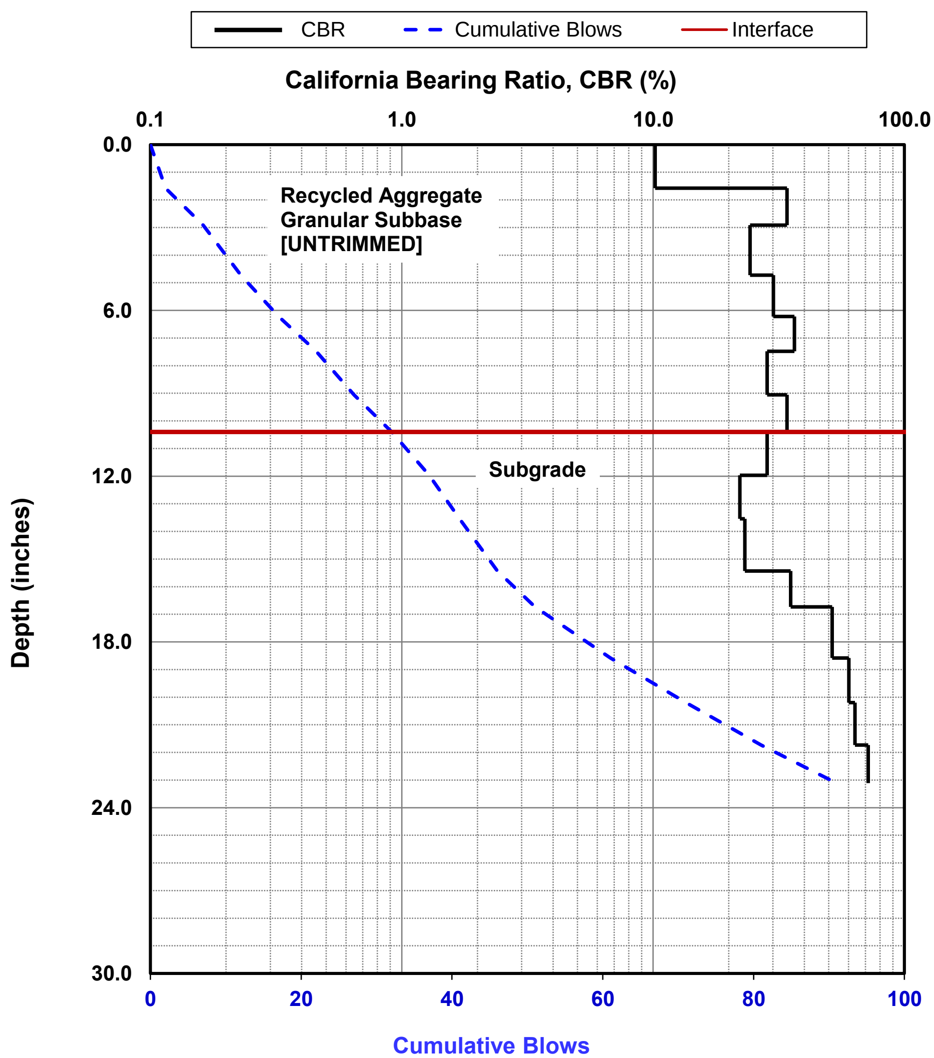
[2] $E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3] $S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2] Powell et al. (1986)

[3] Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

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Date of Test	10/28/2017	Test ID	Untrimmed_2	Operator	PV	ASTM	D6951
Latitude	42.0064320		Longitude	93.5688630		Elevation (ft)	901
Location	I35NB R./Hwy 30 EB		Station	NA			
Comments	Recyled aggregate subbase. Testing on untrimmed subbase.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	12.6	17.1	15.7	3,593
Avg. Subgrade Layer (top 12 in.)	11.2	19.5	17.1	3,930
Ratio of Avg. Top/Bottom Layer	1.1	0.9	0.9	0.9
Std.Dev.Subbase Layer	14.4	8.8	10.2	2,310
Std. Dev. Subgrade Layer (top 12 in.)	2.0	4.0	6.2	1,380

NOTES:

Subgrade is assumed as sandy clay.

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

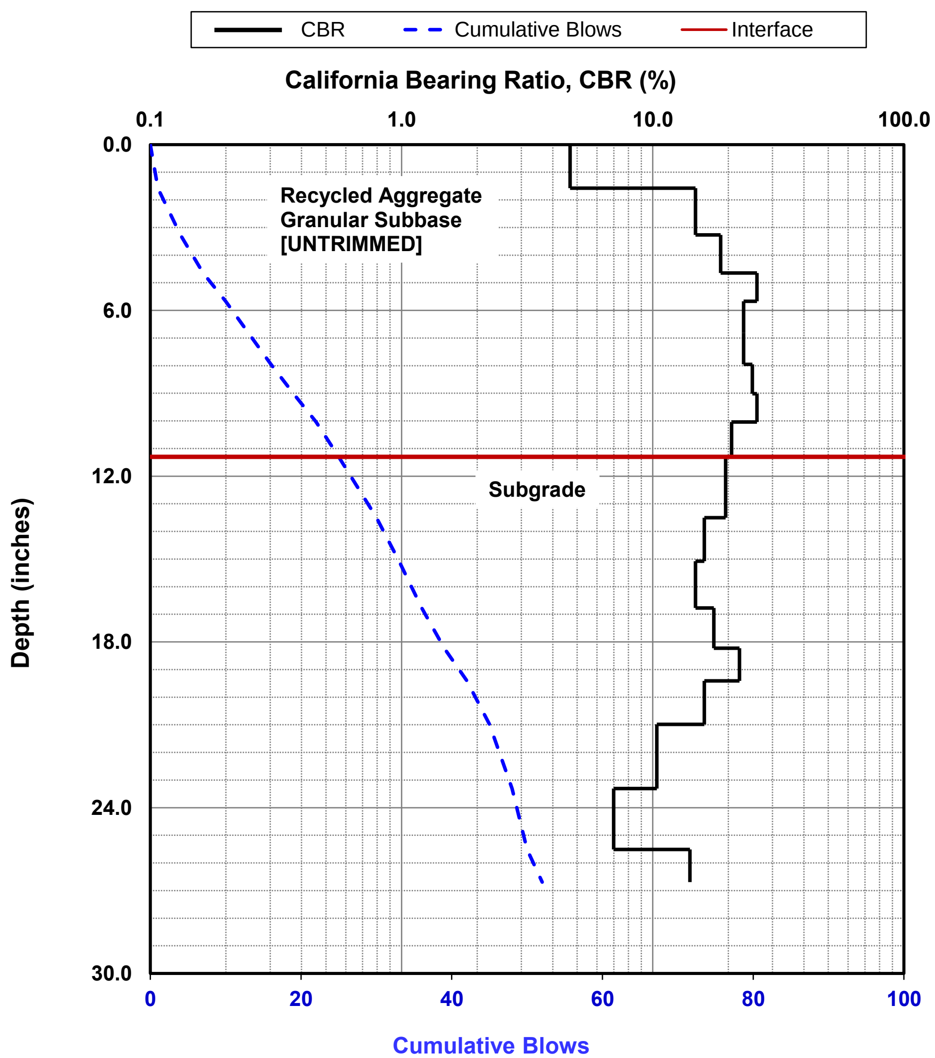
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

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Date of Test	10/28/2017	Test ID	Untrimmed_3	Operator	PV	ASTM	D6951
Latitude	42.0072360		Longitude	93.5677260		Elevation (ft)	903
Location	I35NB R./Hwy 30 EB		Station	NA			
Comments	Recyled aggregate subbase. Testing on untrimmed subbase.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	13.0	16.5	15.4	3,516
Avg. Subgrade Layer (top 12 in.)	22.7	6.7	8.6	1,928
Ratio of Avg. Top/Bottom Layer	0.6	2.5	1.8	1.8
Std.Dev.Subbase Layer	18.3	9.9	11.1	2,508
Std. Dev. Subgrade Layer (top 12 in.)	19.1	10.8	11.7	2,645

NOTES:

Subgrade is assumed as sandy clay.

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

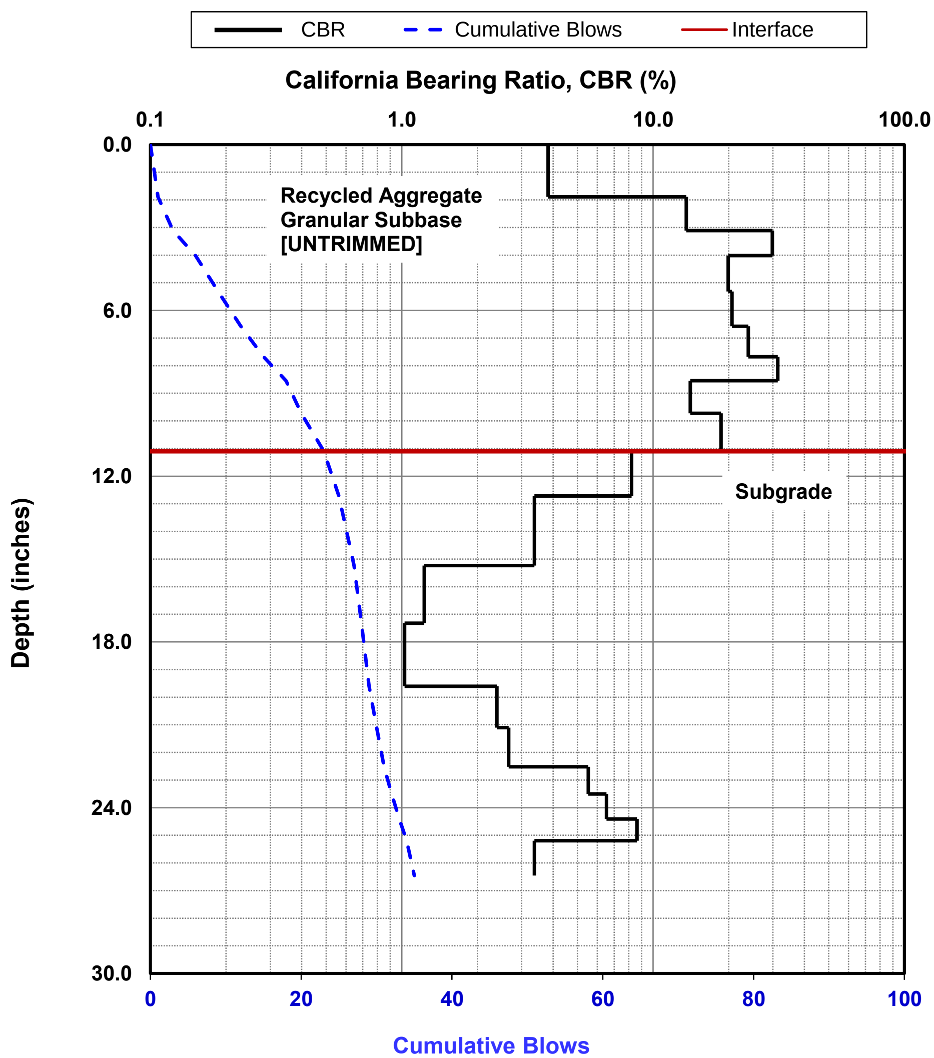
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	I35NB Ramp to Hwy 30 EB, Ames, IA (Project #3)

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Field Project # 4

Hwy330 near Hwy65, Jasper County, IA

11/2/2017

Special backfill over embankment cut/fill

Project Location and Test Locations

Test Locations	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 330 near Hwy 65 (Project #4)

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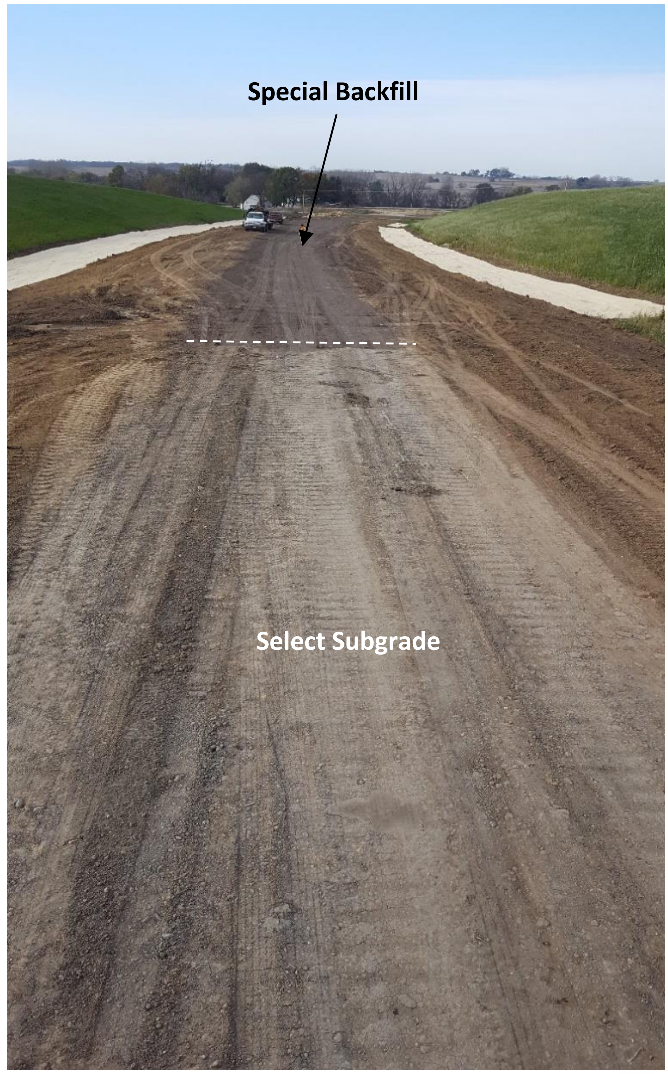
Site Conditions and Pictures



Pictures

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 330 near Hwy 65 (Project #4)

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Summary of Test Results

Summary of Cyclic APLT Test Results

Point #	4 psi cyclic stress @ surface $M_{r\text{-Comp}}$ (psi)	$M_{r\text{-Base}}$ (psi)	$M_{r\text{-SG}}$ (psi)	$\Delta\delta_p$ ([in.)	8 psi plate cyclic stress @ surface $M_{r\text{-Comp}}$ (psi)	$M_{r\text{-Base}}$ (psi)	$M_{r\text{-SG}}$ (psi)	$\Delta\delta_p$ ([in.)
Special1	38,523	40,316	29,907	-0.0001	38,617	40,366	31,454	0.0000
Special2	41,732	47,805	23,412	0.0000	35,628	39,623	22,456	0.0002
Special3	25,144	26,338	19,271	-0.0006	23,347	24,909	17,183	-0.0005
Special4	6,262	8,247	2,353	-0.0006	5,598	7,485	2,061	0.0007
Special5	8,142	10,059	3,876	-0.0002	8,050	9,937	3,675	0.0008
Select6	13,152	NA	NA	-0.0005	11,132	NA	NA	-0.0005
Select7	12,751	NA	NA	0.0002	10,270	NA	NA	0.0003
Select8	18,743	NA	NA	-0.0001	17,009	NA	NA	0.0000
AVG	**20,556**	**26,553**	**15,764**	**(0.0002)**	**18,706**	**24,464**	**15,366**	**0.0001**
COV	66%	67%	77%	-132%	68%	64%	81%	413%

Point #	13 psi cyclic stress @ surface $M_{r\text{-Comp}}$ (psi)	$M_{r\text{-Base}}$ (psi)	$M_{r\text{-SG}}$ (psi)	$\Delta\delta_p$ ([in.)	18 psi plate cyclic stress @ surface $M_{r\text{-Comp}}$ (psi)	$M_{r\text{-Base}}$ (psi)	$M_{r\text{-SG}}$ (psi)	$\Delta\delta_p$ ([in.)
Special1	40,902	43,286	30,806	0.0001	42,608	46,044	30,366	0.0023
Special2	36,527	41,634	21,032	0.0009	32,887	36,831	20,000	0.0060
Special3	23,922	25,910	16,630	0.0009	22,240	23,810	16,196	0.0063
Special4	5,244	7,091	1,899	0.0050	4,968	6,441	1,999	0.0334
Special5	8,303	10,352	3,667	0.0033	8,302	10,477	3,580	0.0181
Select6	11,096	NA	NA	-0.0001	9,698	NA	NA	0.0033
Select7	9,080	NA	NA	0.0007	8,561	NA	NA	0.0067
Select8	15,156	NA	NA	0.0001	13,435	NA	NA	0.0027
AVG	**18,779**	**25,655**	**14,807**	**0.0014**	**17,837**	**24,721**	**14,428**	**0.0098**
COV	72%	66%	82%	133%	76%	68%	82%	109%

Point #	28 psi cyclic stress @ surface $M_{r\text{-Comp}}$ (psi)	$M_{r\text{-Base}}$ (psi)	$M_{r\text{-SG}}$ (psi)	$\Delta\delta_p$ ([in.)	38 psi plate cyclic stress @ surface $M_{r\text{-Comp}}$ (psi)	$M_{r\text{-Base}}$ (psi)	$M_{r\text{-SG}}$ (psi)	$\Delta\delta_p$ ([in.)
Special1	44,026	49,191	27,843	0.0088	43,568	49,437	26,047	0.0158
Special2	32,707	37,703	18,261	0.0213	32,751	38,653	17,035	0.0383
Special3	23,919	26,415	15,502	0.0264	24,678	27,580	15,245	0.0495
Special4	4,489	6,062	1,633	0.1597	4,318	5,983	1,478	0.3115
Special5	8,710	11,014	3,725	0.0671	9,645	12,197	4,112	0.1126
Select6	8,201	NA	NA	0.0174	7,180	NA	NA	0.0381
Select7	7,327	NA	NA	0.0267	6,881	NA	NA	0.0474
Select8	11,013	NA	NA	0.0123	9,480	NA	NA	0.0239
AVG	**17,549**	**26,077**	**13,393**	**0.0425**	**17,313**	**26,770**	**12,783**	**0.0796**
COV	82%	69%	81%	119%	84%	67%	79%	123%

Summary of Test Results

Summary of AASHTO (2015) universal model parameters

Point #	$k^*_{1(Comp)}$	$k^*_{2(Comp)}$	$k^*_{3(Comp)}$	$M_{r\text{-}Comp}$ R^2(Adj.)	Std. Error (psi)	$M_{r\text{-}Comp(pred)\text{-}BP}$ (psi)	$\sigma_{cyclic\text{-}BP}$ (psi)
Special1	2,649.8	0.067	0.011	0.877	804	44,156	39.0
Special2	2,557.0	-0.231	0.809	0.871	1,189	49,851	2.0
Special3	1,536.8	-0.186	1.217	0.628	525	28,692	2.0
Special4	410.5	-0.166	-0.120	0.996	44	7,279	2.0
Special5	506.5	-0.107	1.265	0.945	134	9,518	39.0
Select6	949.6	-0.040	-1.713	0.963	410	14,093	2.0
Select7	790.4	-0.328	0.203	0.996	140	17,004	2.0
Select8	1,431.0	-0.023	-2.194	0.997	192	20,613	2.0
AVG	**1,353.9**	**(0.127)**	**-0.065**	**0.909**	**430**	**23,901**	**11.3**
COV	64%	-100%	-19.638	14%	92%	66%	152%

Point #	$k^*_{1(Base)}$	$k^*_{2(Base(}$	$k^*_{3(Base)}$	$M_{r\text{-}Base}$ R^2(Adj.)	Std. Error (psi)
Special1	2,699.5	0.051	0.413	0.922	1,117
Special2	2,797.5	-0.296	1.358	0.791	1,654
Special3	1,606.2	-0.176	1.352	0.593	691
Special4	532.2	-0.194	0.203	0.978	132
Special5	625.7	-0.095	1.276	0.966	151
Select6	NA	NA	NA	NA	NA
Select7	NA	NA	NA	NA	NA
Select8	NA	NA	NA	NA	NA
AVG	**1,652.2**	**(0.142)**	**0.920**	**0.850**	**749**
COV	66%	-91%	0.614	19%	87%

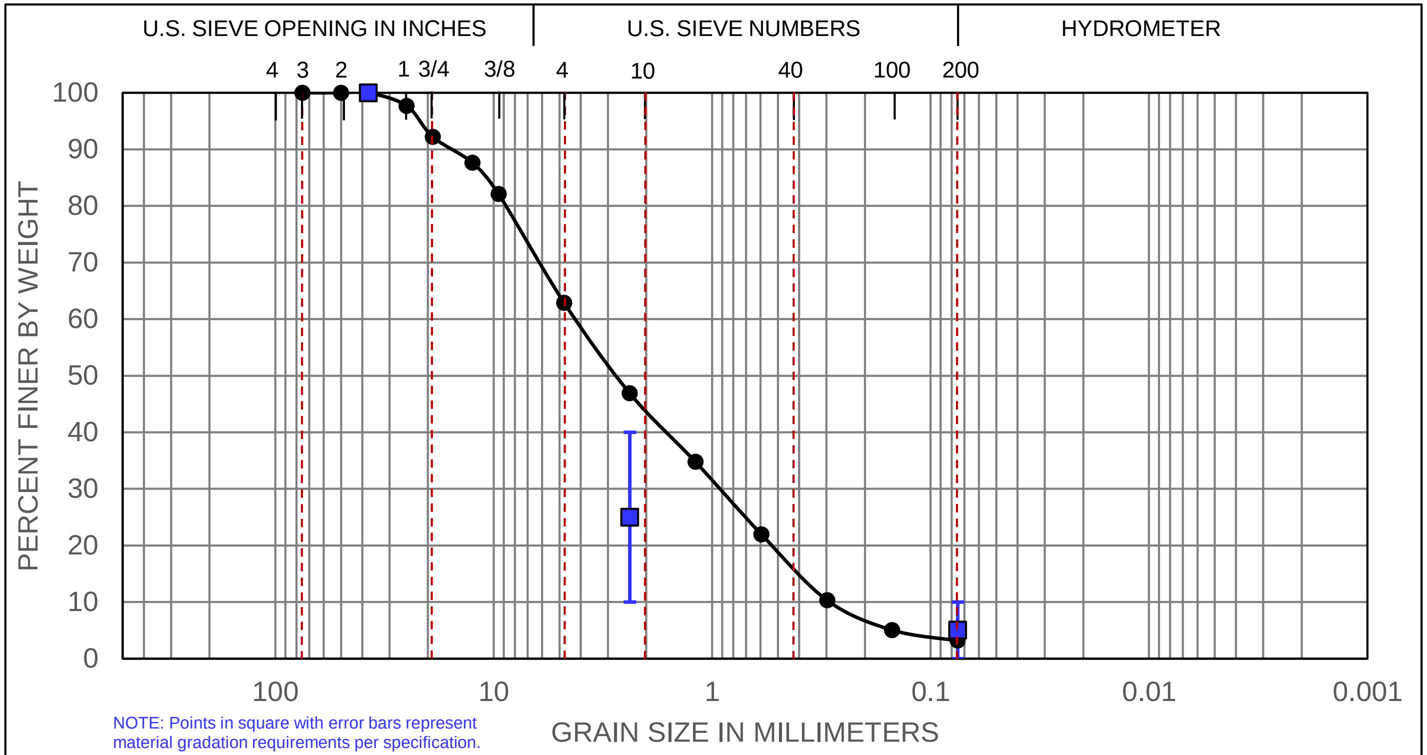
Point #	$k^*_{1(SG)}$	$k^*_{2(SG)}$	$k^*_{3(SG)}$	$M_{r\text{-}SG}$ R^2(Adj.)	Std. Error (psi)
Special1	7,232.7	0.549	-17.693	0.991	186
Special2	1,772.5	-0.128	-7.448	0.998	110
Special3	1,020.5	-0.250	-1.582	0.947	325
Special4	218.3	-0.120	-15.249	0.872	106
Special5	255.0	-0.150	-3.525	0.932	29
Select6	NA	NA	NA	NA	NA
Select7	NA	NA	NA	NA	NA
Select8	NA	NA	NA	NA	NA
AVG	**2,099.8**	**(0.020)**	**(9.099)**	**0.948**	**151**
COV	140%	-1642%	-0.781	5%	74%

Summary of Test Results

Summary of DCP and LWD test results

Point #	Special Backfill Layer: Thickness, H_1 (in.)	Special Backfill Layer: Avg. CBR (%)	Special Backfill Layer: St. Dev CBR (%)	Subgrade Layer: Thickness, H_2 (in.)	Subgrade Layer: Avg. CBR (%)	Subgrade Layer: St. Dev CBR (%)	Ratio CBR_1/ CBR_2	E_{LWD} (psi)
Special1	23.4	48.6	10.6	NA	28.7	10.1	1.7	23,850
Special2	24.0	54.6	15.4	NA	18.9	7.0	2.9	17,873
Special3	24.3	53.3	9.9	NA	6.8	9.0	7.8	8,490
Special4	23.9	27.2	16.8	NA	4.1	2.6	6.6	3,018
Special5	24.0	30.6	11.5	NA	23.6	4.0	1.3	2,886
Select6	NA	NA	NA	12.0	7.2	3.4	NA	6,254
Select7	NA	NA	NA	12.0	9.4	9.7	NA	4,341
Select8	NA	NA	NA	12.0	11.1	7.9	NA	4,554
AVG	**23.9**	**42.9**	**12.8**	**12.0**	**14.9**	**6.0**	**4.1**	**7,918**
COV	1%	30%	0.239	0%	60%	50%	73%	98%

GRAIN SIZE DISTRIBUTION
ASTM D422/C136



NOTE: Points in square with error bars represent material gradation requirements per specification.

COBBLES	GRAVEL		SAND			SILT/CLAY	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

Gradation Summary

% Gravel	37.2
% Sand	59.6
% Fines	3.2
D_{10} (mm)	0.289
D_{30} (mm)	0.970
D_{50} (mm)	2.845
D_{60} (mm)	4.329
D_{85} (mm)	11.073
C_u	15.0
C_c	0.8

Atterberg Limits

LL	NP
PL	NP
PI	NP

Classification

AASHTO:	A-1-a
USCS:	SP

MATERIAL: Special Backfill Material (Iowa DOT Gradation 4132.02 - Crushed Stone)

LOCATION: Hwy 330 near Hwy 65, NE of Des Moines (Project #4) **TESTED BY:** PV/DW

SAMPLE DATE: 11/2/2017 **TEST DATE:** 11/28/2017

Gradation and Soil Classification Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 330 near Hwy 65 (Project #4)

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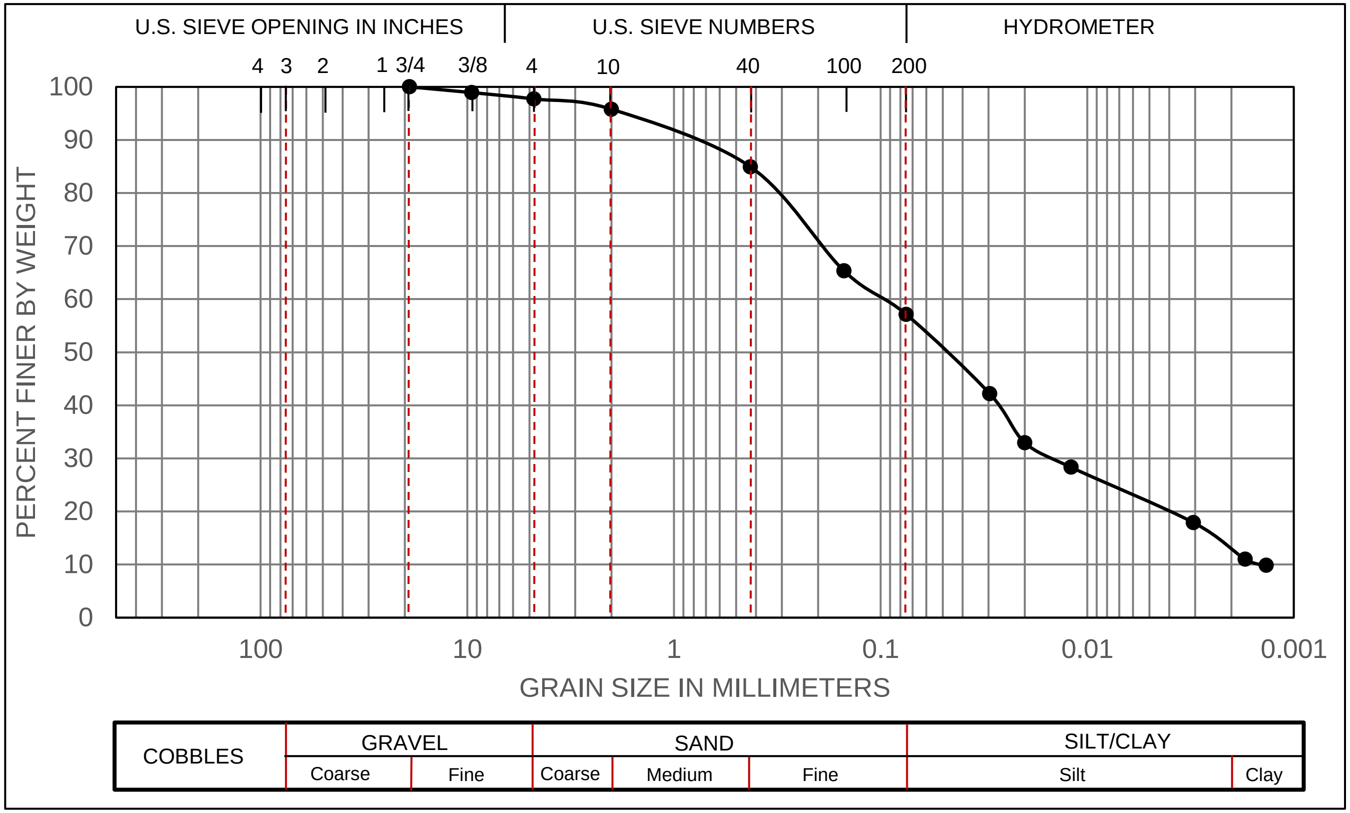
GRAIN SIZE DISTRIBUTION
ASTM D422/C136



Gradation Summary

% Gravel	2.3
% Sand	40.6
% Silt	44.7
% Clay	12.5
D_{10} (mm)	0.008
D_{30} (mm)	0.015
D_{50} (mm)	0.053
D_{60} (mm)	0.101
D_{85} (mm)	0.437
C_u	13.32
C_c	0.29

Atterberg Limits

LL	NA
PL	NA
PI	NA

Classification

AASHTO:	NA
USCS:	NA

MATERIAL: Select Subgrade

LOCATION: Hwy 330 near Hwy 65, NE of Des Moines (Project #4) **TESTED BY:** PV/DW

SAMPLE DATE: 11/2/2017 **TEST DATE:** 11/28/2017

Gradation and Soil Classification Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 330 near Hwy 65 (Project #4)

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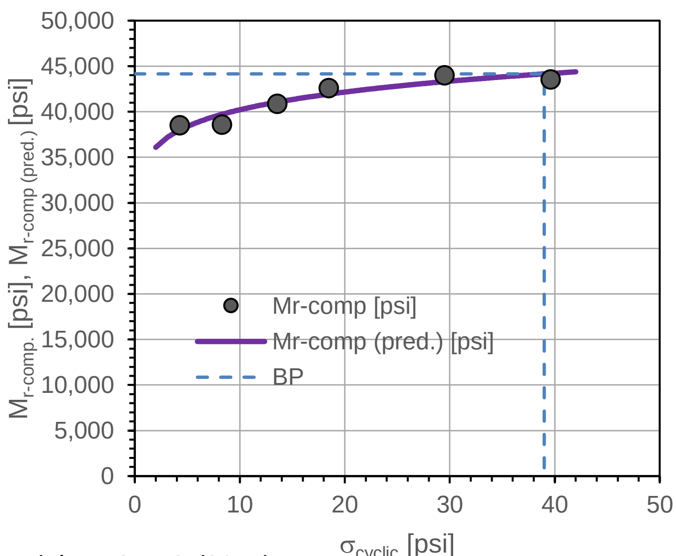
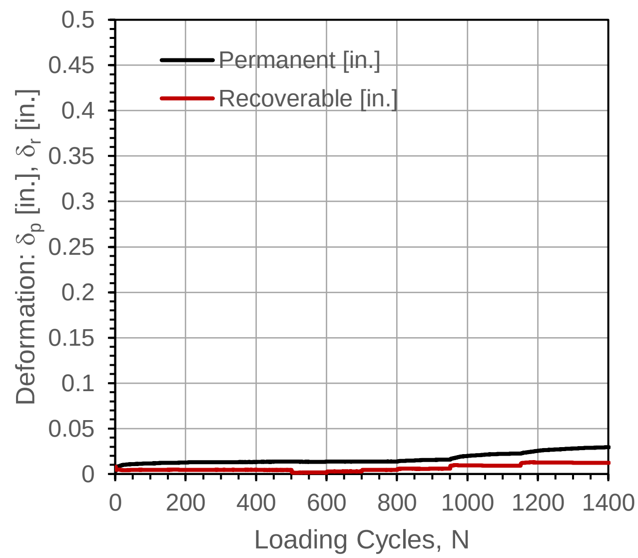
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/2/2017	Time:	12:37:35 PM	Test ID	**Hwy330_12_1**
Tested By	DW, JV	Location:	Hwy330	Sta.	NA
Latitude,N:	41.819519	Longitude,W:	93.307358	Elev. (ft):	871
Comments:	2ft special backfill over geogrid (embankment cut).				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.57	---	---	0.0136	---	0.119	---
1	100	4.30	38,523	37,992	0.0135	-0.0001	-0.426	Y
2	100	8.30	38,617	39,712	0.0136	0.0000	-0.077	Y
3	100	13.57	40,902	41,059	0.0137	0.0001	0.256	Y
4	150	18.49	42,608	41,934	0.0159	0.0023	0.458	Y
5	200	29.52	44,026	43,308	0.0225	0.0088	0.528	N
6	250	39.61	43,568	44,204	0.0294	0.0158	0.614	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	2,649.8	7.87E-08
k^*_2	0.067	2.67E-01
k^*_3	0.011	9.76E-01
Adj. R^2	0.877	
Std. Error [psi]	804	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	44,156
$\sigma_{cyclic\text{-}BP}$ [psi]	39.0

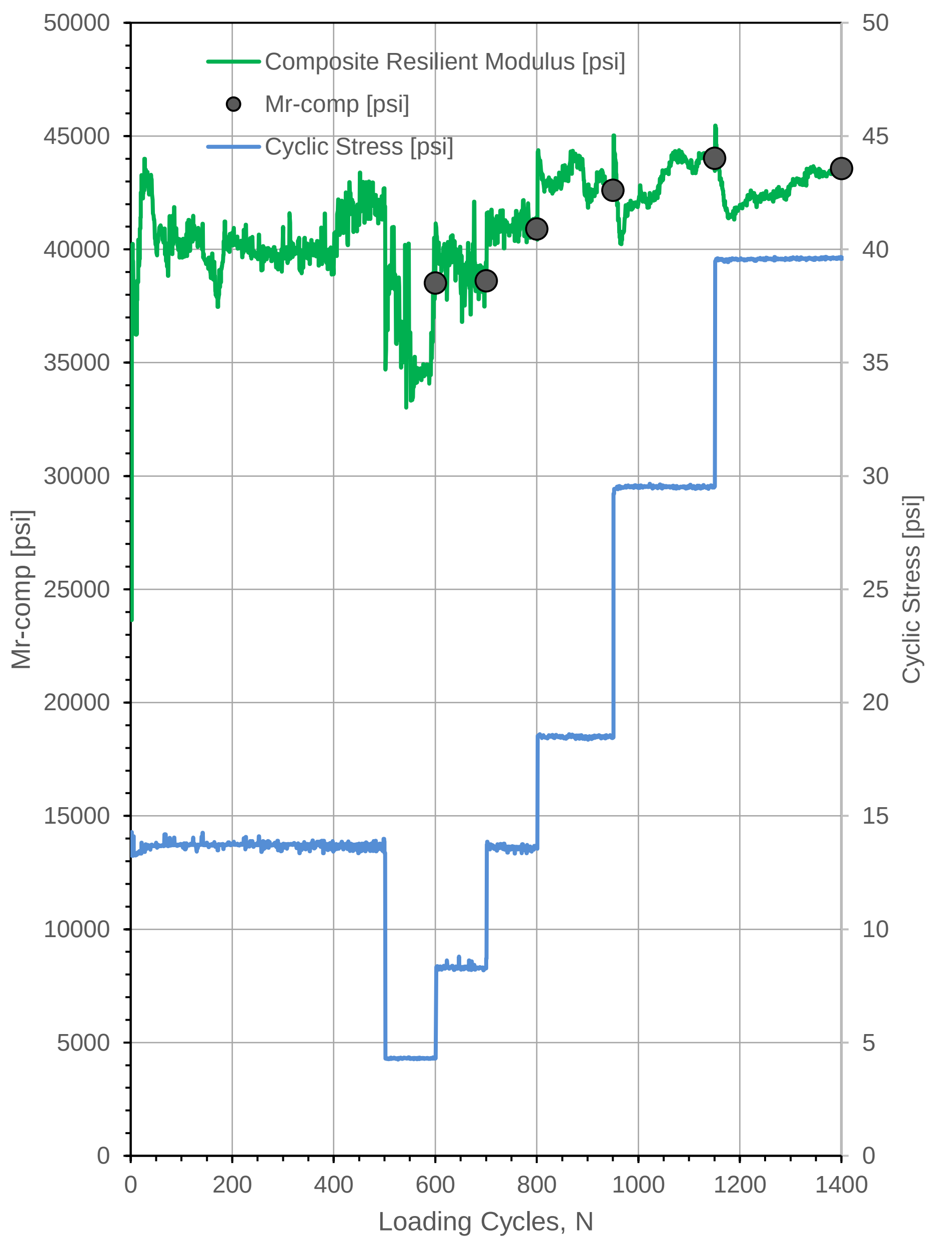
In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 330 near Hwy 65 (Project #4)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/2/2017	Time:	12:37:35 PM	Test ID	**Hwy330_12_1**
Tested By	DW, JV	Location:	Hwy330	Sta.	NA
Latitude,N:	41.819519	Longitude,W:	93.307358	Elev. (ft):	871
Comments:	2ft special backfill over geogrid (embankment cut).				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	36,094
3	37,087
4	37,809
5	38,379
6	38,853
7	39,258
8	39,614
9	39,930
10	40,216
11	40,476
12	40,716
13	40,938
14	41,145
15	41,339
16	41,521
17	41,694
18	41,857
21	42,302
22	42,437
23	42,568
24	42,693
25	42,813
26	42,929
27	43,041
28	43,150
29	43,255
30	43,357
31	43,455
32	43,551
33	43,645
34	43,735
35	43,824
36	43,910
37	43,994
38	44,076
39	44,156
40	44,235



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 330 near Hwy 65 (Project #4)

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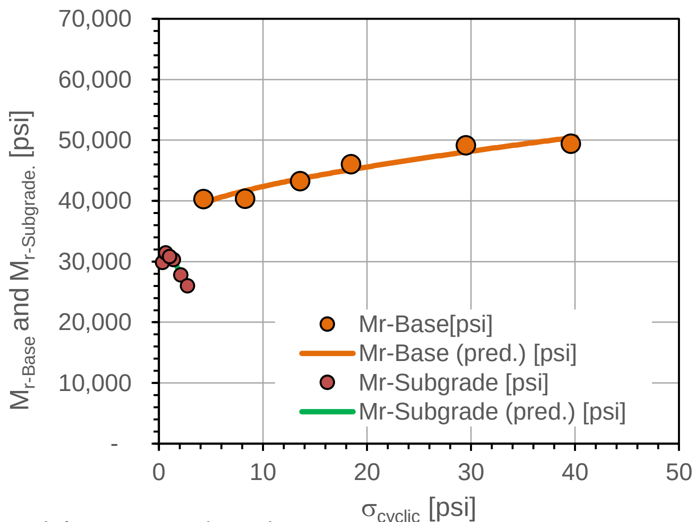
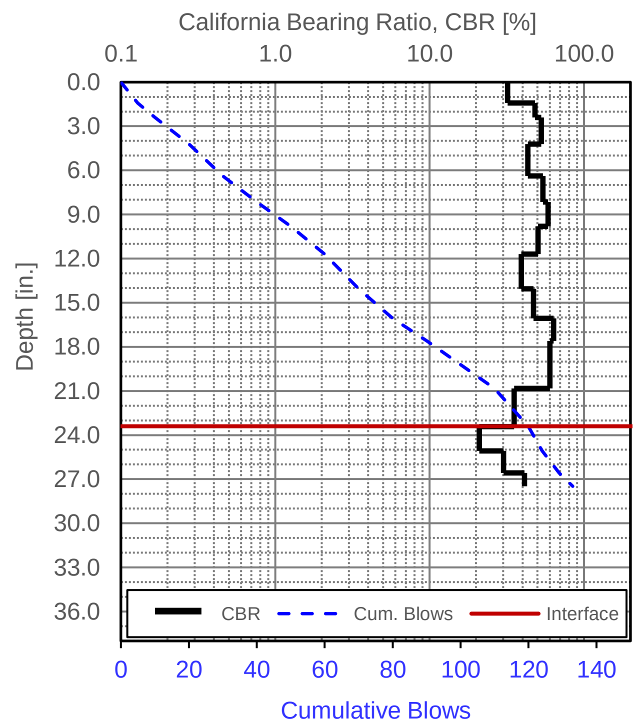
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/2/2017	Time:	12:37:35 PM	Test ID	**Hwy330_12_1**
Tested By	DW, JV	Location:	Hwy330	Sta.	NA
Latitude:	41.819519	Longitude:	93.307358	Elev. (ft):	871
Comments:	2ft special backfill over geogrid (embankment cut).				

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-Base}}$[psi]	$M_{r\text{-Base (pred.)}}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-Subgrade}}$ [psi]	$M_{r\text{-Subgrade (pred.)}}$ [psi]	Modulus Ratio
Conditioning	500	13.57	---	---	---	---	---	---
1	100	4.30	40,316	39,651	0.34	29,907	30,855	1.35
2	100	8.30	40,366	41,680	0.67	31,454	30,855	1.28
3	100	13.57	43,286	43,634	1.06	30,806	30,855	1.41
4	100	18.49	46,044	45,151	1.40	30,366	30,077	1.52
5	100	29.52	49,191	48,064	2.11	27,843	28,054	1.77
6	100	39.61	49,437	50,402	2.76	26,047	25,976	1.90

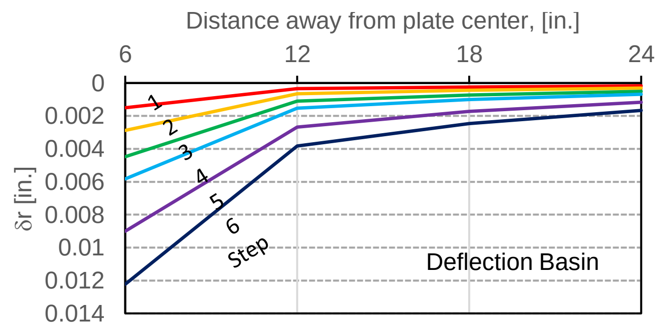




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\text{ (Base)}}$	2699.5	1.50E-07
$k^*_{2\text{ (Base)}}$	0.051	4.66E-01
$k^*_{3\text{ (Base)}}$	0.413	4.05E-01
Adj. R^2	0.922	
Std. Error [psi]	1117	
$k^*_{1\text{ (Subgrade)}}$	7232.7	5.47E-04
$k^*_{2\text{ (Subgrade)}}$	0.549	1.95E-01
$k^*_{3\text{ (Subgrade)}}$	-17.693	6.99E-02
Adj. R^2	0.991	
Std. Error [psi]	186	



In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 330 near Hwy 65 (Project #4)

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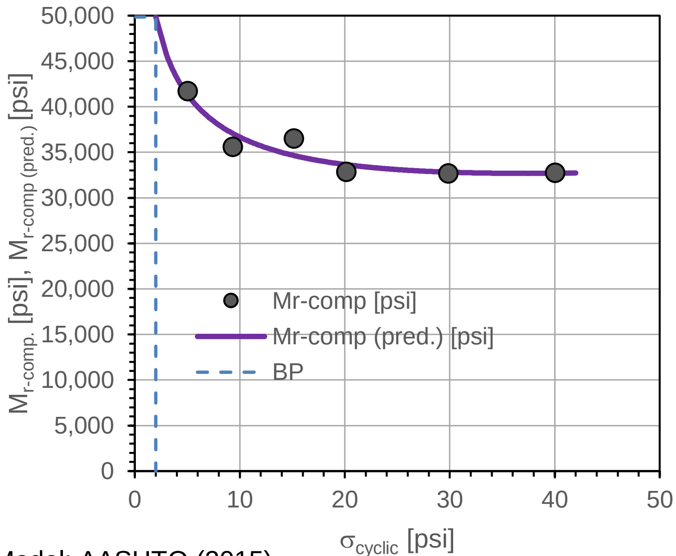
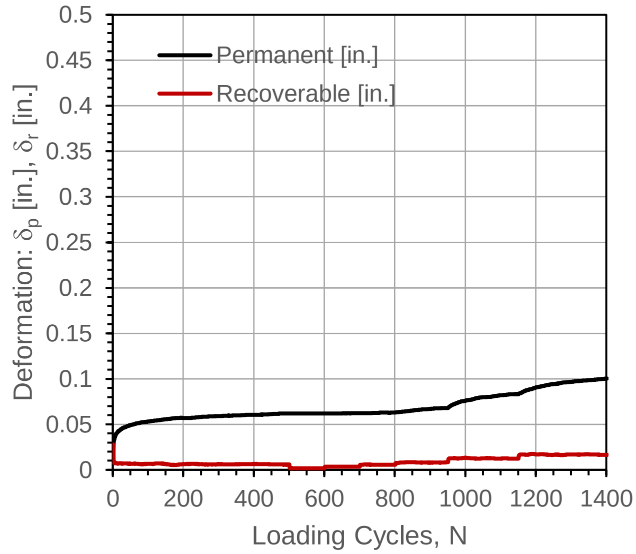
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/2/2017	Time:	1:16:27 PM	Test ID	**Hwy330_12_2**
Tested By	DW, JV	Location:	Hwy330	Sta.	NA
Latitude,N:	41.819351	Longitude,W:	93.307198	Elev. (ft):	878
Comments:	2ft special backfill over geogrid (embankment cut).				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	15.16	---	---	0.0619	---	0.124	---
1	100	5.05	41,732	41,282	0.0619	0.0000	-0.078	Y
2	100	9.34	35,628	37,060	0.0621	0.0002	0.240	Y
3	100	15.16	36,527	34,645	0.0628	0.0009	0.567	Y
4	150	20.15	32,887	33,638	0.0679	0.0060	0.768	N
5	200	29.89	32,707	32,818	0.0833	0.0213	0.638	N
6	250	40.03	32,751	32,697	0.1002	0.0383	0.701	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	2,557.0	3.81E-07
k^*_2	-0.231	9.40E-02
k^*_3	0.809	2.96E-01
Adj. R^2	0.871	
Std. Error [psi]	1,189	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	49,851
$\sigma_{cyclic\text{-}BP}$ [psi]	2.0

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 330 near Hwy 65 (Project #4)

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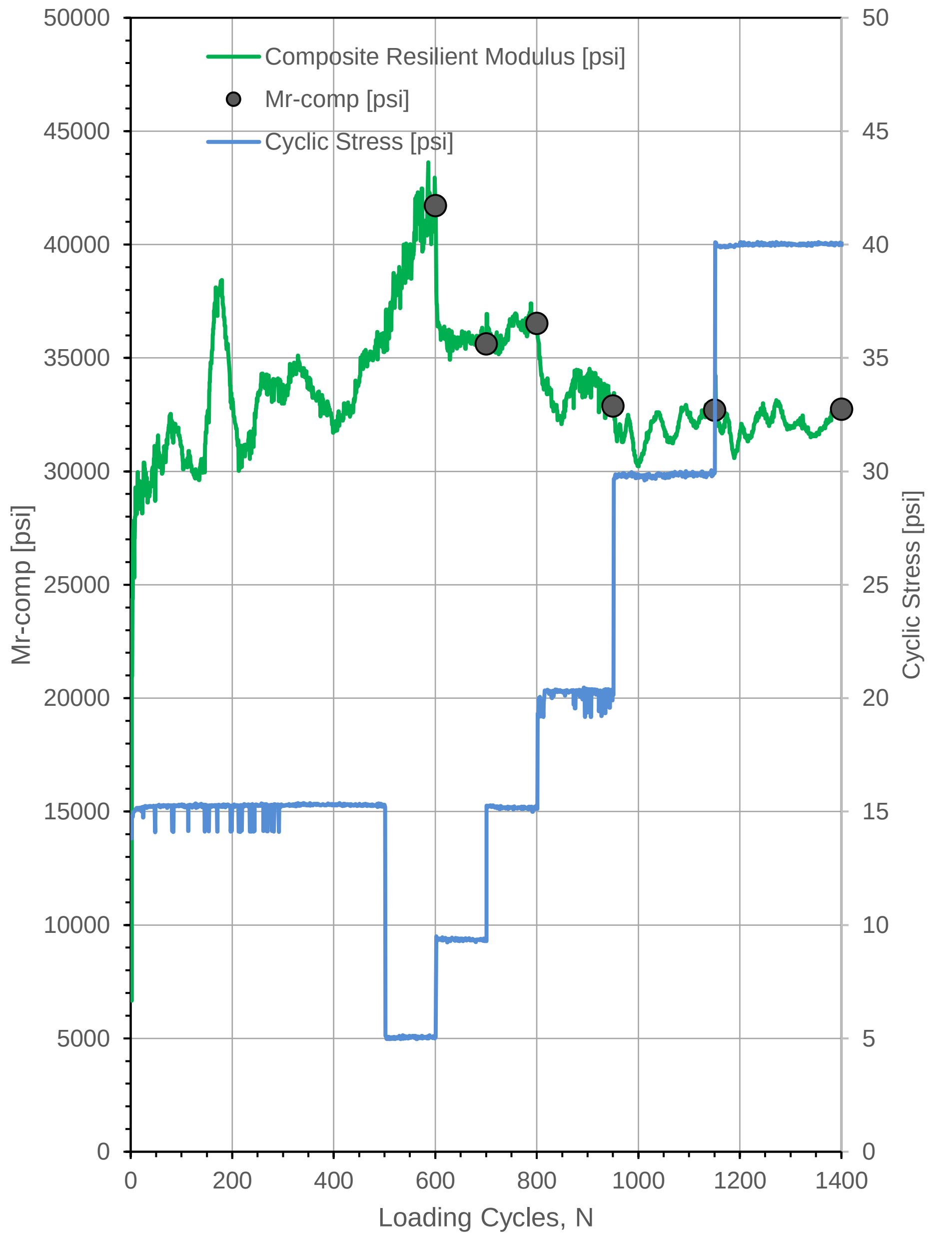
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/2/2017	Time:	1:16:27 PM	Test ID	**Hwy330_12_2**
Tested By	DW, JV	Location:	Hwy330	Sta.	NA
Latitude,N:	41.819351	Longitude,W:	93.307198	Elev. (ft):	878
Comments:	2ft special backfill over geogrid (embankment cut).				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	49,851
3	45,775
4	43,188
5	41,356
6	39,974
7	38,888
8	38,009
9	37,282
10	36,672
11	36,153
12	35,706
13	35,320
14	34,983
15	34,689
16	34,429
17	34,200
18	33,998
21	33,520
22	33,395
23	33,285
24	33,187
25	33,102
26	33,026
27	32,961
28	32,904
29	32,855
30	32,814
31	32,779
32	32,750
33	32,727
34	32,710
35	32,697
36	32,689
37	32,685
38	32,686
39	32,689
40	32,697



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 330 near Hwy 65 (Project #4)

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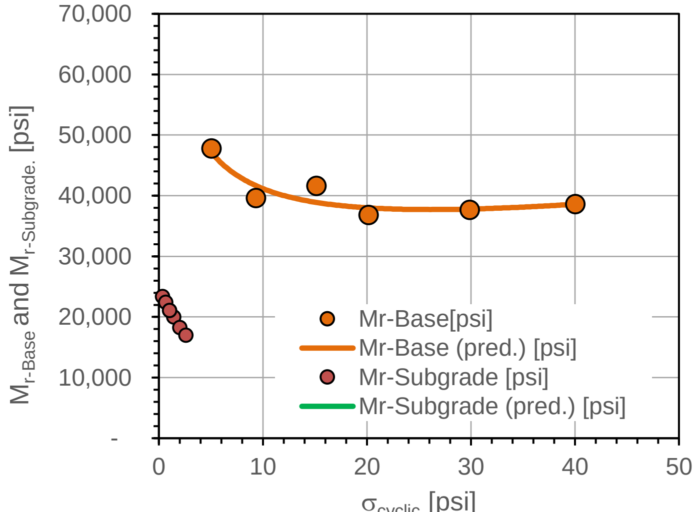
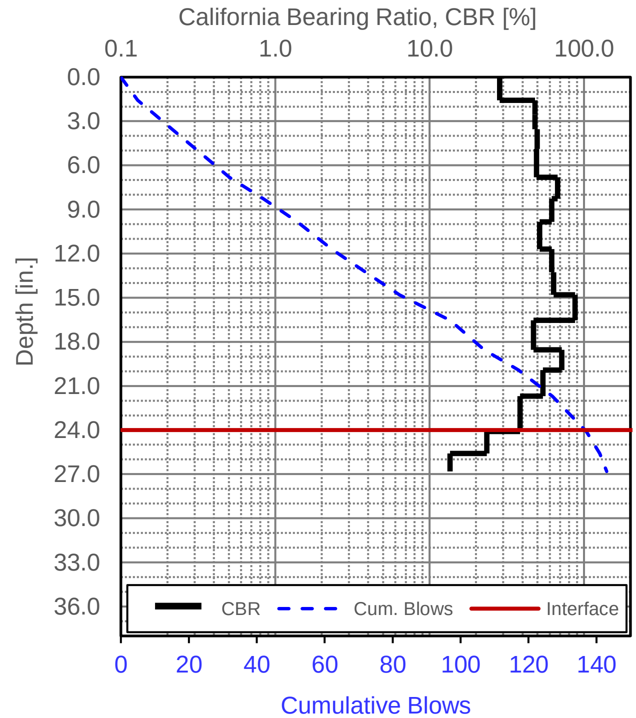
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/2/2017	Time:	1:16:27 PM	Test ID	**Hwy330_12_2**
Tested By	DW, JV	Location:	Hwy330	Sta.	NA
Latitude:	41.819351	Longitude:	93.307198	Elev. (ft):	878
Comments:	2ft special backfill over geogrid (embankment cut).				

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	15.16	---	---	---	---	---	---
1	100	5.05	47,805	47,158	0.34	23,412	23,497	2.04
2	100	9.34	39,623	41,646	0.67	22,456	22,306	1.76
3	100	15.16	41,634	38,887	1.04	21,032	21,090	1.98
4	100	20.15	36,831	37,993	1.42	20,000	19,951	1.84
5	100	29.89	37,703	37,801	2.02	18,261	18,363	2.06
6	100	40.03	38,653	38,594	2.60	17,035	16,987	2.27

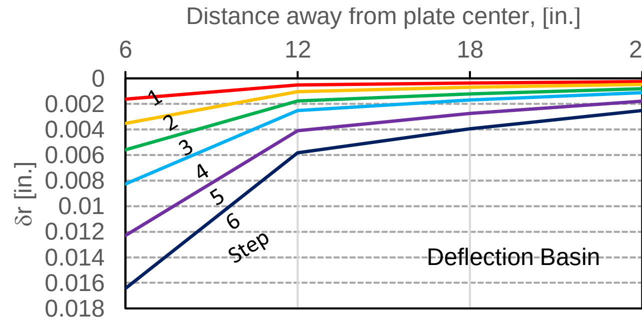




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\ (Base)}$	2797.5	7.87E-07
$k^*_{2\ (Base)}$	-0.296	9.54E-02
$k^*_{3\ (Base)}$	1.358	1.98E-01
Adj. R^2	0.791	
Std. Error [psi]	1654	
$k^*_{1\ (Subgrade)}$	1772.5	4.36E-05
$k^*_{2\ (Subgrade)}$	-0.128	3.35E-01
$k^*_{3\ (Subgrade)}$	-7.448	5.34E-02
Adj. R^2	0.998	
Std. Error [psi]	110	



In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 330 near Hwy 65 (Project #4)

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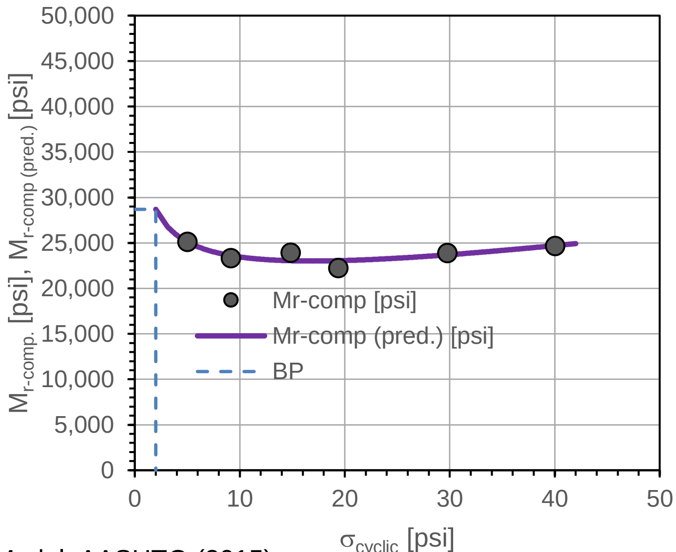
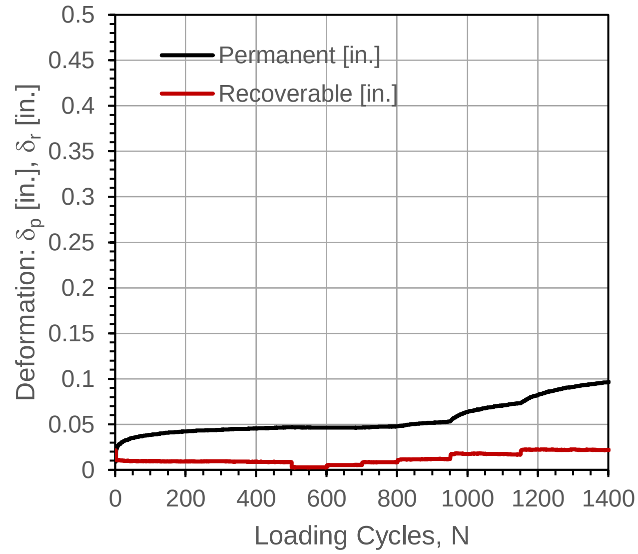
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/2/2017	Time:	1:52:46 PM	Test ID	**Hwy330_12_3**
Tested By	DW, JV	Location:	Hwy330	Sta.	NA
Latitude,N:	41.819035	Longitude,W:	93.306870	Elev. (ft):	882
Comments:	2ft special backfill over geogrid (embankment cut).				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	14.84	---	---	0.0468	---	0.143	---
1	100	5.02	25,144	25,114	0.0463	-0.0006	-0.226	Y
2	100	9.16	23,347	23,609	0.0463	-0.0005	-0.001	Y
3	100	14.84	23,922	23,044	0.0477	0.0009	0.508	Y
4	150	19.38	22,240	23,051	0.0531	0.0063	0.653	N
5	200	29.79	23,919	23,690	0.0733	0.0264	0.667	N
6	250	40.03	24,678	24,709	0.0963	0.0495	0.753	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	1,536.8	2.01E-07
k^*_2	-0.186	8.23E-02
k^*_3	1.217	8.68E-02
Adj. R^2	0.628	
Std. Error [psi]	525	

$M_{r\text{-comp (pred.)-BP}}$ [psi]	28,692
$\sigma_{cyclic\text{-}BP}$ [psi]	2.0

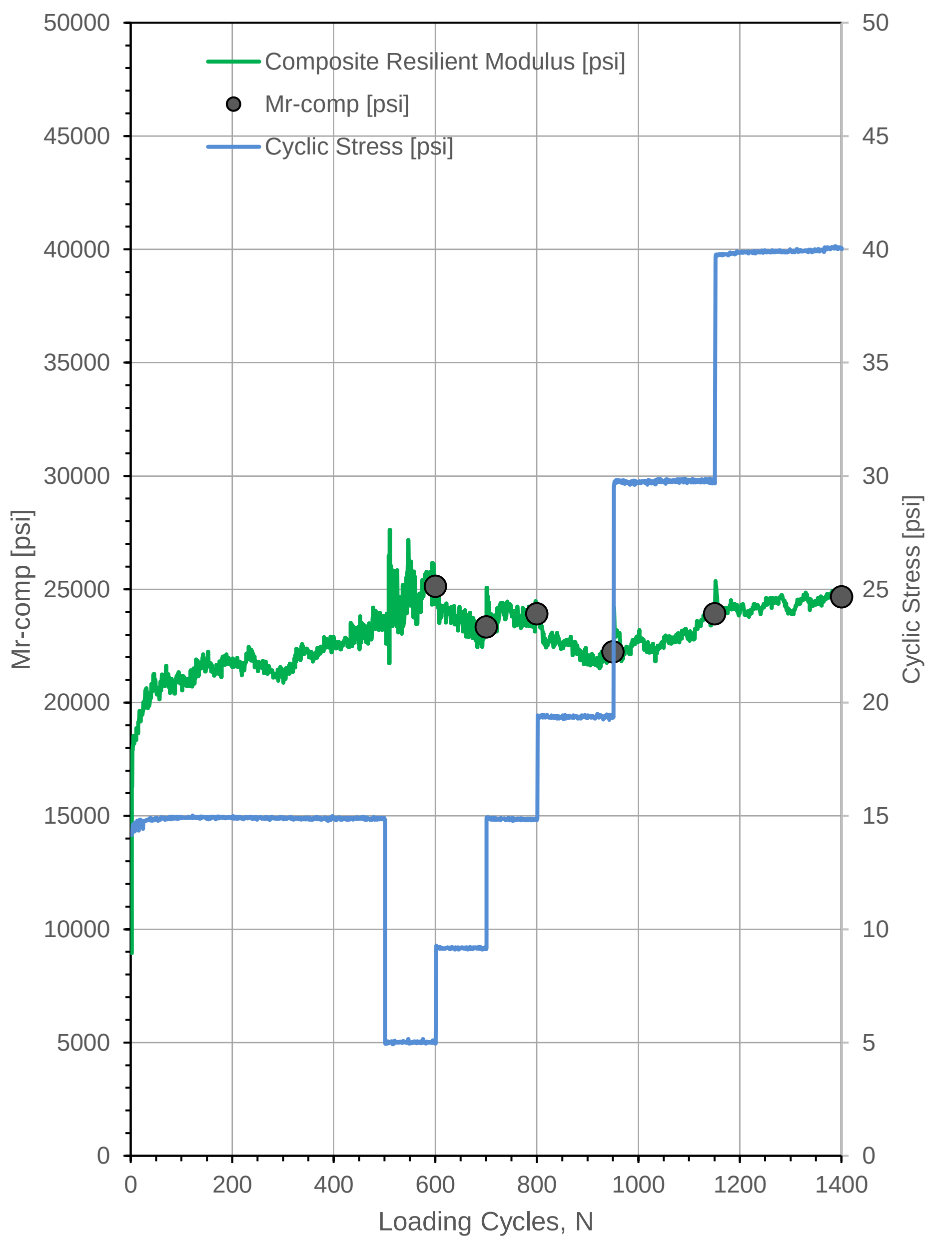
In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 330 near Hwy 65 (Project #4)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/2/2017	Time:	1:52:46 PM	Test ID	**Hwy330_12_3**
Tested By	DW, JV	Location:	Hwy330	Sta.	NA
Latitude,N:	41.819035	Longitude,W:	93.306870	Elev. (ft):	882
Comments:	2ft special backfill over geogrid (embankment cut).				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	28,692
3	26,948
4	25,867
5	25,125
6	24,588
7	24,186
8	23,878
9	23,641
10	23,458
11	23,317
12	23,210
13	23,131
14	23,075
15	23,039
16	23,020
17	23,015
18	23,022
21	23,106
22	23,151
23	23,202
24	23,260
25	23,323
26	23,392
27	23,465
28	23,542
29	23,623
30	23,708
31	23,796
32	23,887
33	23,982
34	24,078
35	24,178
36	24,279
37	24,383
38	24,489
39	24,596
40	24,706



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 330 near Hwy 65 (Project #4)

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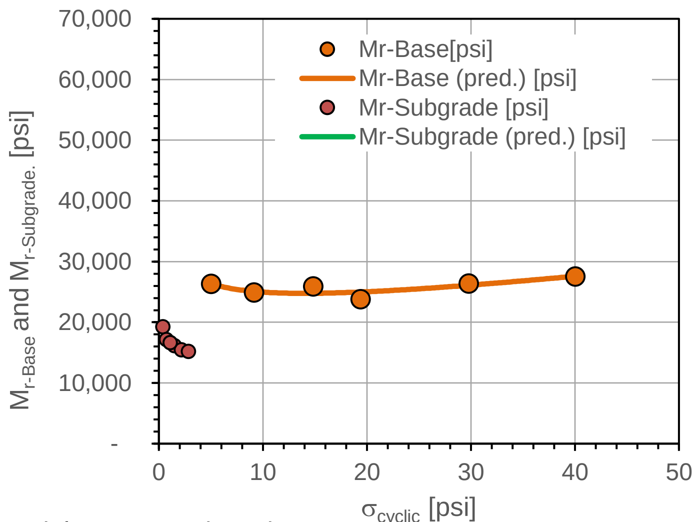
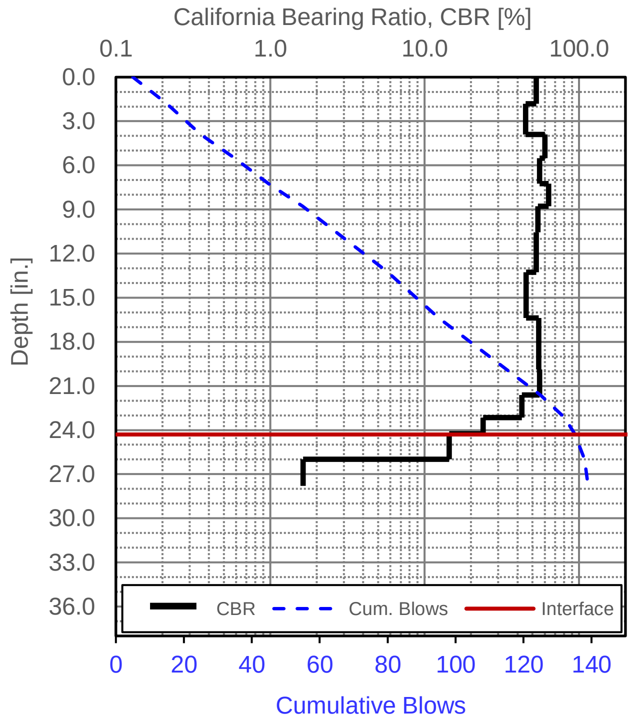
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/2/2017	Time:	1:52:46 PM	Test ID	**Hwy330_12_3**
Tested By	DW, JV	Location:	Hwy330	Sta.	NA
Latitude:	41.819035	Longitude:	93.306870	Elev. (ft):	882
Comments:	2ft special backfill over geogrid (embankment cut).				

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	14.84	---	---	---	---	---	---
1	100	5.02	26,338	26,375	0.39	19,271	18,691	1.37
2	100	9.16	24,909	25,080	0.70	17,183	17,996	1.45
3	100	14.84	25,910	24,775	1.11	16,630	17,208	1.56
4	100	19.38	23,810	24,986	1.48	16,196	16,588	1.47
5	100	29.79	26,415	26,096	2.16	15,502	15,624	1.70
6	100	40.03	27,580	27,593	2.84	15,245	14,818	1.81

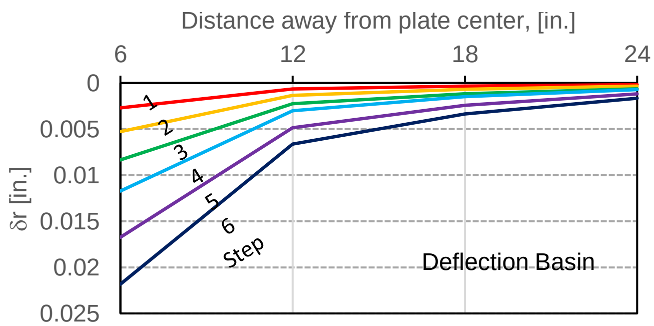




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\ (Base)}$	1606.2	3.84E-07
$k^*_{2\ (Base)}$	-0.176	1.46E-01
$k^*_{3\ (Base)}$	1.352	1.11E-01
Adj. R^2	0.593	
Std. Error [psi]	691	
$k^*_{1\ (Subgrade)}$	1020.5	4.55E-03
$k^*_{2\ (Subgrade)}$	-0.250	4.76E-02
$k^*_{3\ (Subgrade)}$	-1.582	9.02E-02
Adj. R^2	0.947	
Std. Error [psi]	325	



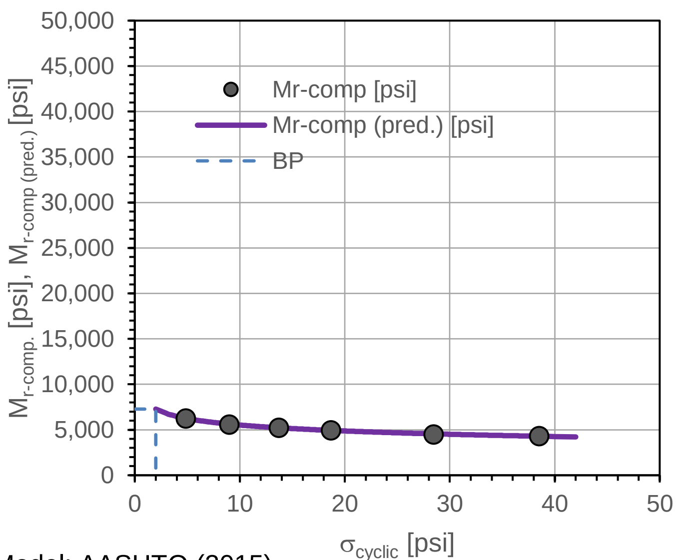
In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

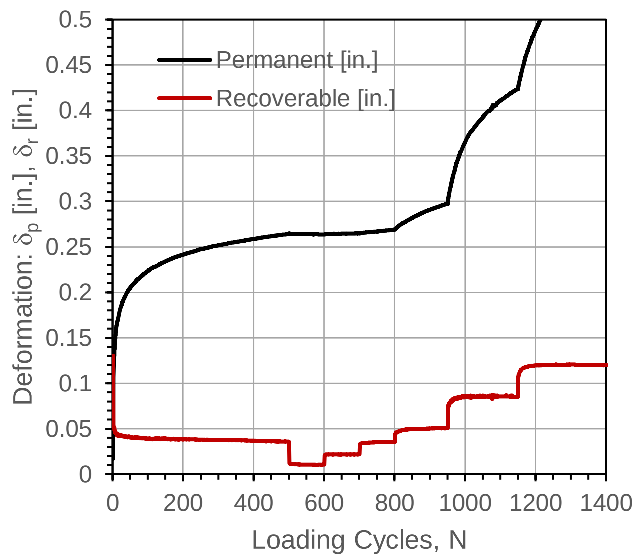
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 330 near Hwy 65 (Project #4)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/2/2017	Time:	2:43:03 PM	Test ID	**Hwy330_12_4**
Tested By	DW, JV	Location:	Hwy330	Sta.	NA
Latitude,N:	41.818527	Longitude,W:	93.306229	Elev. (ft):	903
Comments:	2ft special backfill over geogrid (embankment cut). Described as soft area on project.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-comp}}$ [psi]	$M_{r\text{-comp (pred.)}}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.72	---	---	0.2642	---	0.148	---
1	100	4.87	6,262	6,259	0.2635	-0.0006	-0.372	Y
2	100	9.01	5,598	5,625	0.2648	0.0007	0.403	Y
3	100	13.72	5,244	5,219	0.2691	0.0050	0.685	N
4	150	18.68	4,968	4,932	0.2975	0.0334	0.816	N
5	200	28.47	4,489	4,553	0.4238	0.1597	0.717	N
6	250	38.53	4,318	4,290	0.5757	0.3115	0.743	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	410.5	1.69E-08
k^*_2	-0.166	7.13E-03
k^*_3	-0.120	5.39E-01
Adj. R^2	0.996	
Std. Error [psi]	44	

$M_{r\text{-comp (pred.)-BP}}$ [psi]	7,279
$\sigma_{cyclic\text{-BP}}$ [psi]	2.0

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 330 near Hwy 65 (Project #4)

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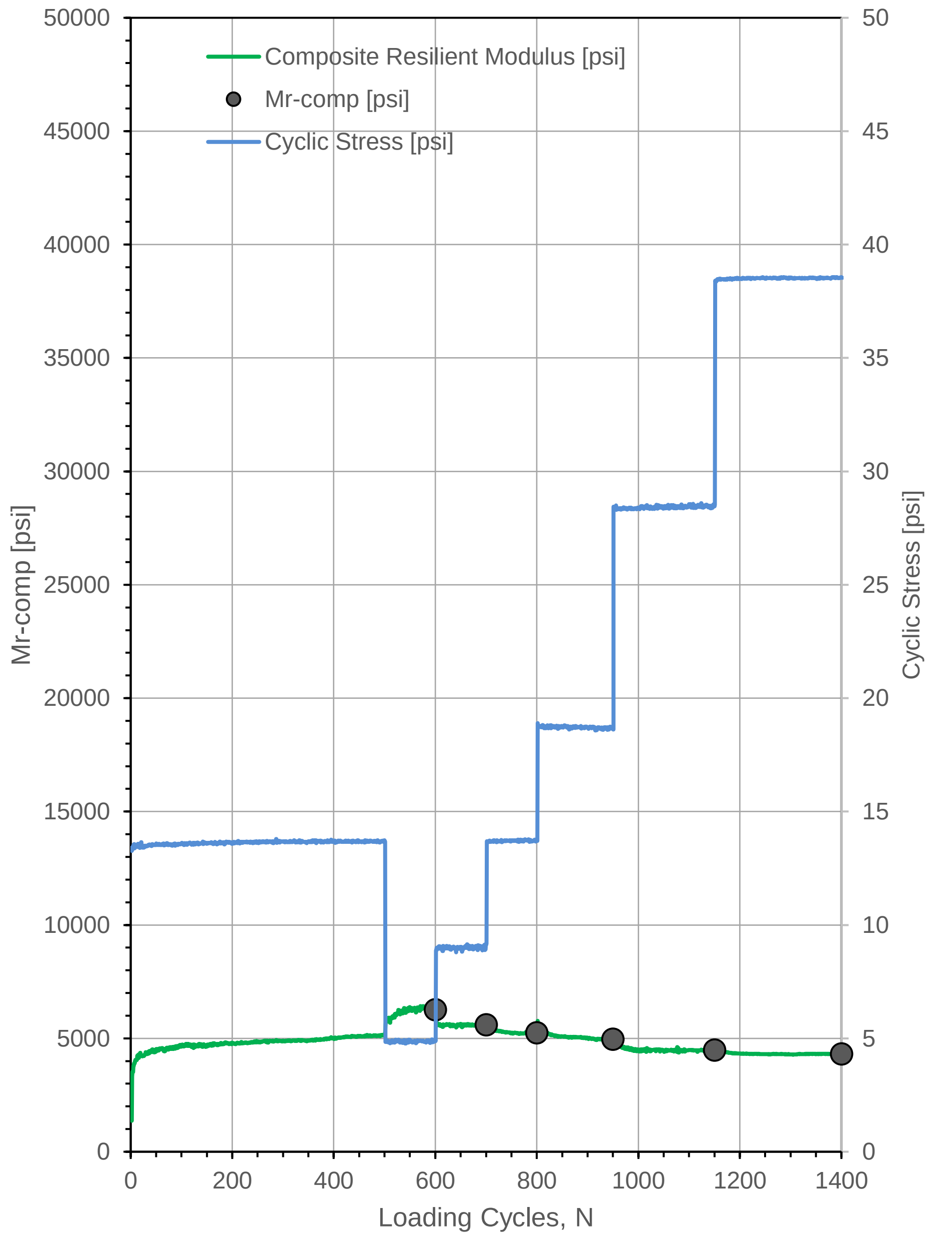
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/2/2017	Time:	2:43:03 PM	Test ID	**Hwy330_12_4**
Tested By	DW, JV	Location:	Hwy330	Sta.	NA
Latitude,N:	41.818527	Longitude,W:	93.306229	Elev. (ft):	903
Comments:	2ft special backfill over geogrid (embankment cut). Described as soft area on project.				

σ_{cyclic} [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]
2	7,279
3	6,798
4	6,473
5	6,231
6	6,038
7	5,879
8	5,744
9	5,626
10	5,522
11	5,430
12	5,346
13	5,270
14	5,199
15	5,135
16	5,075
17	5,018
18	4,966
21	4,825
22	4,783
23	4,743
24	4,705
25	4,669
26	4,634
27	4,600
28	4,568
29	4,537
30	4,507
31	4,479
32	4,451
33	4,424
34	4,398
35	4,373
36	4,349
37	4,325
38	4,302
39	4,280
40	4,258



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 330 near Hwy 65 (Project #4)

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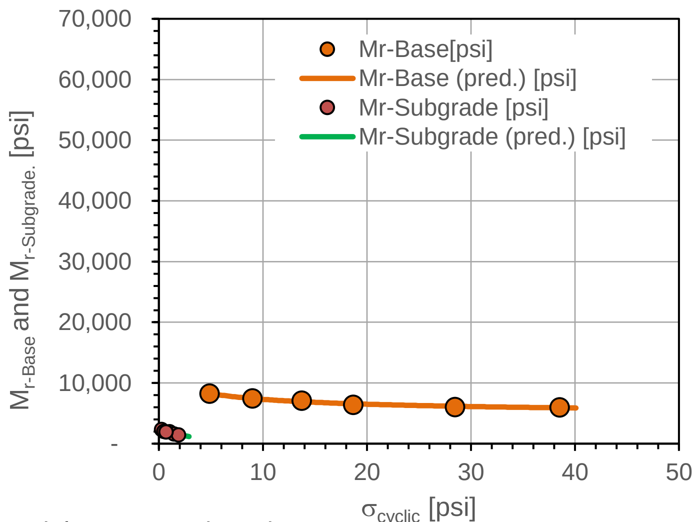
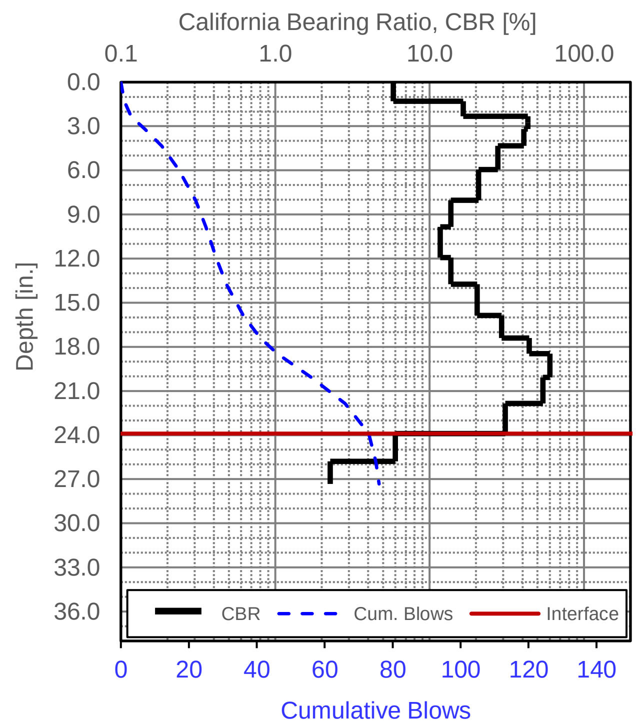
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/2/2017	Time:	2:43:03 PM	Test ID	**Hwy330_12_4**
Tested By	DW, JV	Location:	Hwy330	Sta.	NA
Latitude:	41.818527	Longitude:	93.306229	Elev. (ft):	903
Comments:	2ft special backfill over geogrid (embankment cut). Described as soft area on project.				

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	13.72	---	---	---	---	---	---
1	100	4.87	8,247	8,308	0.26	2,353	2,267	3.50
2	100	9.01	7,485	7,436	0.47	2,061	2,141	3.63
3	100	13.72	7,091	6,917	0.71	1,899	2,012	3.73
4	100	18.68	6,441	6,575	1.04	1,999	1,847	3.22
5	100	28.47	6,062	6,163	1.47	1,633	1,655	3.71
6	100	38.53	5,983	5,906	1.90	1,478	1,488	4.05

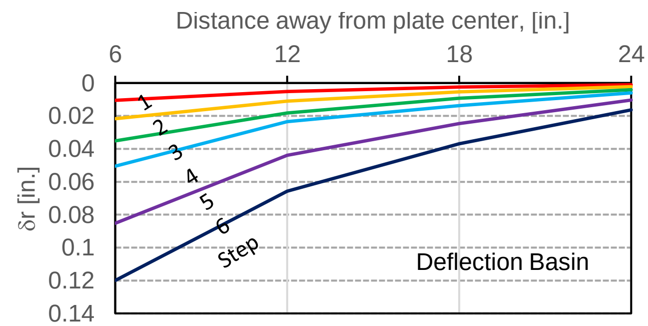




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\ (Base)}$	532.2	1.44E-07
$k^*_{2\ (Base)}$	-0.194	3.63E-02
$k^*_{3\ (Base)}$	0.203	6.20E-01
Adj. R^2	0.978	
Std. Error [psi]	132	
$k^*_{1\ (Subgrade)}$	218.3	2.22E-01
$k^*_{2\ (Subgrade)}$	-0.120	9.52E-01
$k^*_{3\ (Subgrade)}$	-15.249	7.51E-01
Adj. R^2	0.872	
Std. Error [psi]	106	



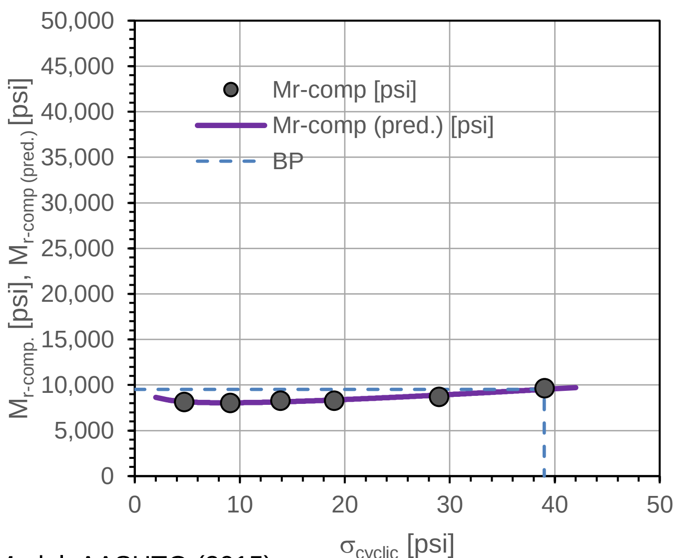
In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

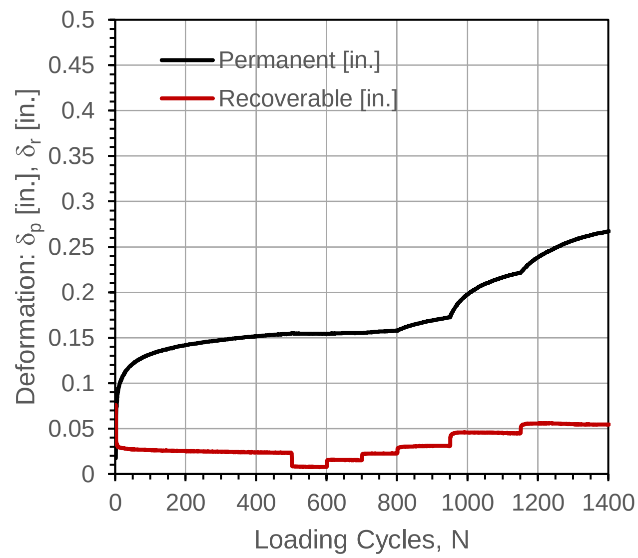
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 330 near Hwy 65 (Project #4)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/2/2017	Time:	3:20:47 PM	Test ID	**Hwy330_12_5**
Tested By	DW, JV	Location:	Hwy330	Sta.	NA
Latitude,N:	41.818401	Longitude,W:	93.306107	Elev. (ft):	890
Comments:	2ft special backfill over geogrid (embankment cut). Described as soft area on project.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.88	---	---	0.1545	---	0.136	---
1	100	4.71	8,142	8,173	0.1543	-0.0002	-0.349	Y
2	100	9.10	8,050	8,050	0.1553	0.0008	0.474	Y
3	100	13.88	8,303	8,150	0.1578	0.0033	0.678	N
4	150	19.01	8,302	8,359	0.1726	0.0181	0.753	N
5	200	28.98	8,710	8,895	0.2216	0.0671	0.702	N
6	250	39.04	9,645	9,520	0.2671	0.1126	0.789	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	506.5	7.40E-08
k^*_2	-0.107	8.06E-02
k^*_3	1.265	2.11E-02
Adj. R^2	0.945	
Std. Error [psi]	134	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	9,518
$\sigma_{cyclic\text{-}BP}$ [psi]	39.0

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 330 near Hwy 65 (Project #4)

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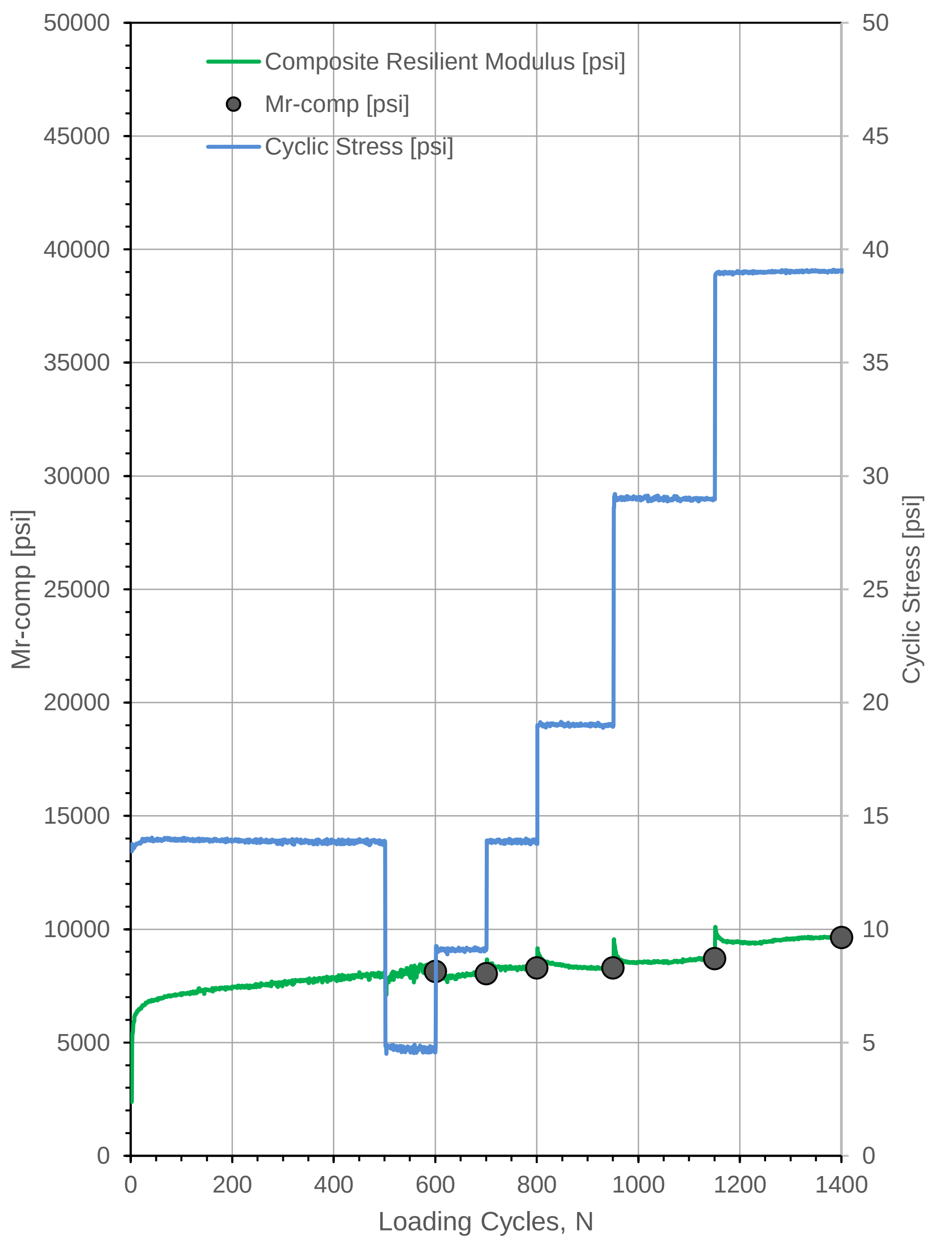
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/2/2017	Time:	3:20:47 PM	Test ID	**Hwy330_12_5**
Tested By	DW, JV	Location:	Hwy330	Sta.	NA
Latitude,N:	41.818401	Longitude,W:	93.306107	Elev. (ft):	890
Comments:	2ft special backfill over geogrid (embankment cut). Described as soft area on project.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	8,647
3	8,389
4	8,242
5	8,152
6	8,097
7	8,065
8	8,051
9	8,049
10	8,057
11	8,073
12	8,095
13	8,122
14	8,154
15	8,189
16	8,228
17	8,269
18	8,313
21	8,456
22	8,507
23	8,559
24	8,613
25	8,668
26	8,723
27	8,780
28	8,838
29	8,897
30	8,956
31	9,016
32	9,077
33	9,138
34	9,200
35	9,263
36	9,326
37	9,389
38	9,453
39	9,518
40	9,583



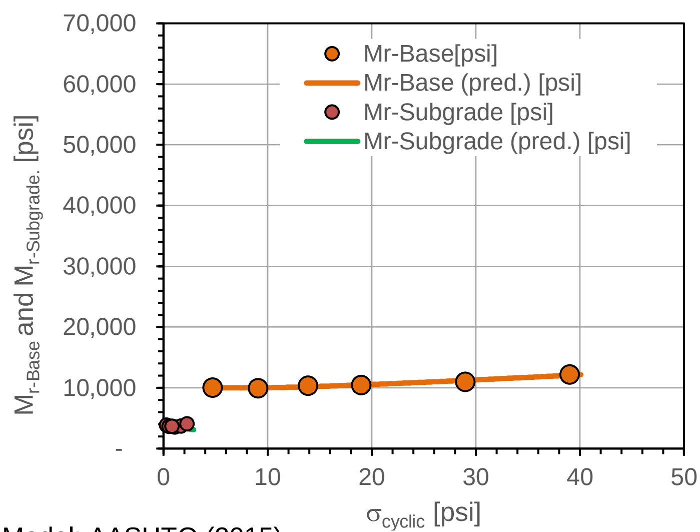
In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

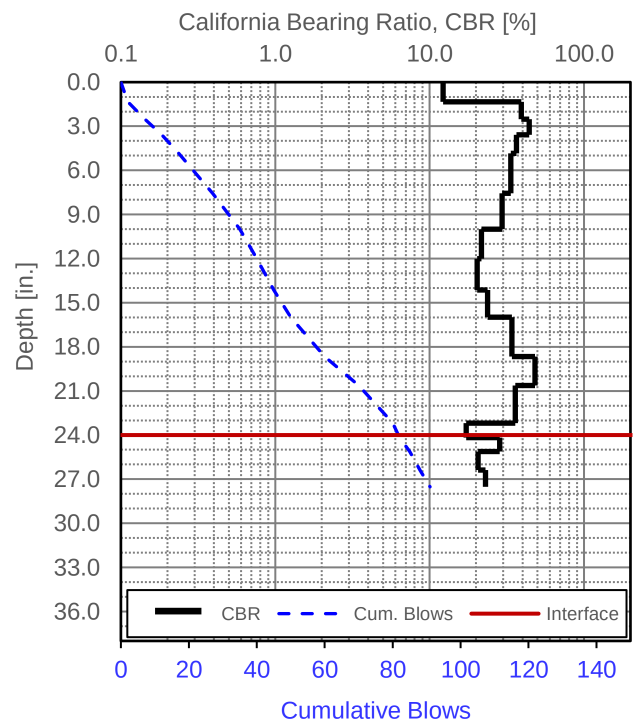
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 330 near Hwy 65 (Project #4)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/2/2017	Time:	3:20:47 PM	Test ID	**Hwy330_12_5**
Tested By	DW, JV	Location:	Hwy330	Sta.	NA
Latitude:	41.818401	Longitude:	93.306107	Elev. (ft):	890
Comments:	2ft special backfill over geogrid (embankment cut). Described as soft area on project.				

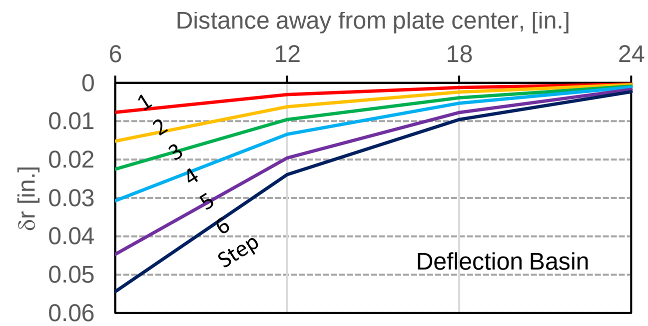
Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	13.88	---	---	---	---	---	---
1	100	4.71	10,059	10,068	0.29	3,876	3,974	2.60
2	100	9.10	9,937	9,999	0.55	3,675	3,859	2.70
3	100	13.88	10,352	10,181	0.82	3,667	3,748	2.82
4	100	19.01	10,477	10,487	1.10	3,580	3,641	2.93
5	100	28.98	11,014	11,227	1.67	3,725	3,641	2.96
6	100	39.04	12,197	12,070	2.25	4,112	3,641	2.97





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
$k^*_{1\ (Base)}$	625.7	4.62E-08
$k^*_{2\ (Base)}$	-0.095	7.97E-02
$k^*_{3\ (Base)}$	1.276	1.47E-02
Adj. R^2	0.966	
Std. Error [psi]	151	
$k^*_{1\ (Subgrade)}$	255.0	1.83E-01
$k^*_{2\ (Subgrade)}$	-0.150	1.89E-01
$k^*_{3\ (Subgrade)}$	-3.525	2.50E-01
Adj. R^2	0.932	
Std. Error [psi]	29	

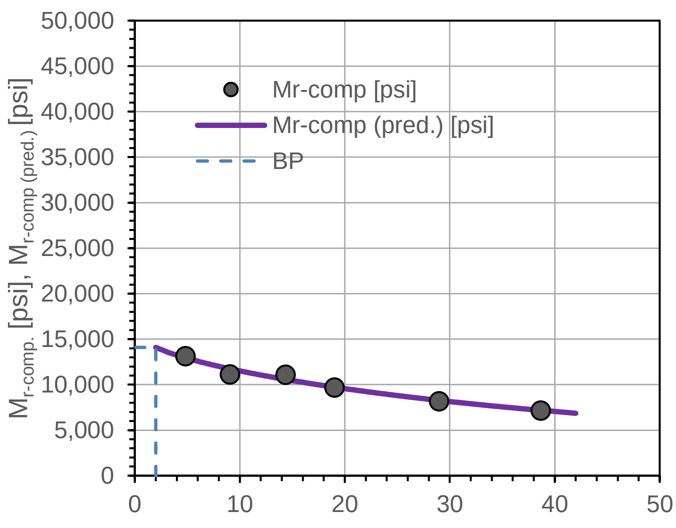
In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

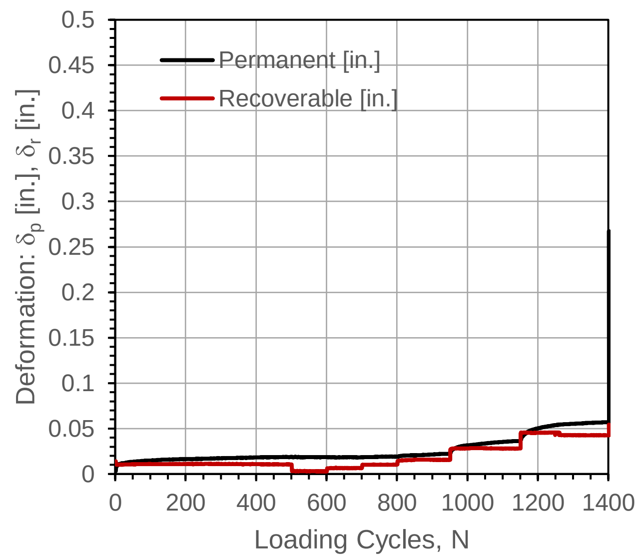
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 330 near Hwy 65 (Project #4)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/2/2017	Time:	4:03:54 PM	Test ID	**Hwy330_12_6**
Tested By	DW, JV	Location:	Hwy330	Sta.	NA
Latitude,N:	41.817860	Longitude,W:	93.305367	Elev. (ft):	892
Comments:	2ft select subgrade (embankment fill).				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	14.36	---	---	0.0190	---	0.159	---
1	100	4.84	13,152	12,938	0.0185	-0.0005	-0.127	Y
2	100	9.08	11,132	11,739	0.0184	-0.0005	-0.013	Y
3	100	14.36	11,096	10,576	0.0188	-0.0001	0.435	Y
4	150	19.02	9,698	9,727	0.0223	0.0033	0.505	Y
5	200	28.99	8,201	8,272	0.0364	0.0174	0.438	N
6	250	38.67	7,180	7,178	0.0570	0.0381	0.445	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	949.6	7.18E-07
k^*_2	-0.040	7.13E-01
k^*_3	-1.713	8.62E-02
Adj. R^2	0.963	
Std. Error [psi]	410	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	14,093
$\sigma_{cyclic\text{-}BP}$ [psi]	2.0

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 330 near Hwy 65 (Project #4)

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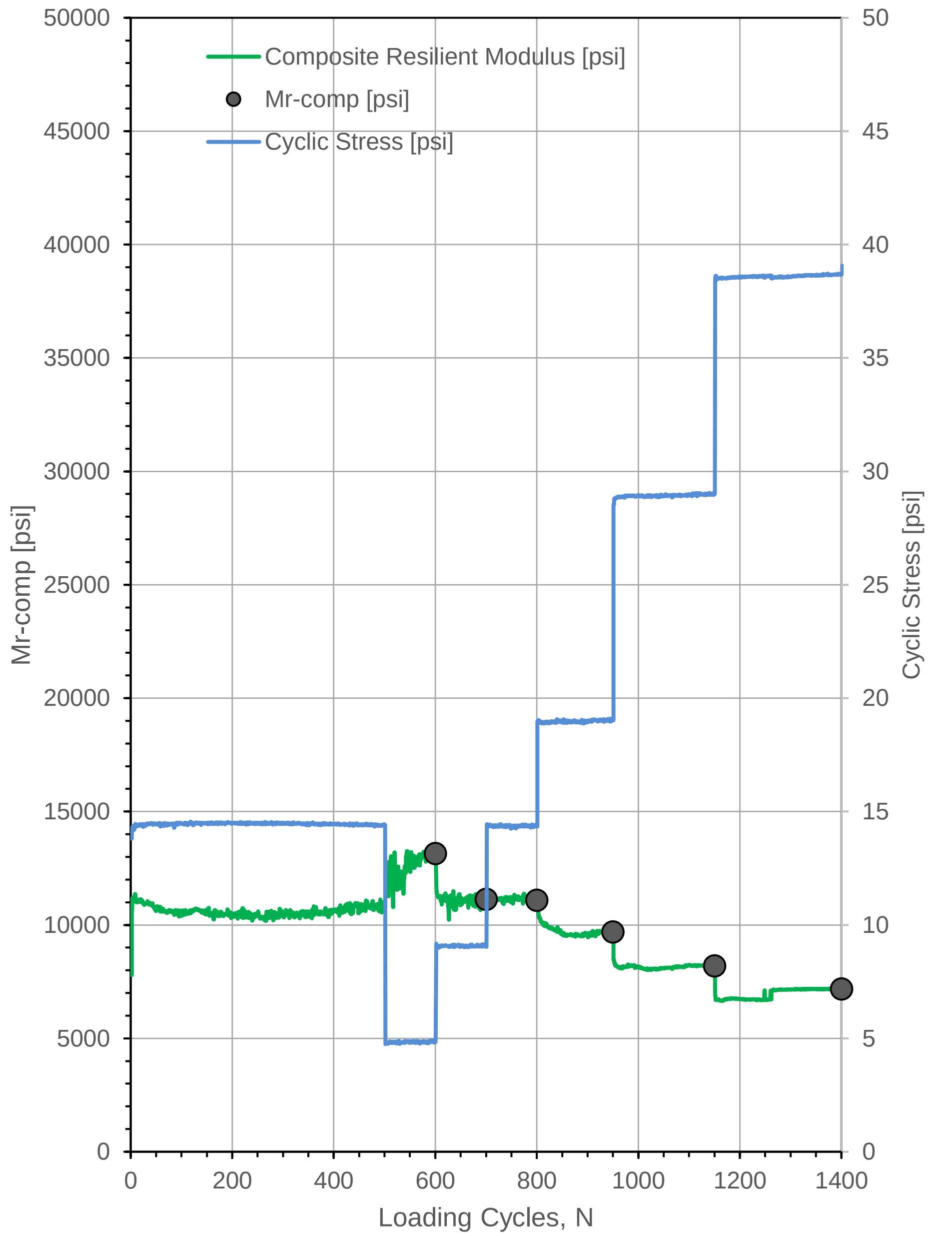
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/2/2017	Time:	4:03:54 PM	Test ID	**Hwy330_12_6**
Tested By	DW, JV	Location:	Hwy330	Sta.	NA
Latitude,N:	41.817860	Longitude,W:	93.305367	Elev. (ft):	892
Comments:	2ft select subgrade (embankment fill).				

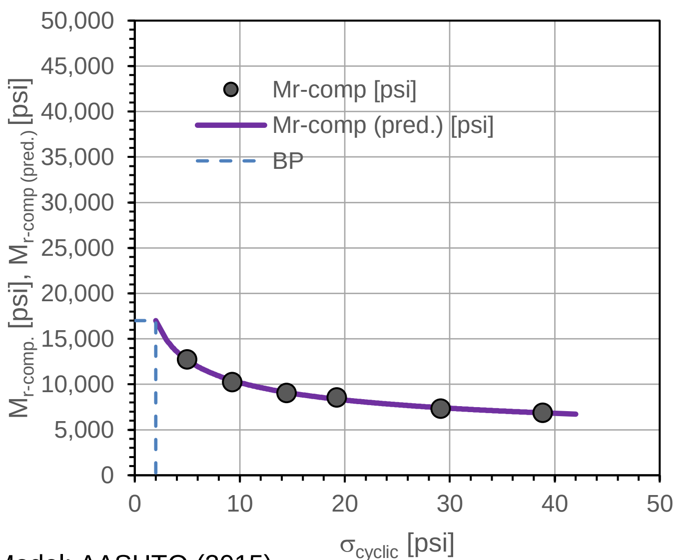
σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	14,093
3	13,622
4	13,231
5	12,886
6	12,574
7	12,284
8	12,014
9	11,758
10	11,516
11	11,285
12	11,064
13	10,852
14	10,648
15	10,452
16	10,262
17	10,079
18	9,902
21	9,404
22	9,248
23	9,096
24	8,949
25	8,806
26	8,666
27	8,531
28	8,399
29	8,270
30	8,145
31	8,022
32	7,903
33	7,787
34	7,673
35	7,563
36	7,455
37	7,349
38	7,246
39	7,145
40	7,047

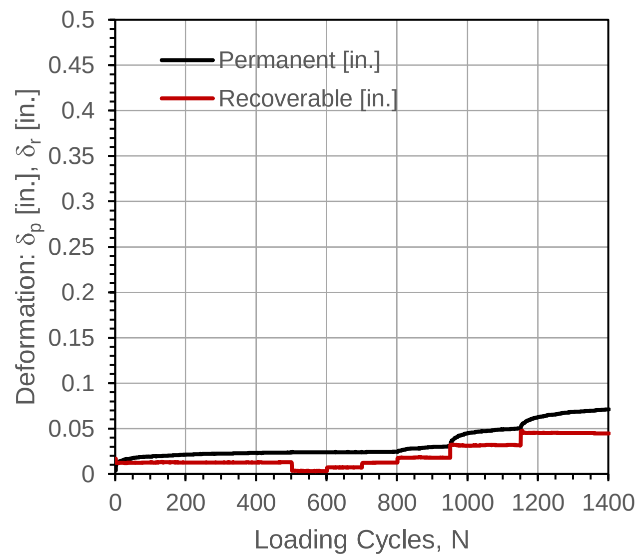


Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/2/2017	Time:	4:43:21 PM	Test ID	**Hwy330_12_7**
Tested By	DW, JV	Location:	Hwy330	Sta.	NA
Latitude,N:	41.817707	Longitude,W:	93.305183	Elev. (ft):	894
Comments:	2ft select subgrade (embankment fill).				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\,(pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	14.45	---	---	0.0237	---	0.157	---
1	100	4.99	12,751	12,675	0.0239	0.0002	-0.073	Y
2	100	9.30	10,270	10,425	0.0241	0.0003	0.217	Y
3	100	14.45	9,080	9,109	0.0244	0.0007	0.393	Y
4	150	19.25	8,561	8,365	0.0304	0.0067	0.555	N
5	200	29.13	7,327	7,427	0.0504	0.0267	0.440	N
6	250	38.84	6,881	6,863	0.0711	0.0474	0.464	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	790.4	5.86E-08
k^*_2	-0.328	4.70E-03
k^*_3	0.203	5.39E-01
Adj. R^2	0.996	
Std. Error [psi]	140	

$M_{r\text{-}comp\,(pred.)\text{-}BP}$ [psi]	17,004
$\sigma_{cyclic\text{-}BP}$ [psi]	2.0

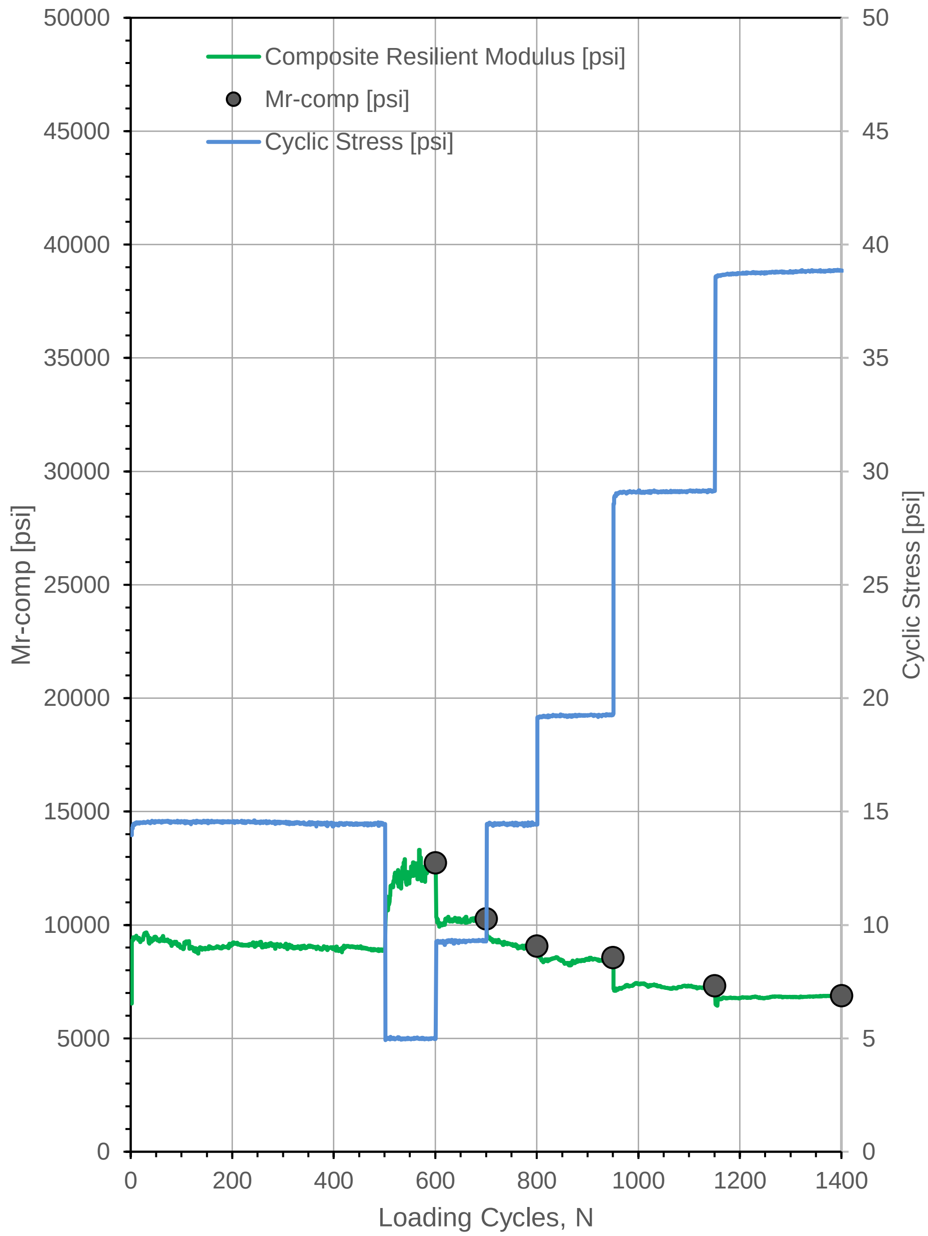
In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 330 near Hwy 65 (Project #4)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/2/2017	Time:	4:43:21 PM	Test ID	**Hwy330_12_7**
Tested By	DW, JV	Location:	Hwy330	Sta.	NA
Latitude,N:	41.817707	Longitude,W:	93.305183	Elev. (ft):	894
Comments:	2ft select subgrade (embankment fill).				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	17,004
3	14,917
4	13,602
5	12,667
6	11,956
7	11,389
8	10,923
9	10,530
10	10,192
11	9,897
12	9,637
13	9,406
14	9,197
15	9,008
16	8,836
17	8,678
18	8,532
21	8,155
22	8,046
23	7,943
24	7,846
25	7,755
26	7,669
27	7,588
28	7,510
29	7,436
30	7,366
31	7,299
32	7,236
33	7,174
34	7,116
35	7,060
36	7,006
37	6,954
38	6,904
39	6,856
40	6,809



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

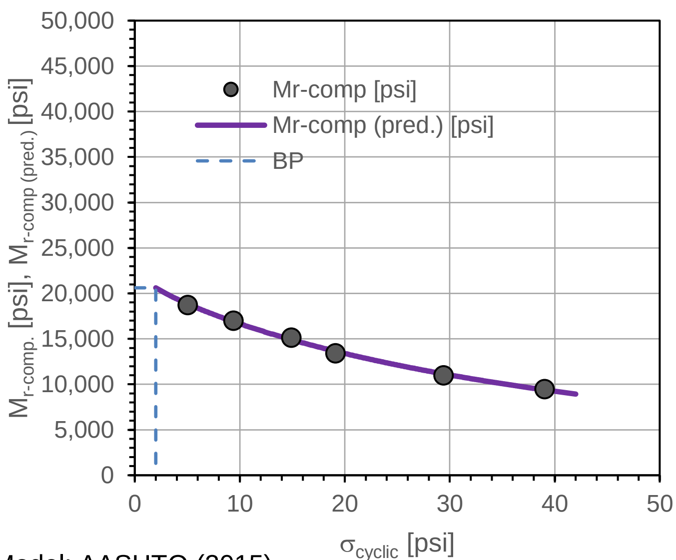
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 330 near Hwy 65 (Project #4)

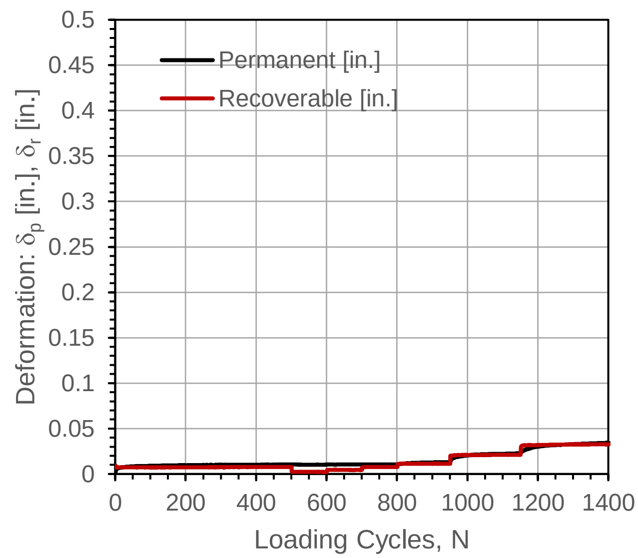
ingios GEOTECHNICS

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/2/2017	Time:	5:23:30 PM	Test ID	**Hwy330_12_8**
Tested By	DW, JV	Location:	Hwy330	Sta.	NA
Latitude,N:	41.817574	Longitude,W:	93.305008	Elev. (ft):	883
Comments:	2ft select subgrade (embankment fill).				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	14.90	---	---	0.0104	---	0.121	---
1	100	5.04	18,743	18,842	0.0103	-0.0001	-0.139	Y
2	100	9.39	17,009	16,897	0.0103	0.0000	0.084	Y
3	100	14.90	15,156	14,913	0.0105	0.0001	0.067	Y
4	150	19.12	13,435	13,638	0.0131	0.0027	0.523	Y
5	200	29.42	11,013	11,146	0.0227	0.0123	0.378	Y
6	250	39.02	9,480	9,390	0.0343	0.0239	0.457	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	1,431.0	3.17E-08
k^*_2	-0.023	5.97E-01
k^*_3	-2.194	3.54E-03
Adj. R^2	0.997	
Std. Error [psi]	192	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]		20,613
	$\sigma_{cyclic\text{-}BP}$ [psi]	2.0

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

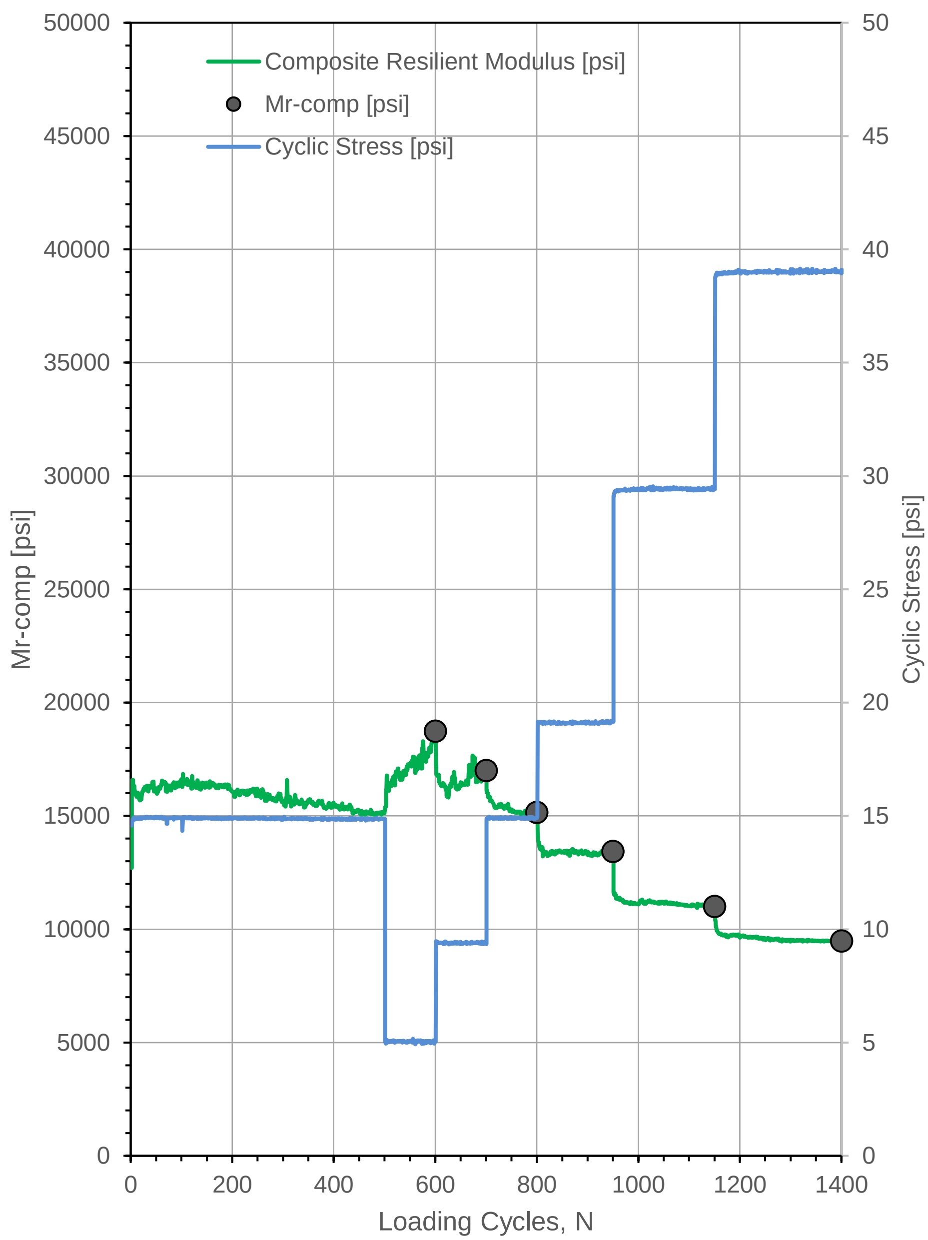
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 330 near Hwy 65 (Project #4)

ingios GEOTECHNICS

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/2/2017	Time:	5:23:30 PM	Test ID	**Hwy330_12_8**
Tested By	DW, JV	Location:	Hwy330	Sta.	NA
Latitude,N:	41.817574	Longitude,W:	93.305008	Elev. (ft):	883
Comments:	2ft select subgrade (embankment fill).				

σ_{cyclic} [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]
2	20,613
3	19,962
4	19,389
5	18,863
6	18,374
7	17,912
8	17,474
9	17,057
10	16,657
11	16,274
12	15,906
13	15,552
14	15,211
15	14,882
16	14,564
17	14,257
18	13,959
21	13,124
22	12,862
23	12,608
24	12,362
25	12,123
26	11,891
27	11,666
28	11,447
29	11,234
30	11,027
31	10,825
32	10,629
33	10,438
34	10,253
35	10,072
36	9,896
37	9,724
38	9,557
39	9,394
40	9,235



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 330 near Hwy 65 (Project #4)

Date of Test	11/2/2017	Test ID	Special1	Operator	DW/JV	ASTM	D6951
Latitude	41.8195190		Longitude	93.3073580		Elevation (ft)	871
Location	Hwy330		Station	NA			
Comments	2ft special backfill over geogrid (embankment cut).						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Special Backfill layer	5.0	48.6	30.6	7,201
Avg. Subgrade Layer	7.9	28.7	21.9	5,081
Ratio of Avg. Top/Bottom Layer	0.6	1.7	1.4	1.4
Std.Dev.Special Backfill Layer	1.1	10.6	11.5	2,613
Std. Dev. Subgrade Layer	2.4	10.1	11.2	2,539

NOTES:

Subgrade assumed as CL.

[1]CBR = $292/DPI^{1.12}$

[1]CBR = $1/(0.017019DPI)^2$

for CL soils with CBR < 10

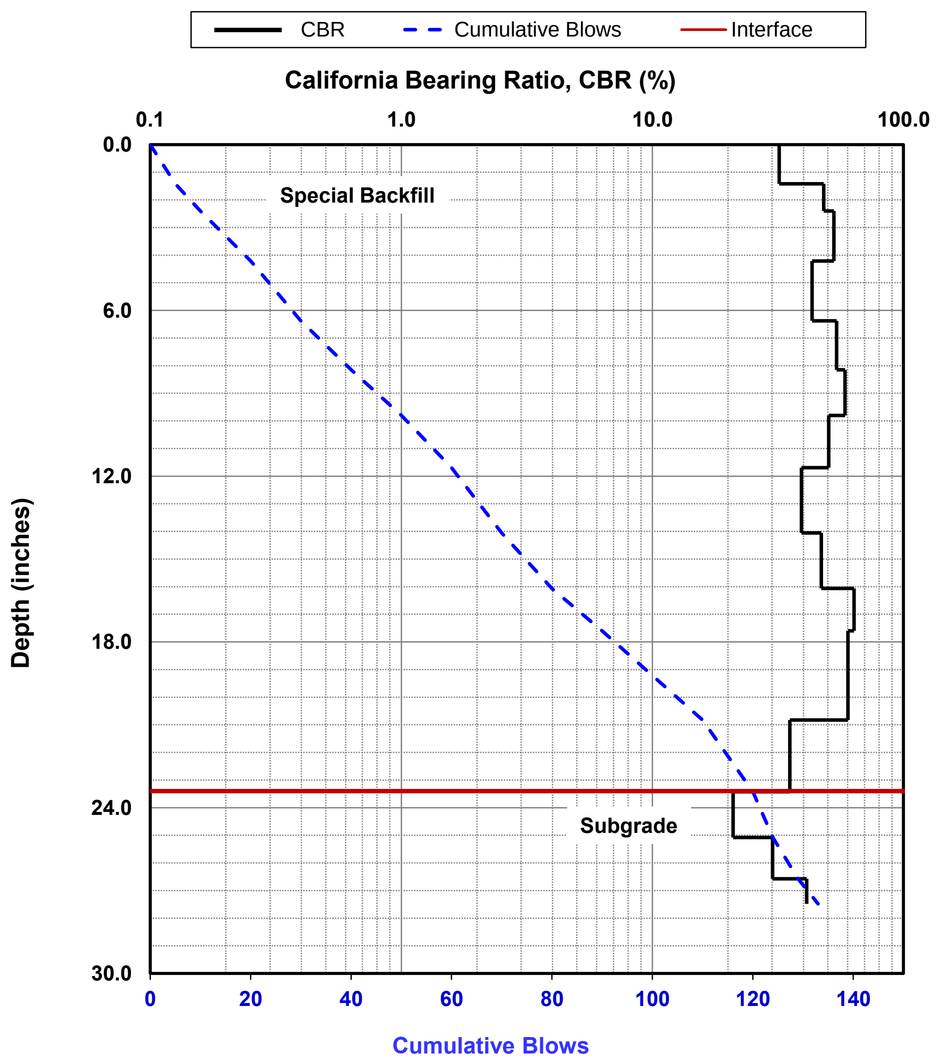
[2]E (ksi) = $(17.6\ CBR^{0.64}) \times 0.1450377$

[3]S_u (psf) = $(3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 330 near Hwy 65 (Project #4)

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Date of Test	11/2/2017	Test ID	Special2	Operator	DW/JV	ASTM	D6951
Latitude	41.8193510		Longitude	93.3071980		Elevation (ft)	878
Location	Hwy330		Station	NA			
Comments	2ft special backfill over geogrid (embankment cut).						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Special Backfill layer	4.5	54.6	33.0	7,781
Avg. Subgrade Layer	11.5	18.9	16.8	3,852
Ratio of Avg. Top/Bottom Layer	0.4	2.9	2.0	2.0
Std.Dev.Special Backfill Layer	1.4	15.4	14.7	3,351
Std. Dev. Subgrade Layer	4.2	7.0	8.9	1,989

NOTES:

Subgrade assumed as CL.

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

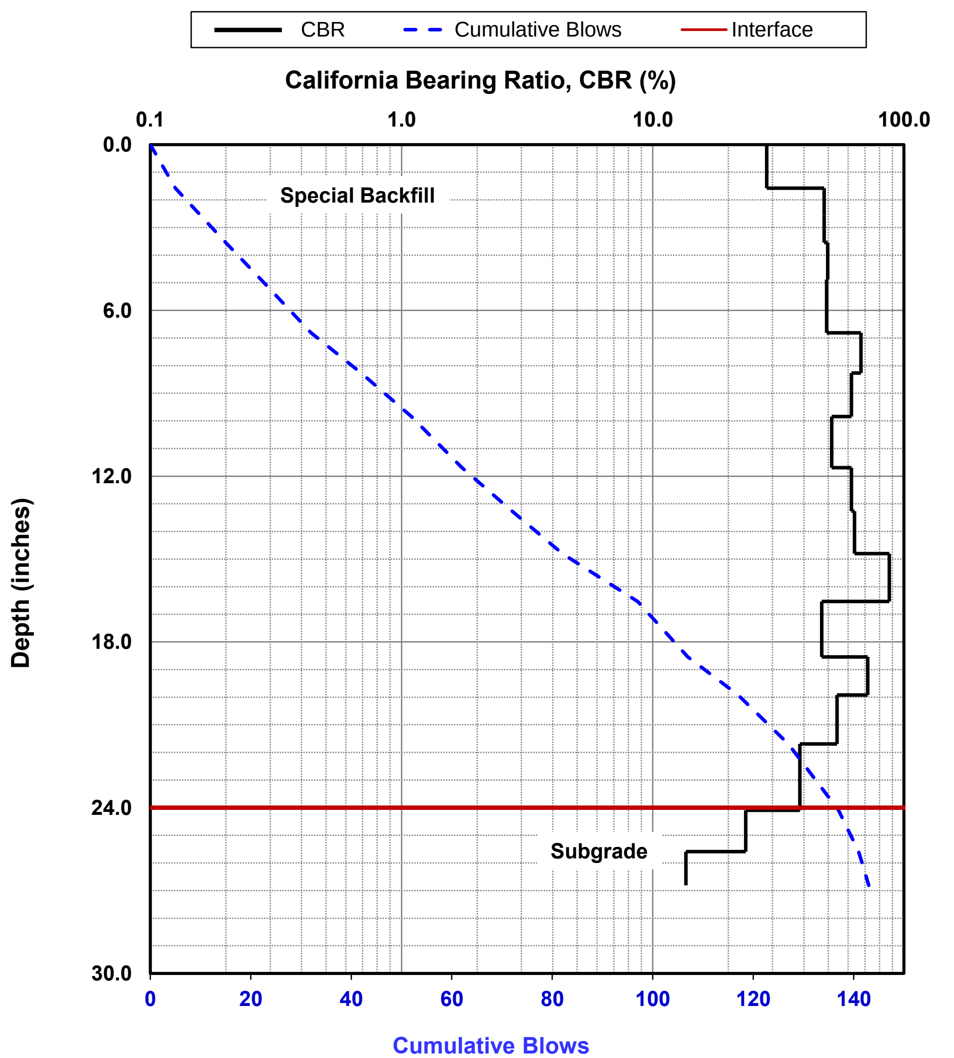
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 330 near Hwy 65 (Project #4)

ingios GEOTECHNICS

Date of Test	11/2/2017	Test ID	Special3	Operator	DW/JV	ASTM	D6951
Latitude	41.8190350		Longitude	93.3068700		Elevation (ft)	882
Location	Hwy330		Station	NA			
Comments	2ft special backfill over geogrid (embankment cut).						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Special Backfill layer	4.6	53.3	32.5	7,660
Avg. Subgrade Layer	22.5	6.8	8.7	1,955
Ratio of Avg. Top/Bottom Layer	0.2	7.8	3.7	3.9
Std.Dev.Special Backfill Layer	1.4	9.9	11.1	2,511
Std. Dev. Subgrade Layer	22.2	9.0	10.5	2,358

NOTES:

Subgrade assumed as CL.

[1]CBR = $292/DPI^{1.12}$

[1]CBR = $1/(0.017019DPI)^2$

for CL soils with CBR < 10

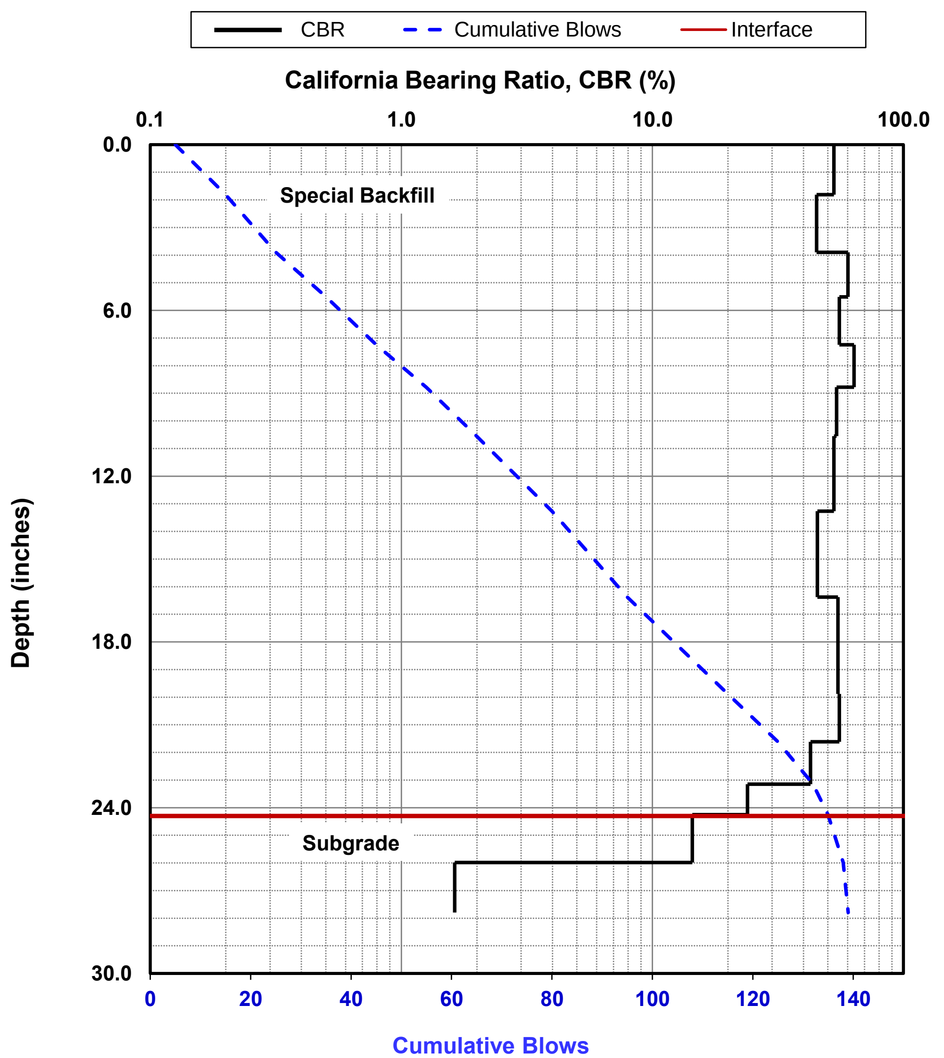
[2]E (ksi) = $(17.6\ CBR^{0.64}) \times 0.1450377$

[3]S_u (psf) = $(3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 330 near Hwy 65 (Project #4)

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Date of Test	11/2/2017	Test ID	Special4	Operator	DW/JV	ASTM	D6951
Latitude	41.8185270		Longitude	93.3062290		Elevation (ft)	903
Location	Hwy330		Station	NA			
Comments	2ft special backfill over geogrid (embankment cut). Described as soft area on project.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Special Backfill layer	8.3	27.2	21.2	4,902
Avg. Subgrade Layer	29.0	4.1	6.3	1,395
Ratio of Avg. Top/Bottom Layer	0.3	6.6	3.4	3.5
Std.Dev.Special Backfill Layer	8.9	16.8	15.5	3,557
Std. Dev. Subgrade Layer	10.6	2.6	4.7	1,039

NOTES:

Subgrade assumed as CL.

[1] $CBR = 292/DPI^{1.12}$

[1] $CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

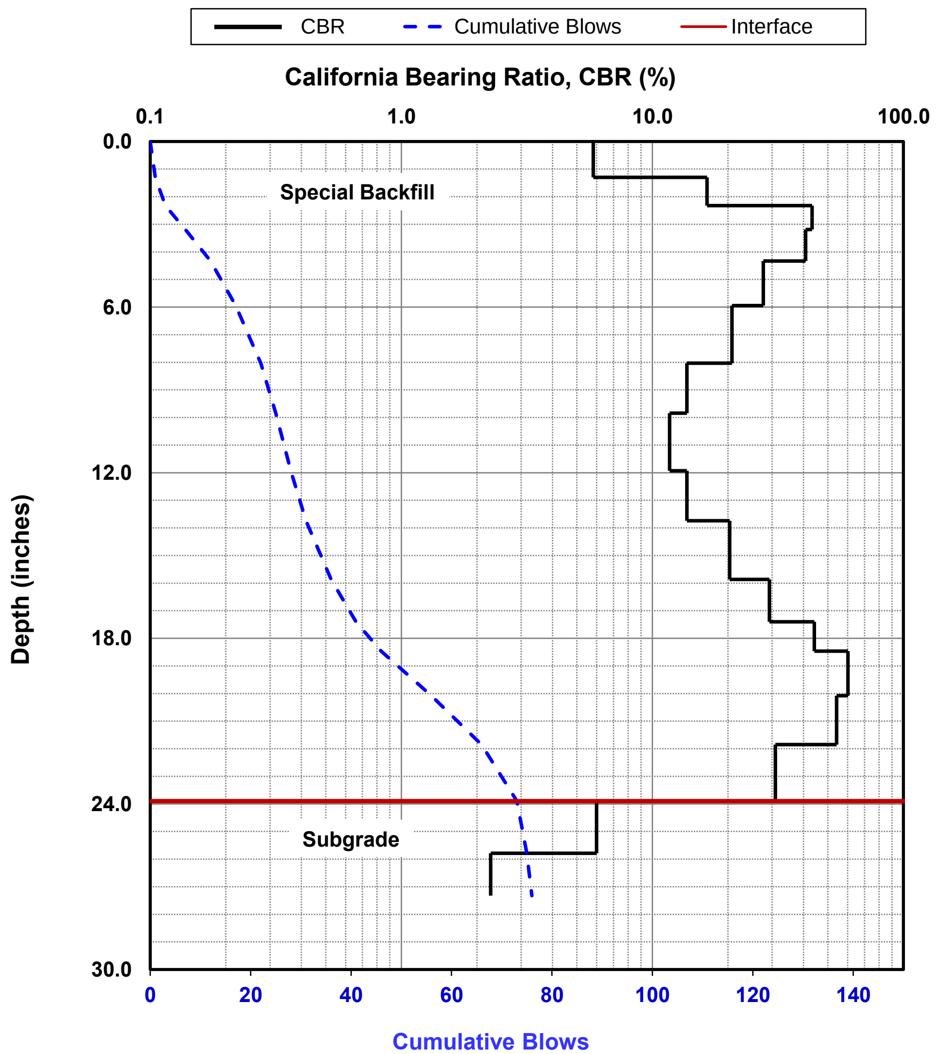
[2] $E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3] $S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2] Powell et al. (1986)

[3] Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name: Iowa DOT STIC

Project ID: SIA-00001

Location: Hwy 330 near Hwy 65 (Project #4)

Date of Test	11/2/2017	Test ID	Special5	Operator	DW/JV	ASTM	D6951
Latitude	41.8184010		Longitude	93.3061070		Elevation (ft)	890
Location	Hwy330		Station	NA			
Comments	2ft special backfill over geogrid (embankment cut). Described as soft area on project.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Special Backfill layer	7.5	30.6	22.8	5,299
Avg. Subgrade Layer	9.4	23.6	19.3	4,459
Ratio of Avg. Top/Bottom Layer	0.8	1.3	1.2	1.2
Std.Dev.Special Backfill Layer	4.0	11.5	12.2	2,760
Std. Dev. Subgrade Layer	1.3	4.0	6.2	1,375

NOTES:

Subgrade assumed as CL.

[1]CBR = $292/DPI^{1.12}$

[1]CBR = $1/(0.017019DPI)^2$

for CL soils with CBR < 10

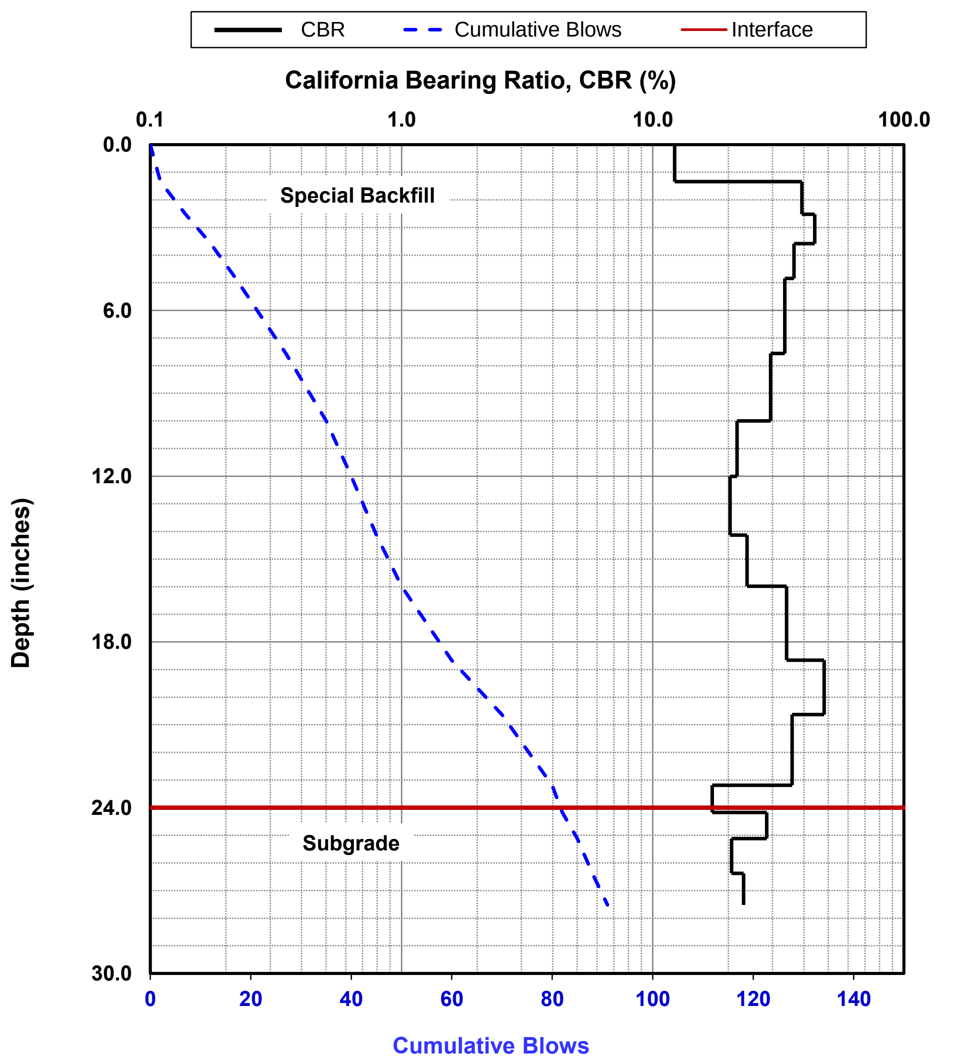
[2]E (ksi) = $(17.6\ CBR^{0.64}) \times 0.1450377$

[3]S_u (psf) = $(3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 330 near Hwy 65 (Project #4)

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Date of Test	11/2/2017	Test ID	Select6	Operator	DW/JV	ASTM	D6951
Latitude	41.8178600		Longitude	93.3053670		Elevation (ft)	892
Location	Hwy330		Station	NA			
Comments	2ft select subgrade (embankment fill).						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	S_{u-CBR}, Bearing Capacity (psf)
Avg. Subgrade (Top Layer)	27.1	7.2	9.1	2,035
Avg. Subgrade (Bottom Layer)	32.2	3.3	5.5	1,215
Ratio of Avg. Top/Bottom Layer	0.8	2.2	1.6	1.7
Std.Dev.Subgrade (Top Layer)	7.9	3.4	5.6	1,226
Std. Dev. Subgrade (Bottom Layer)	19.1	3.2	5.3	1,175

NOTES:

Subgrade assumed as CL.

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

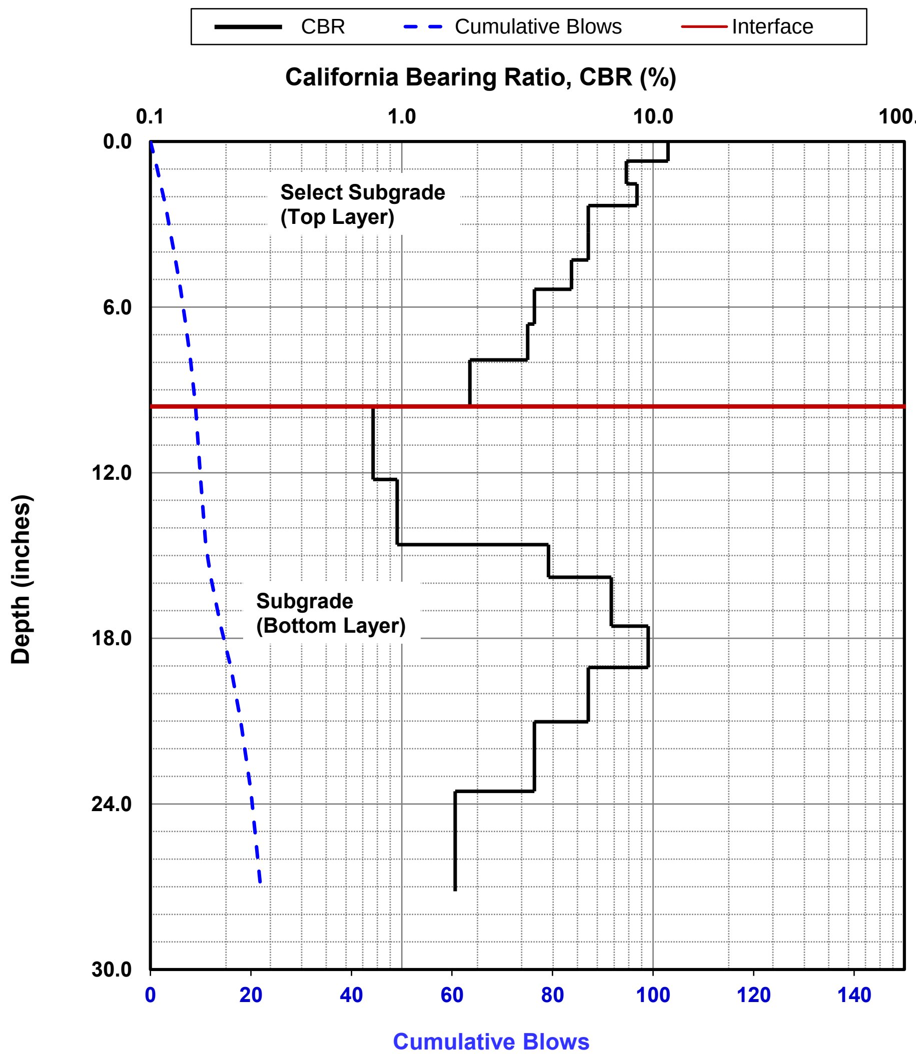
[2]E (ksi) = $(17.6\ CBR^{0.64}) \times 0.1450377$

[3]S_u (psf) = $(3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 330 near Hwy 65 (Project #4)

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Date of Test	11/2/2017	Test ID	Select7	Operator	DW/JV	ASTM	D6951
Latitude	41.8177070		Longitude	93.3051830		Elevation (ft)	894
Location	Hwy330		Station	NA			
Comments	2ft select subgrade (embankment fill).						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subgrade (Top Layer)	21.5	9.4	10.7	2,422
Avg. Subgrade (Bottom Layer)	25.1	5.5	7.6	1,688
Ratio of Avg. Top/Bottom Layer	0.9	1.7	1.4	1.4
Std.Dev.Subgrade (Top Layer)	12.4	9.7	10.9	2,469
Std. Dev. Subgrade (Bottom Layer)	7.4	3.1	5.3	1,156

NOTES:

Subgrade assumed as CL.

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

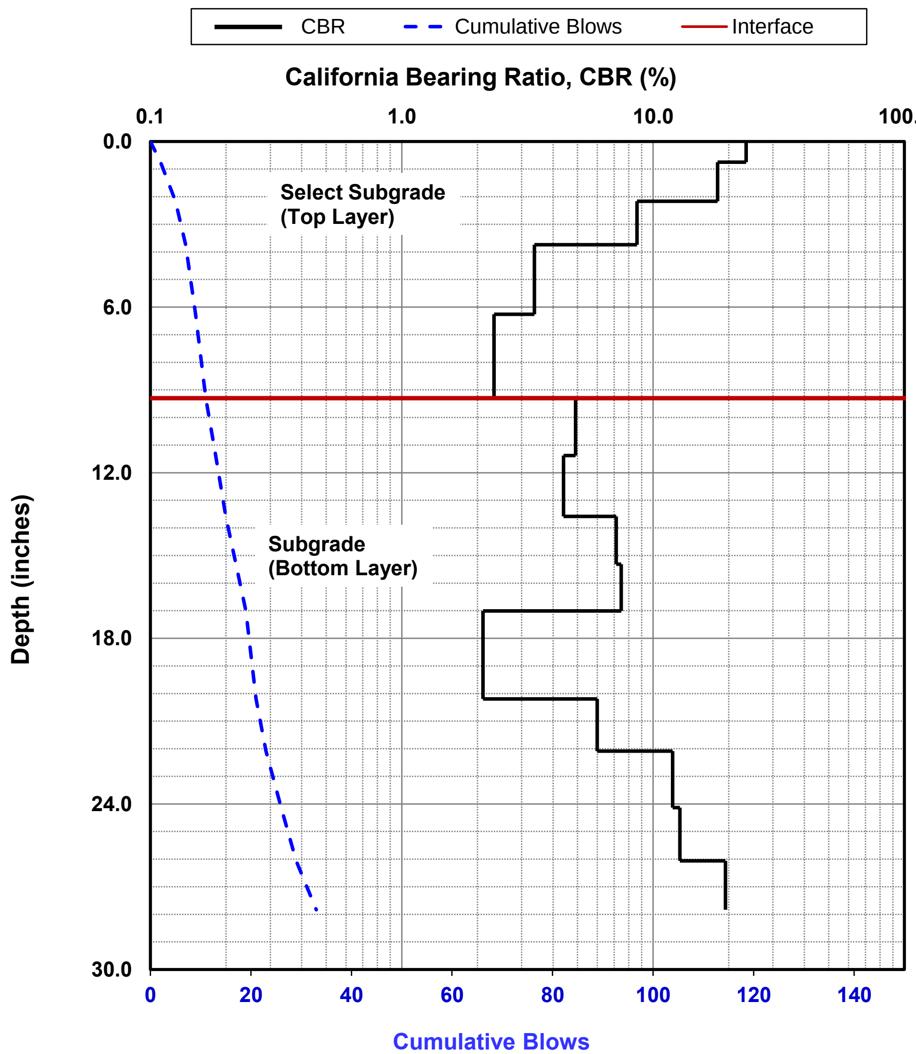
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 330 near Hwy 65 (Project #4)

Date of Test	11/2/2017	Test ID	Select8	Operator	DW/JV	ASTM	D6951
Latitude	41.8175740		Longitude	93.3050080		Elevation (ft)	883
Location	Hwy330		Station	NA			
Comments	2ft select subgrade (embankment fill).						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subgrade (Top Layer)	18.6	11.1	11.9	2,696
Avg. Subgrade (Bottom Layer)	24.5	5.7	7.8	1,743
Ratio of Avg. Top/Bottom Layer	0.8	1.9	1.5	1.5
Std.Dev.Subgrade (Top Layer)	6.9	7.9	9.6	2,162
Std. Dev. Subgrade (Bottom Layer)	3.7	1.9	3.9	842

NOTES:

Subgrade assumed as CL.

[1] $CBR = 292/DPI^{1.12}$

[1] $CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

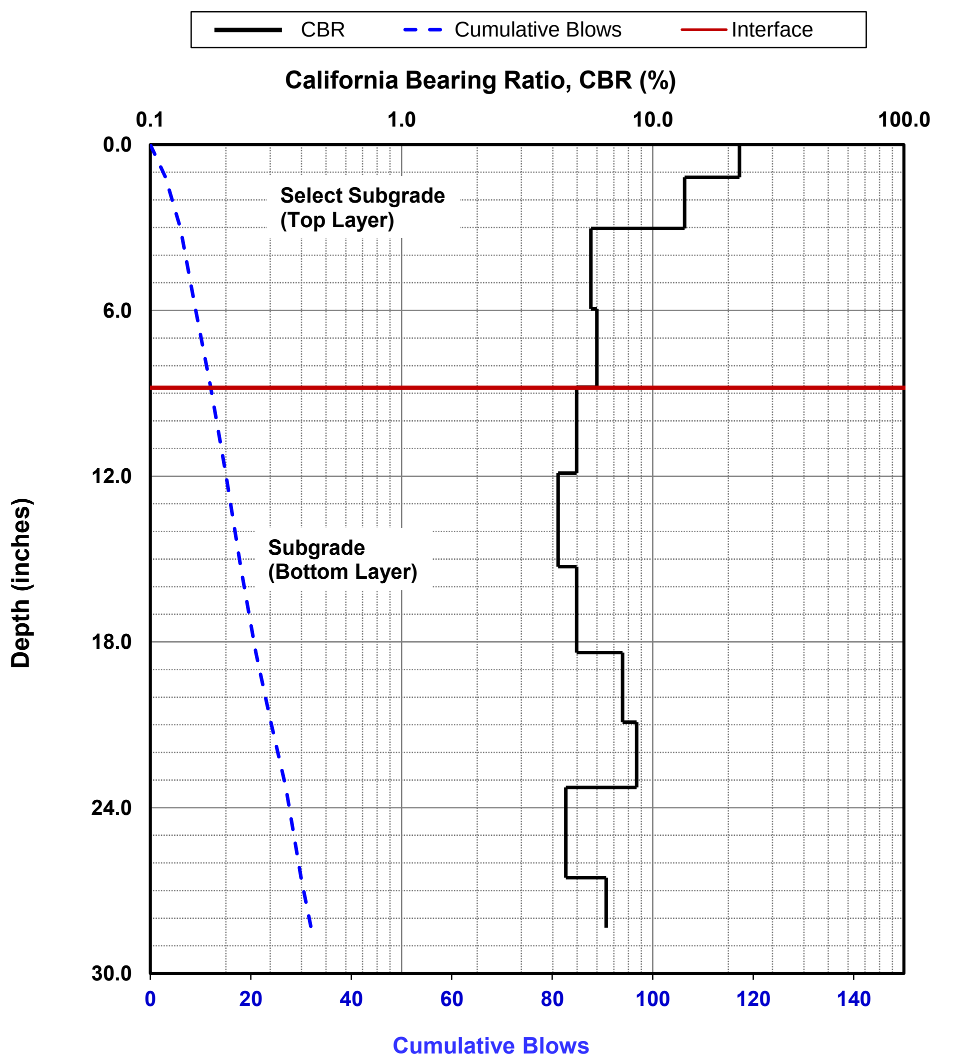
[2] $E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3] $S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2] Powell et al. (1986)

[3] Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name: Iowa DOT STIC

Project ID: SIA-00001

Location: Hwy 330 near Hwy 65 (Project #4)

Field Project # 5

Hwy100N, Linn County, IA

11/3/2017

Select Subgrade

Project Location and Test Locations

Test Locations	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 100 N. of E Ave., Linn County (Project #5)

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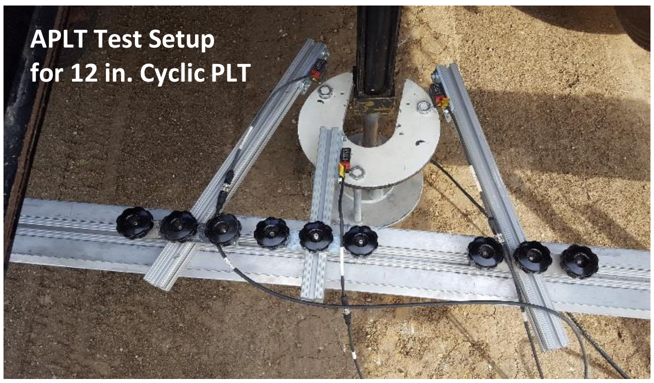
Site Conditions and Pictures


Pictures

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 100 N. of E Ave., Linn County (Project #5)

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Summary of Test Results

Summary of Cyclic APLT Test Results

Point #	4 psi cyclic stress @ surface: $M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)	8 psi plate cyclic stress @ surface: $M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)
1_Fill	11,177	NA	NA	0.0004	12,190	NA	NA	0.0004
2_Fill	18,781	NA	NA	0.0001	15,822	NA	NA	0.0000
3_Fill	26,317	NA	NA	-0.0001	23,982	NA	NA	0.0000
4_Fill	13,712	NA	NA	0.0001	17,160	NA	NA	0.0004
5_Cut	32,562	NA	NA	0.0000	34,629	NA	NA	0.0000
AVG	**20,510**	**NA**	**NA**	**0.0001**	**20,757**	**NA**	**NA**	**0.0002**
COV	43%	NA	NA	180%	43%	NA	NA	116%

Point #	13 psi cyclic stress @ surface: $M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)	18 psi plate cyclic stress @ surface: $M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)
1_Fill	12,881	NA	NA	0.0009	13,129	NA	NA	0.0052
2_Fill	16,188	NA	NA	0.0005	16,004	NA	NA	0.0029
3_Fill	24,541	NA	NA	0.0006	22,620	NA	NA	0.0023
4_Fill	18,941	NA	NA	0.0010	17,809	NA	NA	0.0028
5_Cut	34,393	NA	NA	0.0000	32,464	NA	NA	0.0007
AVG	**21,389**	**NA**	**NA**	**0.0006**	**20,405**	**NA**	**NA**	**0.0028**
COV	39%	NA	NA	66%	37%	NA	NA	58%

Point #	28 psi cyclic stress @ surface: $M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)	38 psi plate cyclic stress @ surface: $M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)
1_Fill	12,213	NA	NA	0.0175	11,812	NA	NA	0.0299
2_Fill	15,478	NA	NA	0.0107	14,962	NA	NA	0.0172
3_Fill	22,026	NA	NA	0.0080	21,100	NA	NA	0.0148
4_Fill	17,368	NA	NA	0.0078	17,398	NA	NA	0.0137
5_Cut	27,593	NA	NA	0.0031	25,522	NA	NA	0.0063
AVG	**18,936**	**NA**	**NA**	**0.0094**	**18,159**	**NA**	**NA**	**0.0164**
COV	32%	NA	NA	56%	29%	NA	NA	52%

Summary of Test Results

Summary of AASHTO (2015) universal model parameters

Point #	$k^*_{1(Comp)}$	$k^*_{2(Comp)}$	$k^*_{3(Comp)}$	$M_{r\text{-}Comp}$ R^2(Adj.)	Std. Error (psi)	$M_{r\text{-}Comp(pred)\text{-}BP}$ (psi)	$\sigma_{cyclic\text{-}BP}$ (psi)
1_Fill	904.2	0.259	-1.715	0.929	182	12,903	16.6
2_Fill	1,154.3	-0.181	0.637	0.795	540	21,178	2.0
3_Fill	1,764.6	-0.075	-0.187	0.895	586	28,164	2.0
4_Fill	1,211.5	0.473	-2.613	0.831	690	18,551	20.7
5_Cut	2,739.9	0.279	-2.803	0.968	654	34,476	10.4
AVG	**1,554.9**	**0.151**	**-1.336**	**0.884**	**530**	**23,054**	**10.3**
COV	47%	180%	-1.131	8%	38%	37%	82%

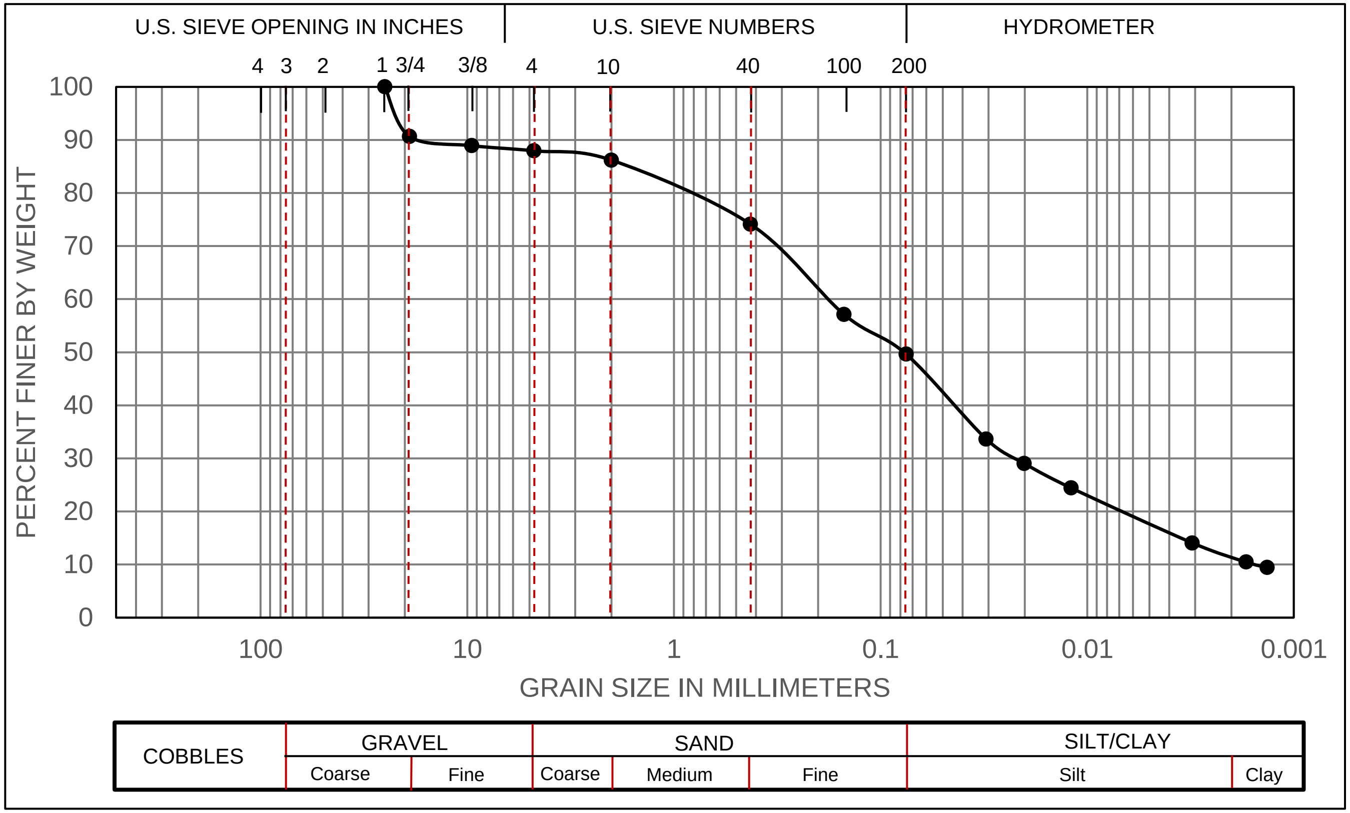
Point #	30 in. static PLT k_u (pci) at δ = 0.05 in.[a]	k_{u1} (pci) at 10 psi[b]	k_{u2} (pci) at 10 psi	Ratio of k_{u2}/k_{u1}
4_Fill	246	239	780	3.3
5_Cut	266	245	690	2.8

[a]per PCA design critera
[b]per AASHTO T222

Summary of DCP and LWD test results

Point #	Subgrade Layer (top 12 in.) Thickness, H_1 (in.)	Avg. CBR (%)	St. Dev CBR (%)	Subgrade Layer (bottom 12 in.) Thickness, H_2 (in.)	Avg. CBR (%)	St. Dev CBR (%)	Ratio CBR_1/ CBR_2	E_{LWD} (psi)
1_Fill	12.0	19.0	3.0	12.0	14.9	7.4	1.3	10,515
2_Fill	12.0	21.6	6.8	12.0	15.0	4.4	1.4	18,506
3_Fill	12.0	29.4	5.4	12.0	18.4	4.7	1.6	22,737
4_Fill	12.0	24.6	9.9	12.0	17.0	17.7	1.4	21,188
5_Cut	12.0	31.2	9.4	12.0	12.3	3.9	2.5	21,066
AVG	**12.0**	**25.2**	**6.9**	**12.0**	**15.5**	**7.6**	**1.7**	**18,802**
COV	0%	20%	41%	0%	15%	76%	30%	26%

GRAIN SIZE DISTRIBUTION
ASTM D422/C136



Gradation Summary

% Gravel	12.0
% Sand	38.3
% Silt	38.4
% Clay	11.2
D_{10} (mm)	0.002
D_{30} (mm)	0.022
D_{50} (mm)	0.079
D_{60} (mm)	0.197
D_{85} (mm)	1.845
C_u	127.4
C_c	1.6

Atterberg Limits

LL	NA
PL	NA
PI	NA

Classification

AASHTO:	NA
USCS:	NA

MATERIAL: Select Subgrade
LOCATION: Hwy 100 N. of E Ave., Linn County (Project #5) **TESTED BY:** PV/DW
SAMPLE DATE: 11/3/2017 **TEST DATE:** 11/28/2017

Gradation and Soil Classification Test Results

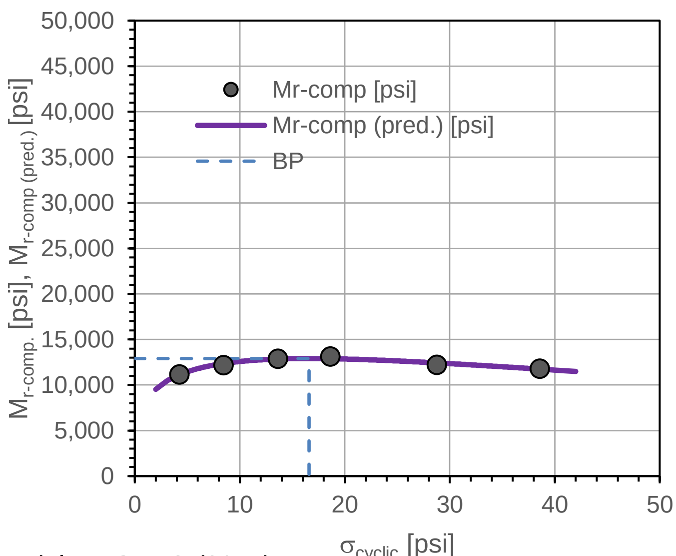
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 100 N. of E Ave., Linn County (Project #5)

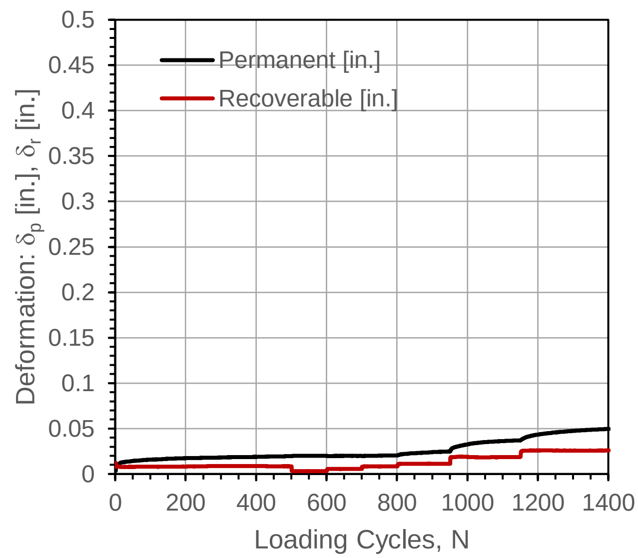
ingios GEOTECHNICS

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/3/2017	Time:	9:05:53 AM	Test ID	**Hwy100_12_1**
Tested By	DW, JV	Location:	Hwy100	Sta.	NA
Latitude,N:	41.989086	Longitude,W:	91.775703	Elev. (ft):	815
Comments:	Select subgrade. Fill area.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.64	---	---	0.0196	---	0.148	---
1	100	4.25	11,177	11,125	0.0199	0.0004	0.111	Y
2	100	8.45	12,190	12,363	0.0200	0.0004	0.254	Y
3	100	13.64	12,881	12,851	0.0204	0.0009	0.434	Y
4	150	18.63	13,129	12,884	0.0247	0.0052	0.581	N
5	200	28.76	12,213	12,428	0.0371	0.0175	0.468	N
6	250	38.57	11,812	11,746	0.0495	0.0299	0.563	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	904.2	5.20E-08
k^*_2	0.259	5.54E-03
k^*_3	-1.715	6.91E-03
Adj. R^2	0.929	
Std. Error [psi]	182	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	12,903
$\sigma_{cyclic\text{-}BP}$ [psi]	16.6

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

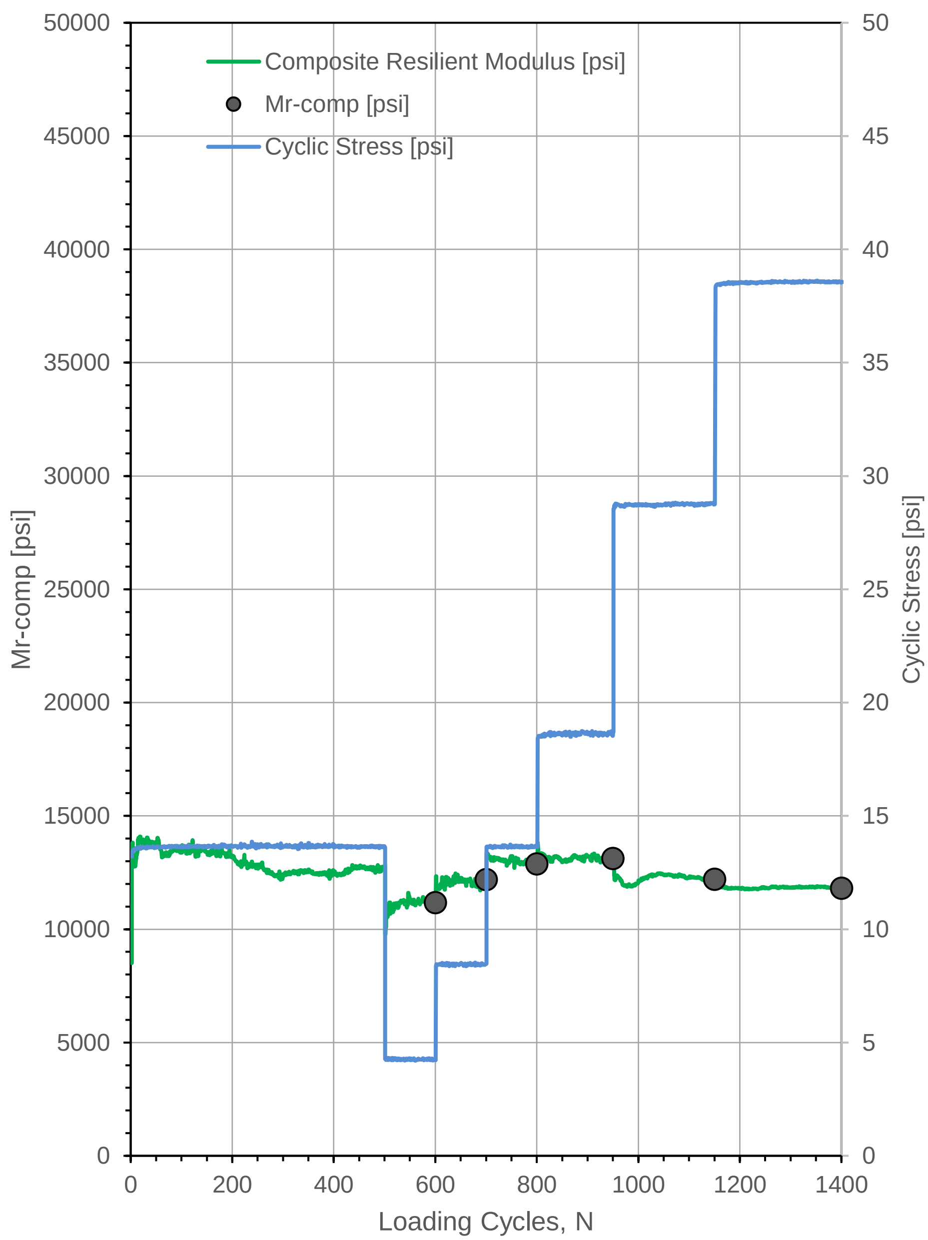
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 100 N. of E Ave., Linn County (Project #5)

ingios GEOTECHNICS

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/3/2017	Time:	9:05:53 AM	Test ID	**Hwy100_12_1**
Tested By	DW, JV	Location:	Hwy100	Sta.	NA
Latitude,N:	41.989086	Longitude,W:	91.775703	Elev. (ft):	815
Comments:	Select subgrade. Fill area.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	9,528
3	10,394
4	11,000
5	11,451
6	11,798
7	12,069
8	12,282
9	12,451
10	12,584
11	12,687
12	12,765
13	12,823
14	12,863
15	12,889
16	12,901
17	12,902
18	12,894
21	12,821
22	12,784
23	12,742
24	12,696
25	12,645
26	12,591
27	12,534
28	12,475
29	12,413
30	12,349
31	12,283
32	12,216
33	12,147
34	12,077
35	12,006
36	11,934
37	11,861
38	11,788
39	11,714
40	11,640



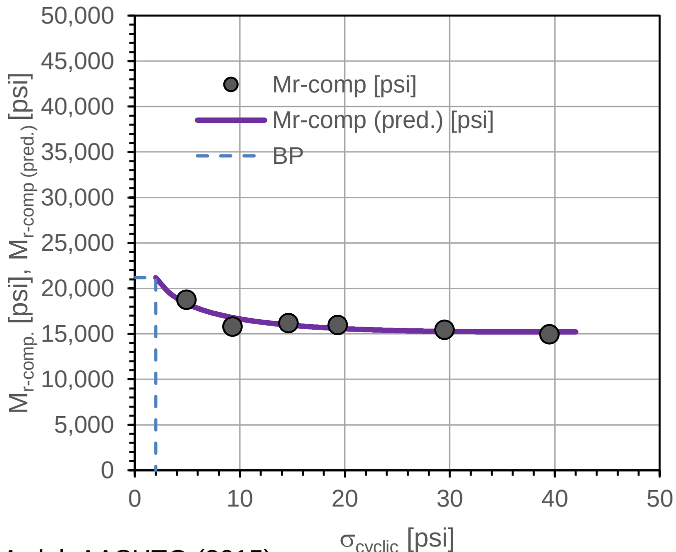
In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 100 N. of E Ave., Linn County (Project #5)

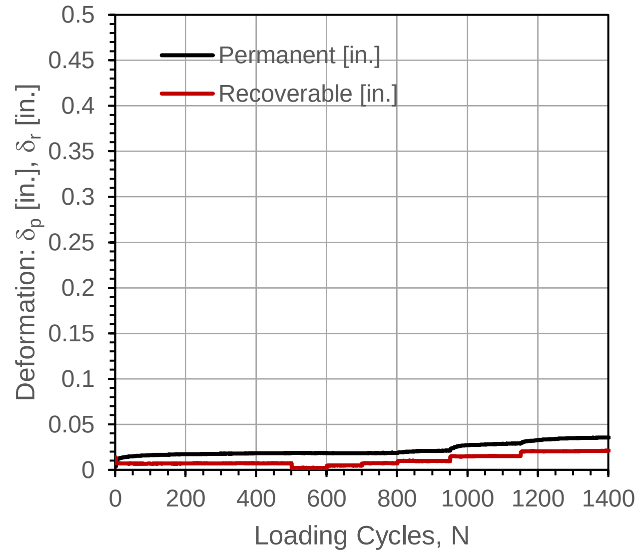
ingios GEOTECHNICS

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/3/2017	Time:	9:37:28 AM	Test ID	**Hwy100_12_2**
Tested By	DW, JV	Location:	Hwy100	Sta.	NA
Latitude,N:	41.988525	Longitude,W:	91.775787	Elev. (ft):	818
Comments:	Select subgrade. Fill area.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	14.64	---	---	0.0183	---	0.104	---
1	100	4.93	18,781	18,327	0.0184	0.0001	-0.189	Y
2	100	9.30	15,822	16,793	0.0184	0.0000	0.008	Y
3	100	14.64	16,188	15,973	0.0188	0.0005	0.289	Y
4	150	19.34	16,004	15,604	0.0212	0.0029	0.536	Y
5	200	29.50	15,478	15,269	0.0290	0.0107	0.374	Y
6	250	39.50	14,962	15,220	0.0355	0.0172	0.455	Y





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	1,154.3	6.04E-07
k^*_2	-0.181	1.62E-01
k^*_3	0.637	4.09E-01
Adj. R^2	0.795	
Std. Error [psi]	540	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	21,178
$\sigma_{cyclic\text{-}BP}$ [psi]	2.0

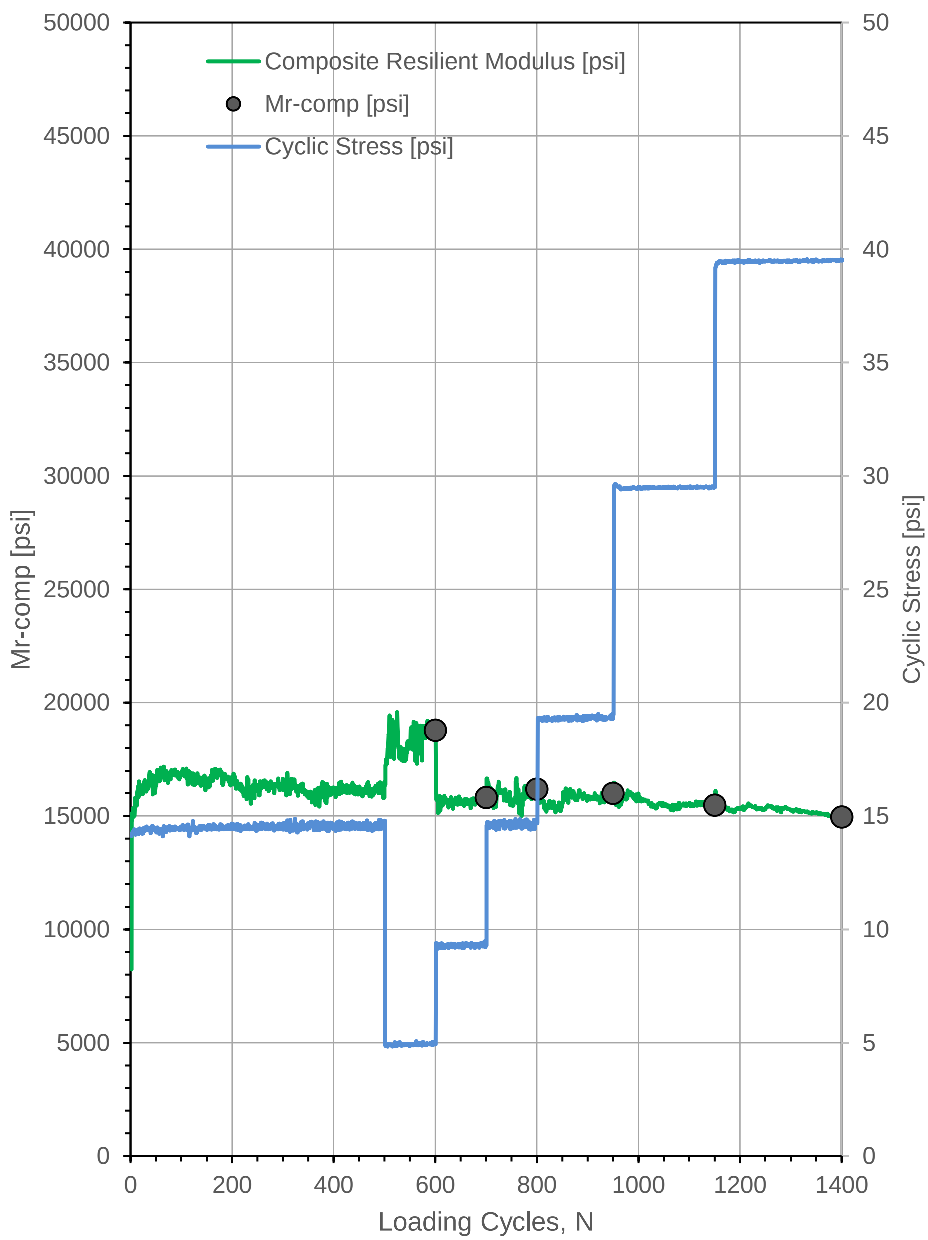
In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 100 N. of E Ave., Linn County (Project #5)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/3/2017	Time:	9:37:28 AM	Test ID	**Hwy100_12_2**
Tested By	DW, JV	Location:	Hwy100	Sta.	NA
Latitude,N:	41.988525	Longitude,W:	91.775787	Elev. (ft):	818
Comments:	Select subgrade. Fill area.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	21,178
3	19,807
4	18,923
5	18,291
6	17,810
7	17,429
8	17,120
9	16,863
10	16,646
11	16,461
12	16,302
13	16,164
14	16,043
15	15,937
16	15,844
17	15,762
18	15,689
21	15,516
22	15,471
23	15,431
24	15,396
25	15,365
26	15,338
27	15,315
28	15,294
29	15,277
30	15,262
31	15,249
32	15,239
33	15,231
34	15,225
35	15,221
36	15,218
37	15,217
38	15,217
39	15,219
40	15,222

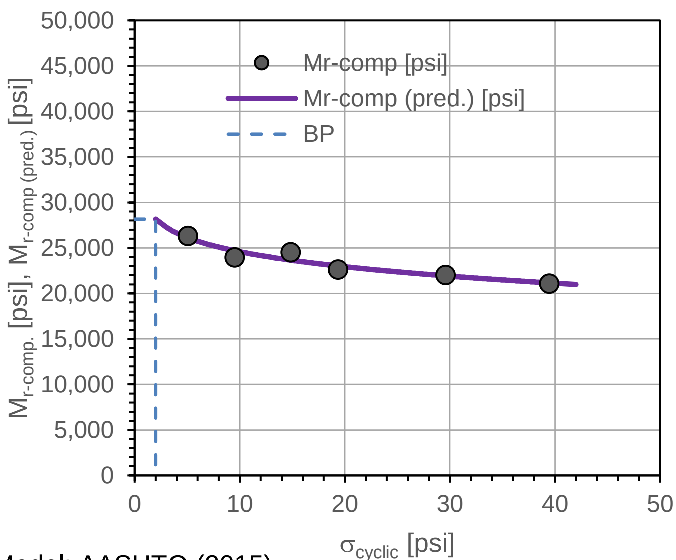


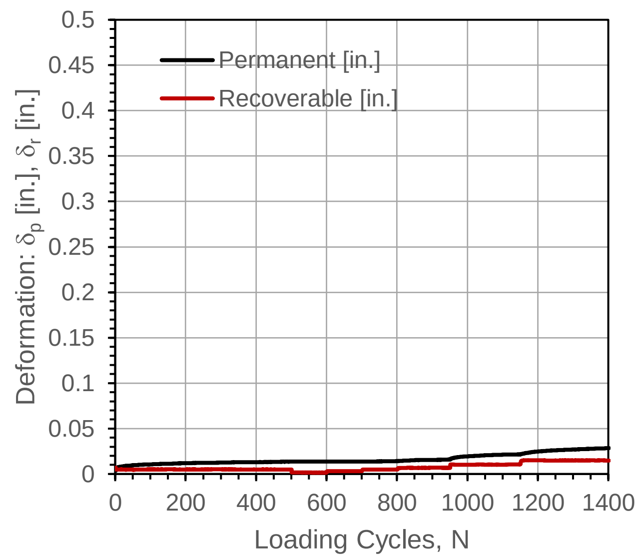
In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 100 N. of E Ave., Linn County (Project #5)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/3/2017	Time:	10:08:17 AM	Test ID	**Hwy100_12_3**
Tested By	DW, JV	Location:	Hwy100	Sta.	NA
Latitude,N:	41.987991	Longitude,W:	91.775833	Elev. (ft):	813
Comments:	Select subgrade. Fill area.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	14.86	---	---	0.0136	---	0.156	---
1	100	5.08	26,317	26,102	0.0135	-0.0001	-0.034	Y
2	100	9.52	23,982	24,695	0.0136	0.0000	0.043	Y
3	100	14.86	24,541	23,656	0.0142	0.0006	0.457	Y
4	150	19.37	22,620	23,014	0.0160	0.0023	0.515	Y
5	200	29.60	22,026	21,932	0.0216	0.0080	0.452	Y
6	250	39.45	21,100	21,156	0.0285	0.0148	0.581	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	1,764.6	1.66E-07
k^*_2	-0.075	3.60E-01
k^*_3	-0.187	7.16E-01
Adj. R^2	0.895	
Std. Error [psi]	586	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	28,164
$\sigma_{cyclic\text{-}BP}$ [psi]	2.0

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 100 N. of E Ave., Linn County (Project #5)

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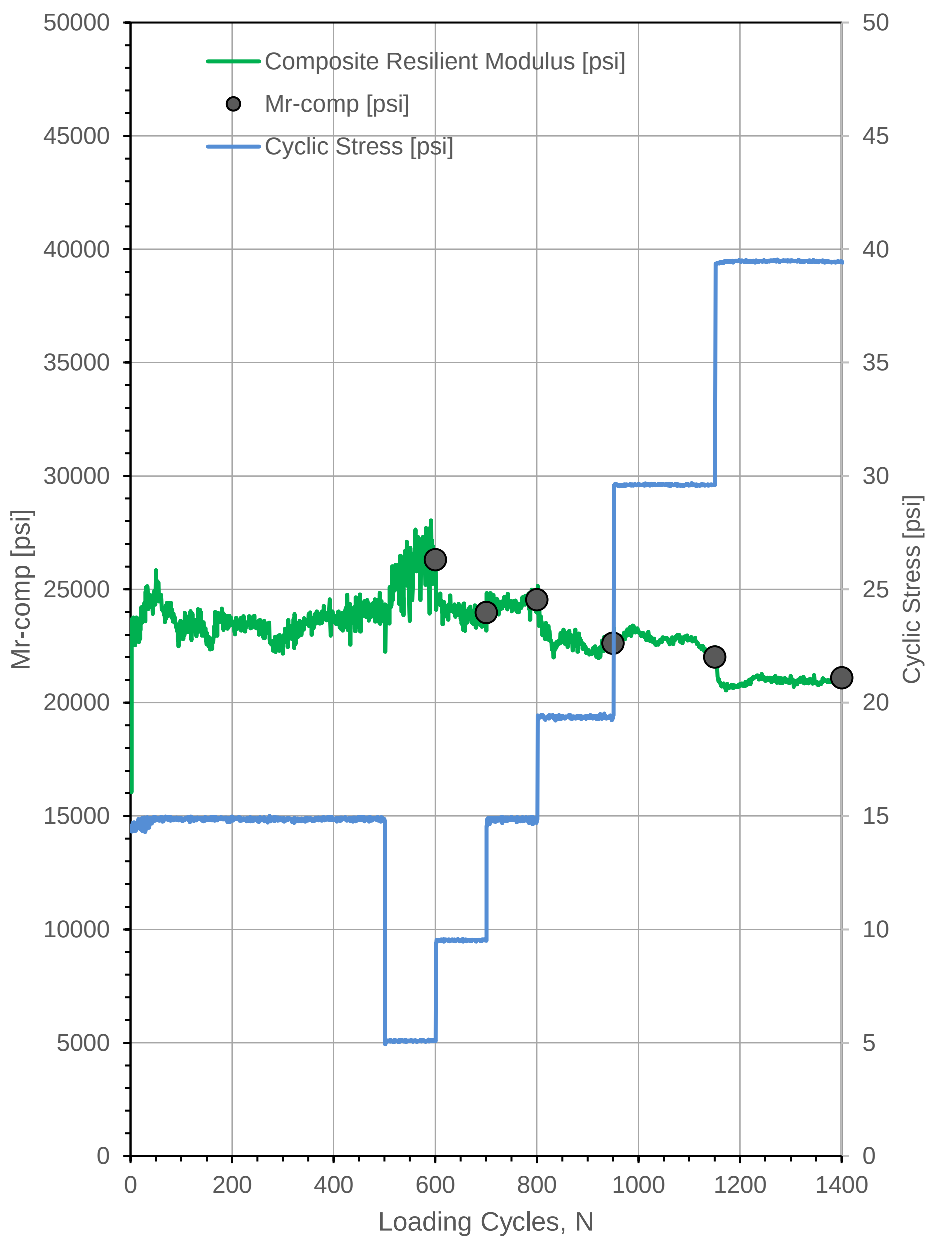
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/3/2017	Time:	10:08:17 AM	Test ID	**Hwy100_12_3**
Tested By	DW, JV	Location:	Hwy100	Sta.	NA
Latitude,N:	41.987991	Longitude,W:	91.775833	Elev. (ft):	813
Comments:	Select subgrade. Fill area.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	28,164
3	27,265
4	26,631
5	26,138
6	25,733
7	25,389
8	25,089
9	24,823
10	24,582
11	24,363
12	24,161
13	23,973
14	23,799
15	23,634
16	23,480
17	23,333
18	23,194
21	22,813
22	22,696
23	22,584
24	22,476
25	22,372
26	22,271
27	22,173
28	22,078
29	21,986
30	21,897
31	21,810
32	21,726
33	21,643
34	21,563
35	21,484
36	21,408
37	21,333
38	21,260
39	21,188
40	21,118



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC

Project ID: SIA-00001

Location: Hwy 100 N. of E Ave., Linn County (Project #5)

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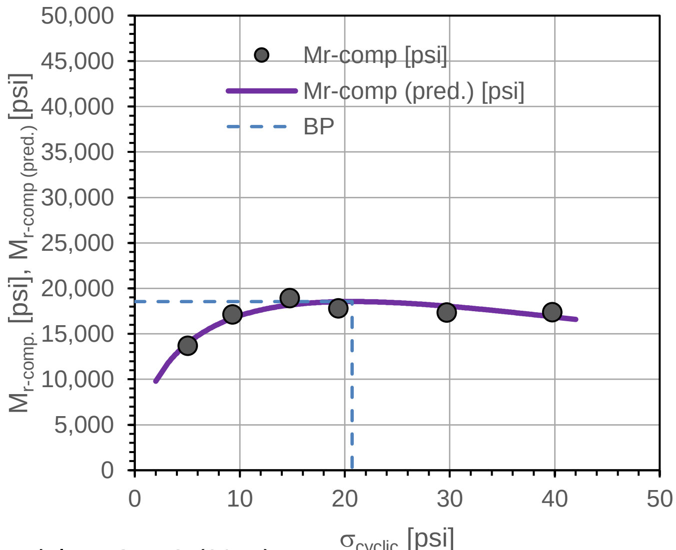
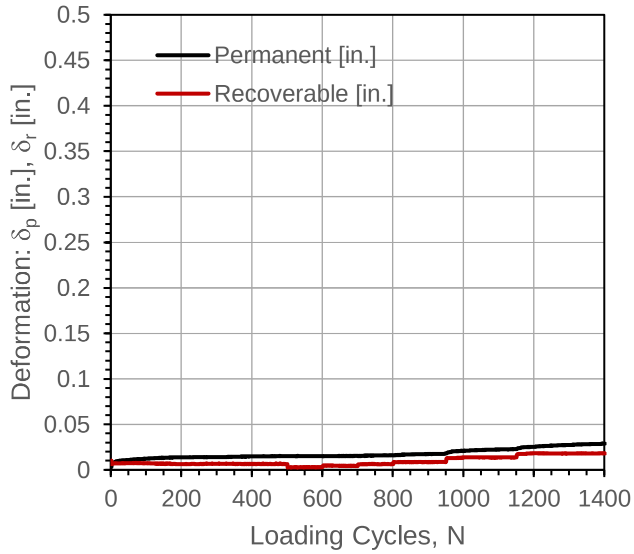
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/3/2017	Time:	10:39:39 AM	Test ID	**Hwy100_12_4**
Tested By	DW, JV	Location:	Hwy100	Sta.	NA
Latitude,N:	41.986927	Longitude,W:	91.775917	Elev. (ft):	808
Comments:	Select subgrade. Fill area.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	14.78	---	---	0.0150	---	0.149	---
1	100	5.04	13,712	13,969	0.0150	0.0001	-0.058	Y
2	100	9.31	17,160	16,723	0.0154	0.0004	0.272	Y
3	100	14.78	18,941	18,175	0.0160	0.0010	0.473	Y
4	150	19.38	17,809	18,536	0.0178	0.0028	0.536	Y
5	200	29.72	17,368	18,051	0.0228	0.0078	0.424	Y
6	250	39.77	17,398	16,883	0.0287	0.0137	0.505	Y





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	1,211.5	7.89E-07
k^*_2	0.473	2.35E-02
k^*_3	-2.613	3.90E-02
Adj. R^2	0.831	
Std. Error [psi]	690	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	18,551
$\sigma_{cyclic\text{-}BP}$ [psi]	20.7

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

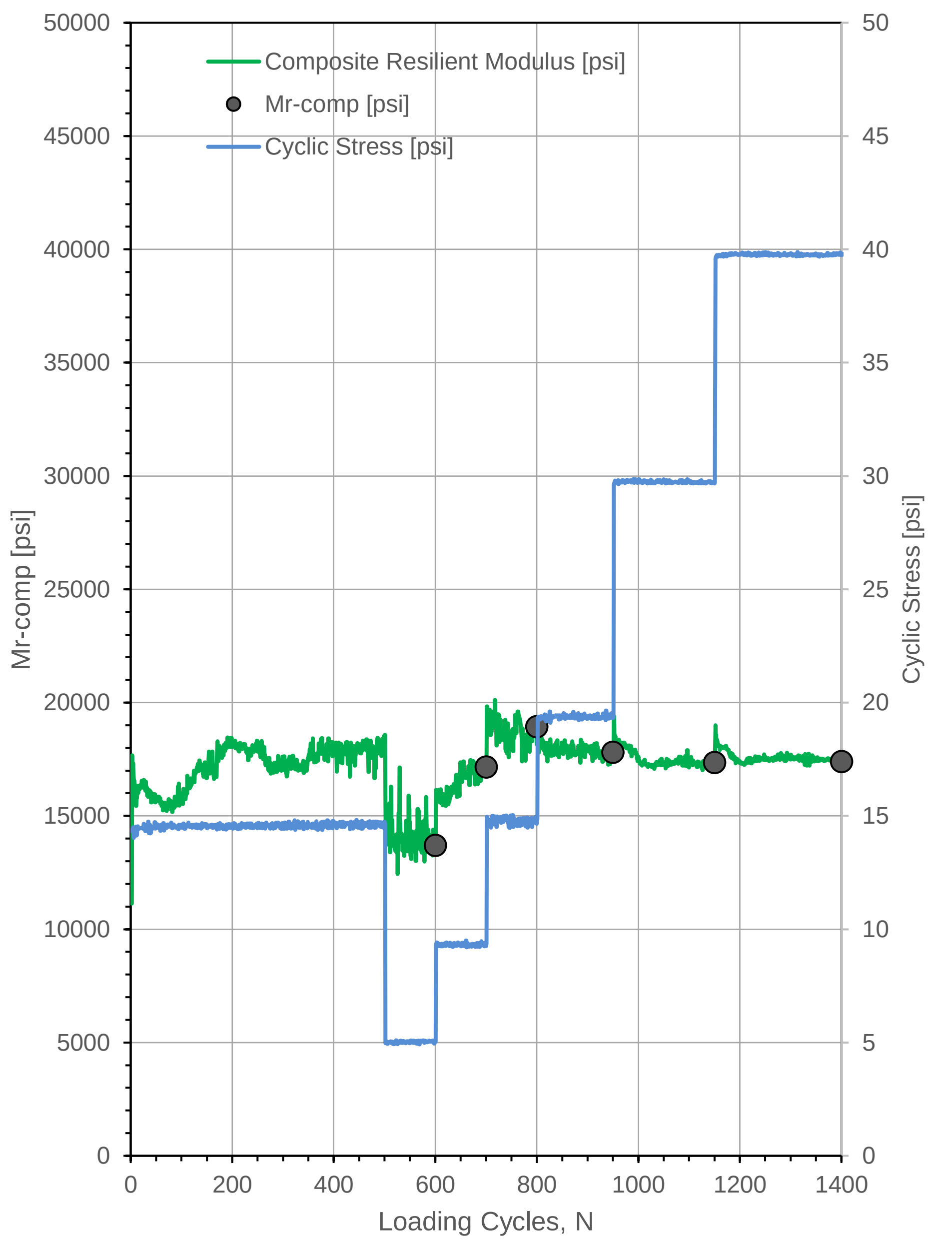
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 100 N. of E Ave., Linn County (Project #5)

ingios GEOTECHNICS

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/3/2017	Time:	10:39:39 AM	Test ID	**Hwy100_12_4**
Tested By	DW, JV	Location:	Hwy100	Sta.	NA
Latitude,N:	41.986927	Longitude,W:	91.775917	Elev. (ft):	808
Comments:	Select subgrade. Fill area.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	9,790
3	11,543
4	12,876
5	13,934
6	14,794
7	15,504
8	16,093
9	16,586
10	16,998
11	17,341
12	17,626
13	17,861
14	18,053
15	18,207
16	18,327
17	18,418
18	18,483
21	18,550
22	18,537
23	18,510
24	18,470
25	18,418
26	18,356
27	18,284
28	18,205
29	18,117
30	18,024
31	17,924
32	17,819
33	17,710
34	17,596
35	17,479
36	17,359
37	17,235
38	17,110
39	16,982
40	16,853



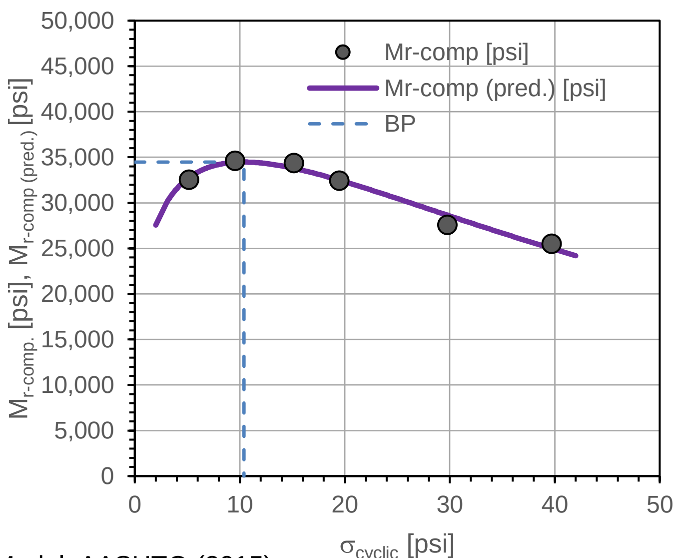
In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

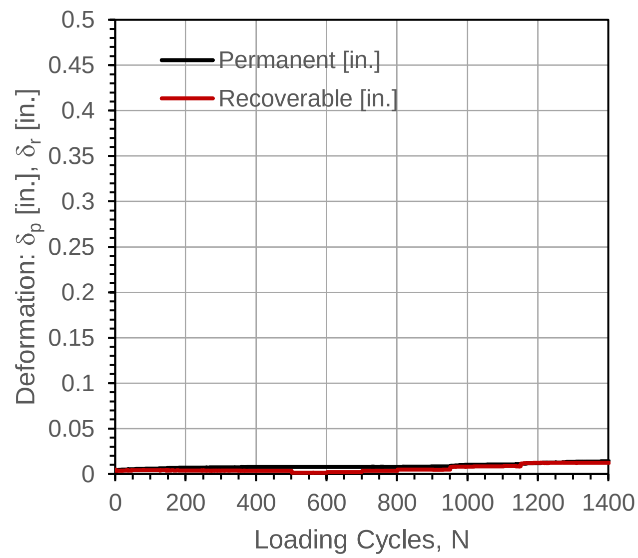
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 100 N. of E Ave., Linn County (Project #5)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/3/2017	Time:	11:10:29 AM	Test ID	**Hwy100_12_5**
Tested By	DW, JV	Location:	Hwy100	Sta.	NA
Latitude,N:	41.985668	Longitude,W:	91.776009	Elev. (ft):	793
Comments:	Select subgrade. Cut area.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	15.16	---	---	0.0077	---	0.168	---
1	100	5.17	32,562	32,777	0.0077	0.0000	-0.039	Y
2	100	9.55	34,629	34,449	0.0077	0.0000	0.059	Y
3	100	15.16	34,393	33,786	0.0077	0.0000	0.066	Y
4	150	19.48	32,464	32,486	0.0084	0.0007	0.500	Y
5	200	29.79	27,593	28,639	0.0108	0.0031	0.378	Y
6	250	39.72	25,522	24,980	0.0140	0.0063	0.517	Y



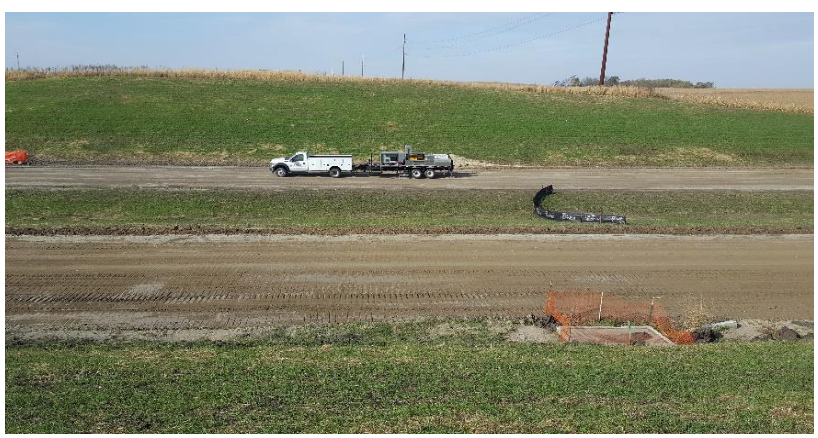


Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	2,739.9	1.09E-07
k^*_2	0.279	2.35E-02
k^*_3	-2.803	7.61E-03
Adj. R^2	0.968	
Std. Error [psi]	654	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	34,476
$\sigma_{cyclic\text{-}BP}$ [psi]	10.4



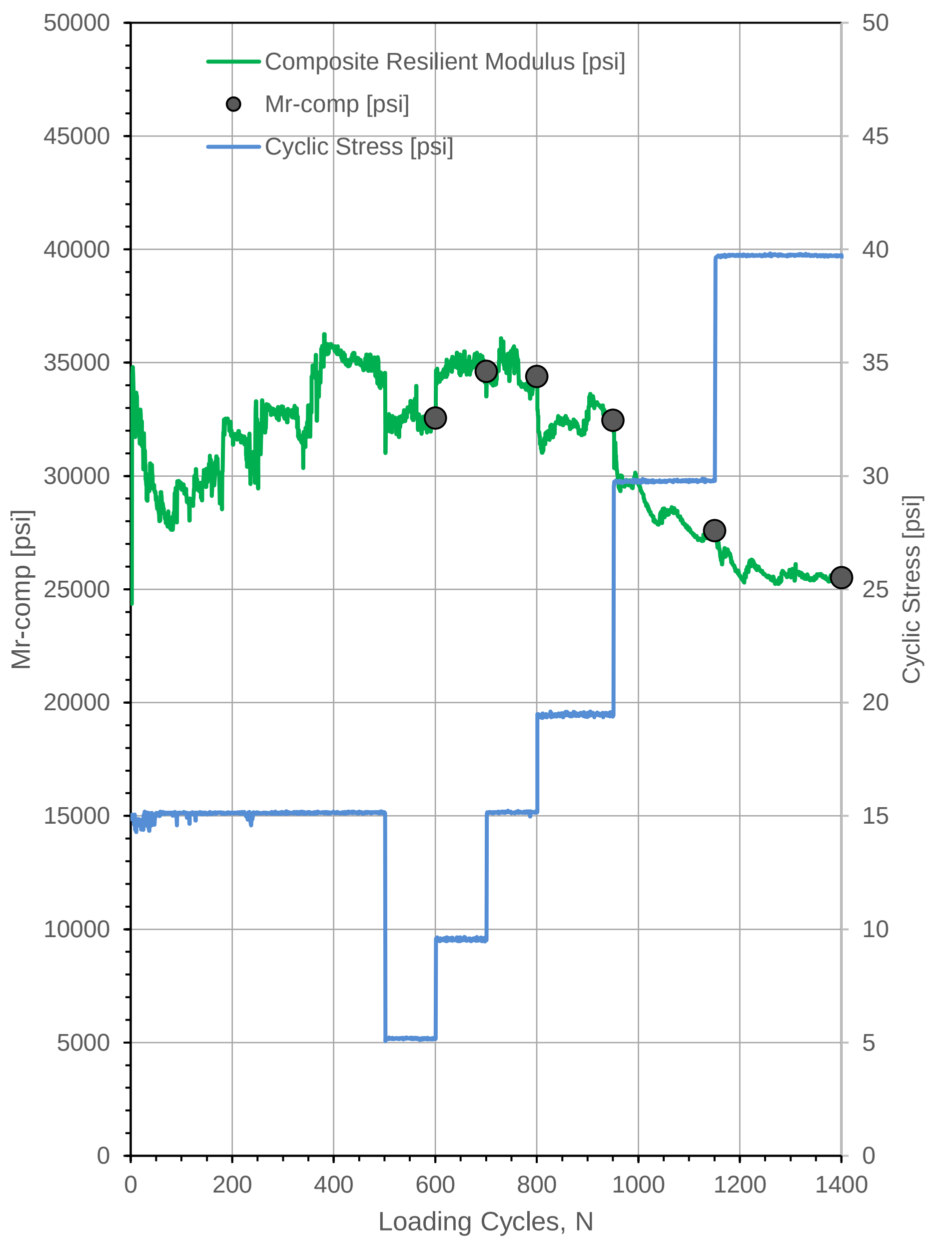
In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 100 N. of E Ave., Linn County (Project #5)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/3/2017	Time:	11:10:29 AM	Test ID	**Hwy100_12_5**
Tested By	DW, JV	Location:	Hwy100	Sta.	NA
Latitude,N:	41.985668	Longitude,W:	91.776009	Elev. (ft):	793
Comments:	Select subgrade. Cut area.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	27,548
3	29,965
4	31,547
5	32,630
6	33,377
7	33,883
8	34,208
9	34,394
10	34,471
11	34,460
12	34,378
13	34,238
14	34,051
15	33,825
16	33,566
17	33,281
18	32,973
21	31,956
22	31,595
23	31,226
24	30,852
25	30,473
26	30,092
27	29,709
28	29,325
29	28,942
30	28,559
31	28,178
32	27,799
33	27,422
34	27,048
35	26,678
36	26,311
37	25,947
38	25,588
39	25,233
40	24,882



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 100 N. of E Ave., Linn County (Project #5)

Automated Plate Load Test [APLT]

Test:	In-Situ Static Plate Load Test: Two Loading Cycles.				
Date:	11/3/2017	Time:	1:13:33 PM	Test ID	Hwy100_30Static_4_Subgrade
Tested By	DW, JV	Location:	Hwy 100	Sta.	NA
Latitude:	41.98695	Longitude:	91.77593	Elev. (ft):	802
Comments:	Select Subgrade, Fill Area.				

Cycle	Stage	Load Step	Target Applied Load (lbs)	Target Applied Stress (psi)	Actual Applied Stress (psi)	Deformation (in.) Sensor 1	Sensor 2	Sensor 3	Average Def. (in.)
0	Seating	0	707	1	*1.38*	0.0109	0.0060	0.0040	**0.0070**
Zero load and deformation sensors after applying the seating stress.									
1	Seating	0	0	0	*0.00*	*0.0000*	*0.0000*	*0.0000*	**0.0000**
1	Load	1	1767	2.5	*2.49*	*0.0166*	*0.0104*	*0.0058*	**0.0109**
1	Load	2	3534	5	*4.97*	*0.0321*	*0.0166*	*0.0123*	**0.0203**
1	Load	3	5301	7.5	*7.45*	*0.0435*	*0.0249*	*0.0197*	**0.0294**
1	Load	4	7069	10	*9.94*	*0.0557*	*0.0307*	*0.0252*	**0.0372**
1	Load	5	8836	12.5	*12.42*	*0.0659*	*0.0356*	*0.0324*	**0.0447**
1	Load	6	10603	15	*14.59*	*0.0772*	*0.0428*	*0.0403*	**0.0535**
1	Unload	7	7069	10	*9.81*	*0.0742*	*0.0416*	*0.0382*	**0.0513**
1	Unload	8	3534	5	*4.90*	*0.0678*	*0.0355*	*0.0332*	**0.0455**
1	Unload	9	1767	2.5	*2.49*	*0.0628*	*0.0319*	*0.0303*	**0.0417**
2	Load	10	3534	5	*4.97*	*0.0634*	*0.0354*	*0.0311*	**0.0433**
2	Load	11	7069	10	*9.94*	*0.0721*	*0.0377*	*0.0360*	**0.0486**
2	Load	12	10603	15	*14.68*	*0.0808*	*0.0450*	*0.0425*	**0.0561**
2	Unload	13	1767	2.5	*2.14*	*0.0642*	*0.0342*	*0.0310*	**0.0431**
2	Unload	14	0	0	*0.00*	*0.0587*	*0.0279*	*0.0292*	**0.0386**

Plate Diameter:	*30.0*	in.
Shape factor:	**1.57**	
Material Type:	*A*	A = Cohesive, B = Granular, C = Intermediate
Poisson's ratio:	*0.35*	
Design Stress:	*10.0*	psi
Target Deformation:	*0.05*	in.

AASHTO T222 Method	**k_{u1} (pci) @ design stress:**	**239**
PCA Design Criteria	**k_u (pci) @ δ = 0.05 in.:**	**246**

Modulus at target deformation

Stress @ δ = 0.05 in. (psi)	**13.9**
E_1 (psi)	**5,094**
k'_u (pci)	**278**
k_u (pci)	**246**

Modulus at target/design applied stress

First Loading Cycle

δ_1 (in.)	**0.0373**
E_1 (psi)	**4,937**
k'_{u1} (pci)	**268**
k_{u1} (pci)	**239**

Second Loading Cycle

δ_2 (in.)	**0.0080**
E_2 (psi)	**16,129**
k'_{u2} (pci)	**1,247**
k_{u2} (pci)	**780**
E_2 / E_1 or k_2 / k_1 Ratio	**3.3**

Plate Bending Correction for

$$k'_u \geq 100 \text{ and } 1{,}000 \text{ pci}$$

$$k_u = -39.9178 + 5.5076\,[k'_u]^{0.7019}$$

In-situ Modulus of Subgrade Reaction (k) and Elastic Modulus

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 100 N. of E Ave., Linn County (Project #5)

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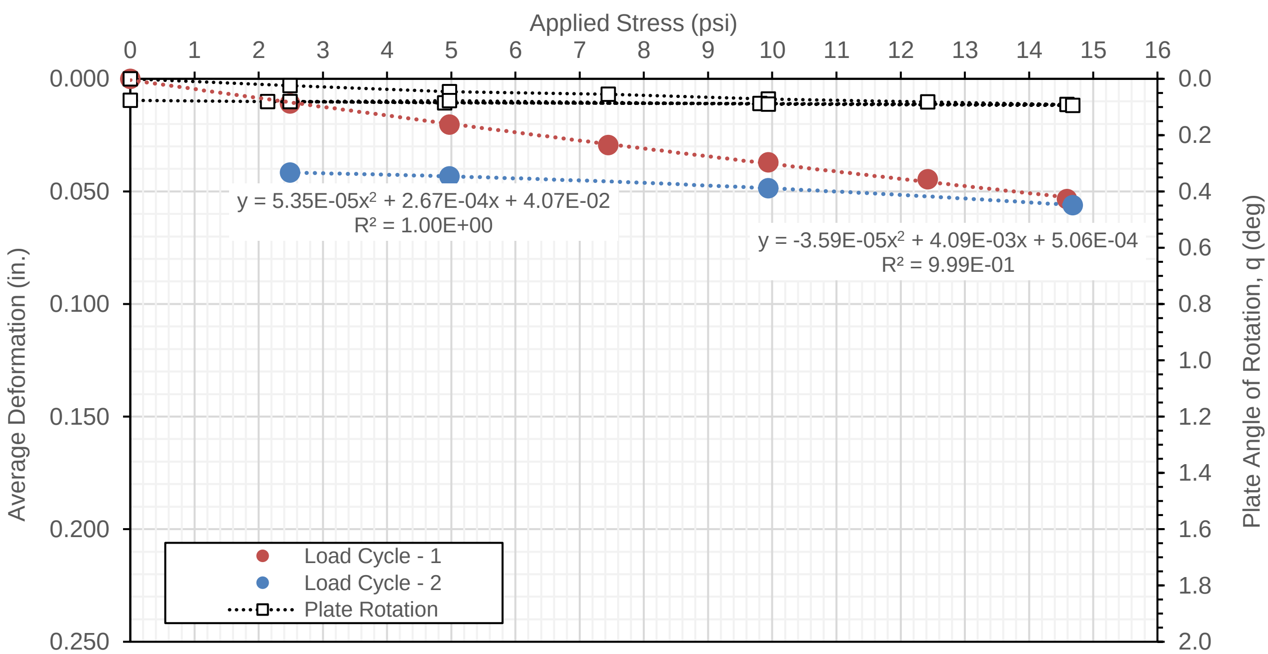
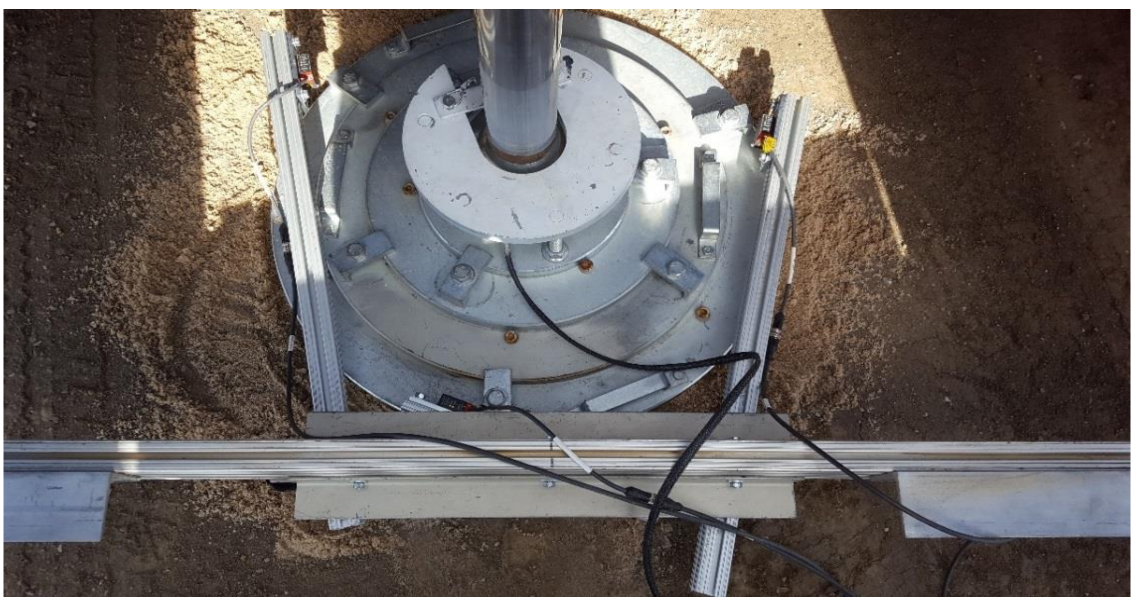
Polynomial Fit Parameters

First Cycle		*Second Cycle*			
a_1	-3.59E-05	a_1	5.35E-05	θ_{max} (deg)	0.0945
a_2	4.09E-03	a_2	2.67E-04		
R^2	1.00	R^2	1.00		

NOTES:
1. Test performed per AASHTO T222/ASTM D1196.
2. k-value determined using:
   (a) calculated stress at 0.05 in. plate deformation (δ) for first loading cycle, per PCA design guidelines, and
   (b) for a defined target stress and calculating corresponding plate deformations using polynomial fit parameters.





Automated Plate Load Test [APLT]

Test:	In-Situ Static Plate Load Test: Two Loading Cycles.				
Date:	11/3/2017	Time:	12:18:33 PM	Test ID	Hwy100_30Static_5_Subgrade
Tested By	DW, JV	Location:	Hwy 100	Sta.	NA
Latitude:	41.98567	Longitude:	91.77604	Elev. (ft):	786
Comments:	Select Subgrade, Cut Area.				

Cycle	Stage	Load Step	Target Applied Load (lbs)	Target Applied Stress (psi)	Actual Applied Stress (psi)	Deformation (in.)			Average Def. (in.)
						Sensor 1	Sensor 2	Sensor 3	
0	Seating	0	707	1	1.36	-0.0002	0.0246	0.0098	0.0114
Zero load and deformation sensors after applying the seating stress.									
1	Seating	0	0	0	0.00	0.0000	0.0000	0.0000	0.0000
1	Load	1	1767	2.5	2.49	0.0023	0.0266	0.0086	0.0125
1	Load	2	3534	5	4.99	0.0043	0.0454	0.0151	0.0216
1	Load	3	5301	7.5	7.47	0.0073	0.0597	0.0209	0.0293
1	Load	4	7069	10	9.95	0.0123	0.0714	0.0253	0.0363
1	Load	5	8836	12.5	12.43	0.0159	0.0814	0.0313	0.0428
1	Load	6	10603	15	14.55	0.0217	0.0922	0.0375	0.0505
1	Unload	7	7069	10	9.73	0.0189	0.0893	0.0353	0.0478
1	Unload	8	3534	5	4.93	0.0145	0.0842	0.0317	0.0435
1	Unload	9	1767	2.5	2.51	0.0110	0.0813	0.0296	0.0406
2	Load	10	3534	5	4.99	0.0136	0.0835	0.0318	0.0429
2	Load	11	7069	10	9.95	0.0188	0.0893	0.0360	0.0481
2	Load	12	10603	15	14.67	0.0238	0.0973	0.0414	0.0541
2	Unload	13	1767	2.5	2.26	0.0116	0.0843	0.0308	0.0422
2	Unload	14	0	0	0.00	0.0039	0.0734	0.0268	0.0347

Plate Diameter:	30.0	in.
Shape factor:	1.57	
Material Type:	A	A = Cohesive, B = Granular, C = Intermediate
Poisson's ratio:	0.35	
Design Stress:	10.0	psi
Target Deformation:	0.05	in.

AASHTO T222 Method
PCA Design Criteria

k_{u1} (pci) @ design stress:	245
k_u (pci) @ δ = 0.05 in.:	266

Modulus at target deformation

Stress @ δ = 0.05 in. (psi	15.3
E_1 (psi)	5,501
k'_u (pci)	306
k_u (pci)	266

Modulus at target/design applied stress

First Loading Cycle

δ_1 (in.)	0.0363
E_1 (psi)	5,057
k'_{u1} (pci)	276
k_{u1} (pci)	245

Second Loading Cycle

δ_2 (in.)	0.0095
E_2 (psi)	14,273
k'_{u2} (pci)	1,057
k_{u2} (pci)	690
E_2 / E_1 or k_2 / k_1 Ratio	2.8

Plate Bending Correction for

$k'_u \geq 100$ *and* $1{,}000$ *pci*

$k_u = -39.9178 + 5.5076\,[k'_u]^{0.7019}$

In-situ Modulus of Subgrade Reaction (k) and Elastic Modulus

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 100 N. of E Ave., Linn County (Project #5)

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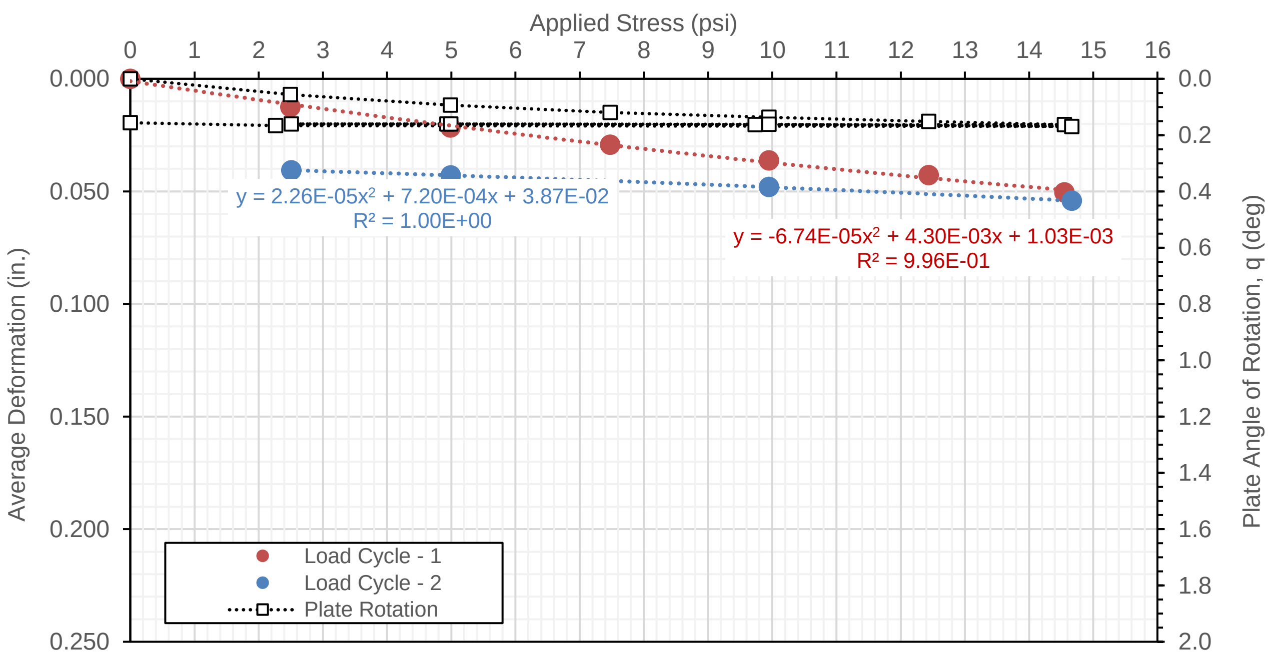
Polynomial Fit Parameters

First Cycle		*Second Cycle*			
a_1	-6.74E-05	a_1	2.26E-05	θ_{max} (deg)	0.1691
a_2	4.30E-03	a_2	7.20E-04		
R^2	1.00	R^2	1.00		

NOTES:
1. Test performed per AASHTO T222/ASTM D1196.
2. k-value determined using:
(a) calculated stress at 0.05 in. plate deformation (δ) for first loading cycle, per PCA design guidelines, and
(b) for a defined target stress and calculating corresponding plate deformations using polynomial fit parameters.



Date of Test	11/3/2017	Test ID	PT 1	Operator	DW/JV	ASTM	D6951
Latitude	41.9890860		Longitude	-91.7757030		Elevation (ft)	815
Location	Hwy 100 N. of E Ave		Station	NA			
Comments	Select Subgrade, Fill Area.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg.Top 12 in. of Subgrade	11.4	19.0	16.8	3,865
Avg. Bottom 12 in. of Subgrade	14.2	14.9	14.4	3,286
Ratio of Avg. Top/Bottom Layer	0.8	1.3	1.2	1.2
Std.Dev.Top 12 in. of Subgrade.	1.5	3.0	5.2	1,141
Std. Dev. Bottom 12 in. of Subgrade	4.9	7.4	9.2	2,059

NOTES:

Subgrade is classified as CL

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

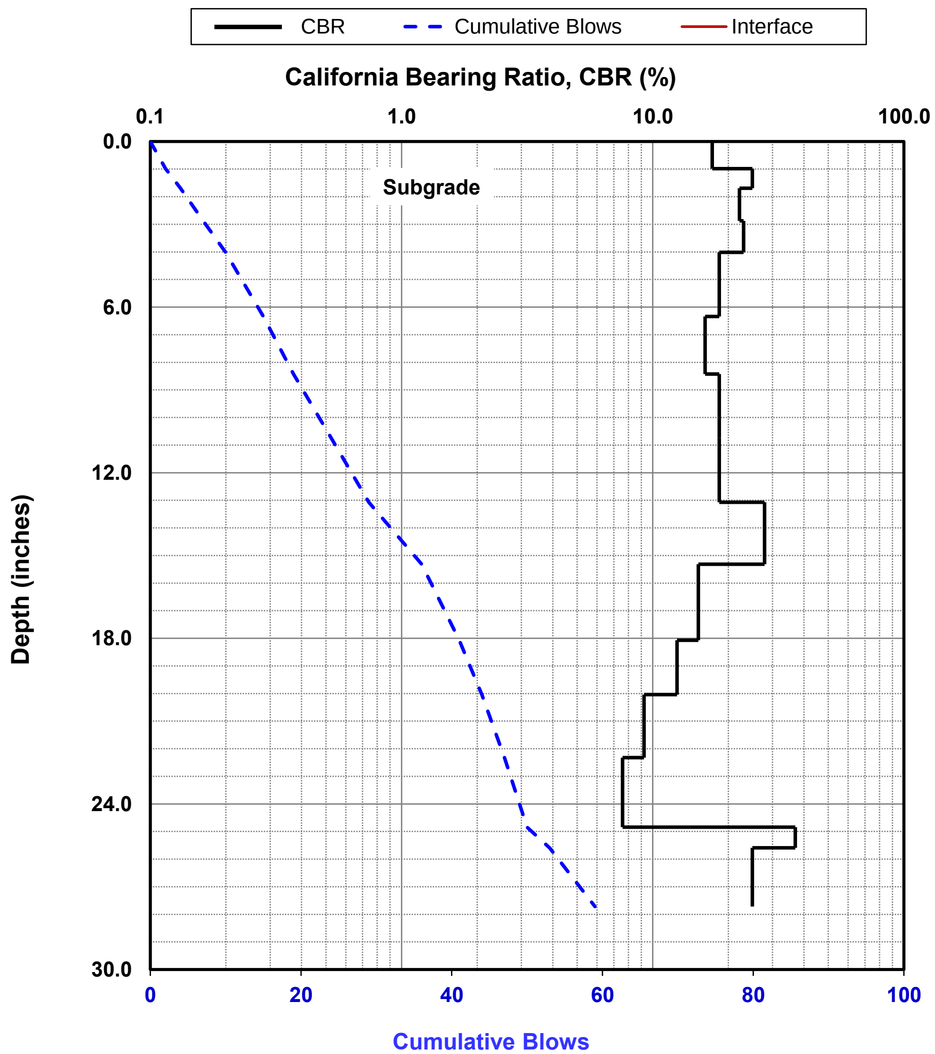
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name: Iowa DOT STIC

Project ID: SIA-00001

Location: Hwy 100 N. of E Ave., Linn County (Project #5)

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Date of Test	11/3/2017	Test ID	PT 2	Operator	DW/JV	ASTM	D6951
Latitude	41.9885250		Longitude	-91.7757870		Elevation (ft)	818
Location	Hwy 100 N. of E Ave		Station	NA			
Comments	Select Subgrade, Fill Area.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg.Top 12 in. of Subgrade	10.2	21.6	18.2	4,200
Avg. Bottom 12 in. of Subgrade	14.2	15.0	14.4	3,293
Ratio of Avg. Top/Bottom Layer	0.7	1.4	1.3	1.3
Std.Dev.Top 12 in. of Subgrade.	2.7	6.8	8.7	1,955
Std. Dev. Bottom 12 in. of Subgrade	3.4	4.4	6.6	1,458

NOTES:

Subgrade is classified as CL

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

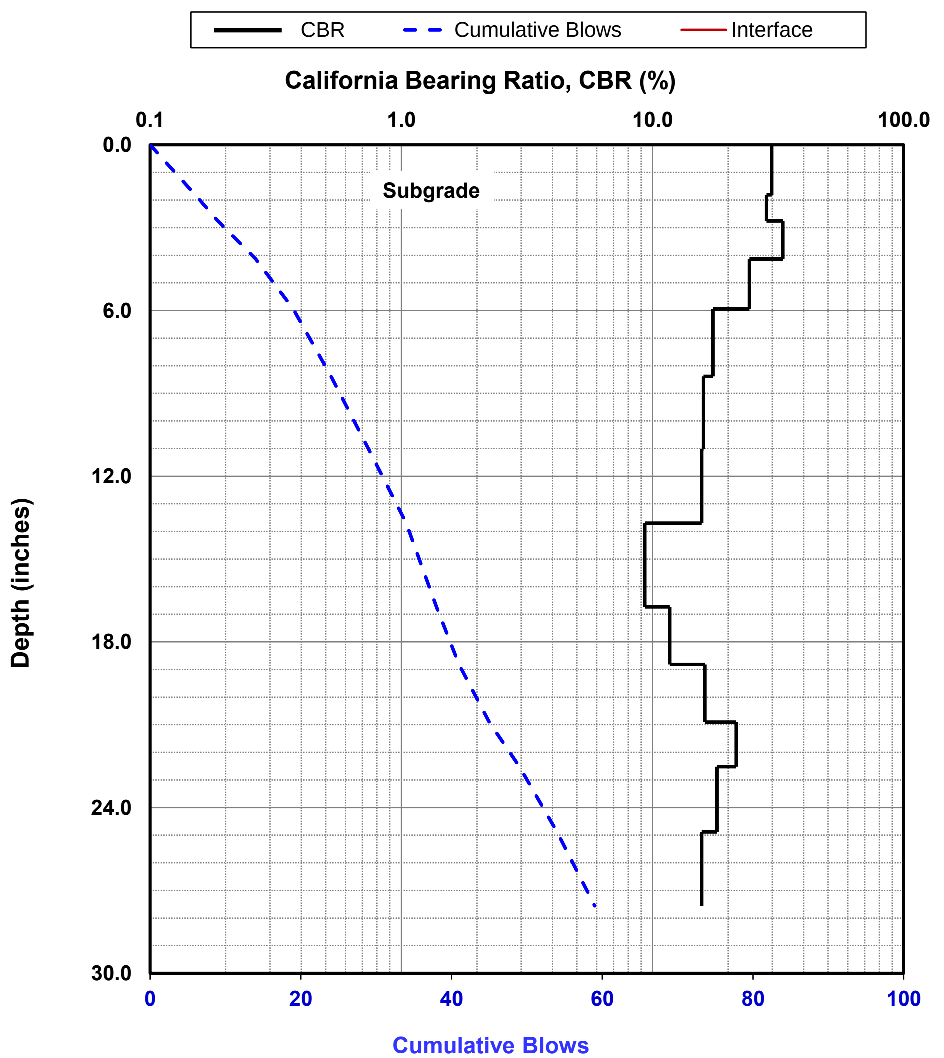
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 100 N. of E Ave., Linn County (Project #5)

Date of Test	11/3/2017	Test ID	PT 3	Operator	DW/JV	ASTM	D6951
Latitude	41.9879910		Longitude	-91.7758330		Elevation (ft)	813
Location	Hwy 100 N. of E Ave		Station	NA			
Comments	Select Subgrade, Fill Area.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg.Top 12 in. of Subgrade	7.8	29.4	22.2	5,152
Avg. Bottom 12 in. of Subgrade	11.8	18.4	16.4	3,775
Ratio of Avg. Top/Bottom Layer	0.7	1.6	1.3	1.4
Std.Dev.Top 12 in. of Subgrade.	1.2	5.4	7.5	1,677
Std. Dev. Bottom 12 in. of Subgrade	2.2	4.7	6.8	1,521

NOTES:

Subgrade is classified as CL

[1] $CBR = 292/DPI^{1.12}$

[1] $CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

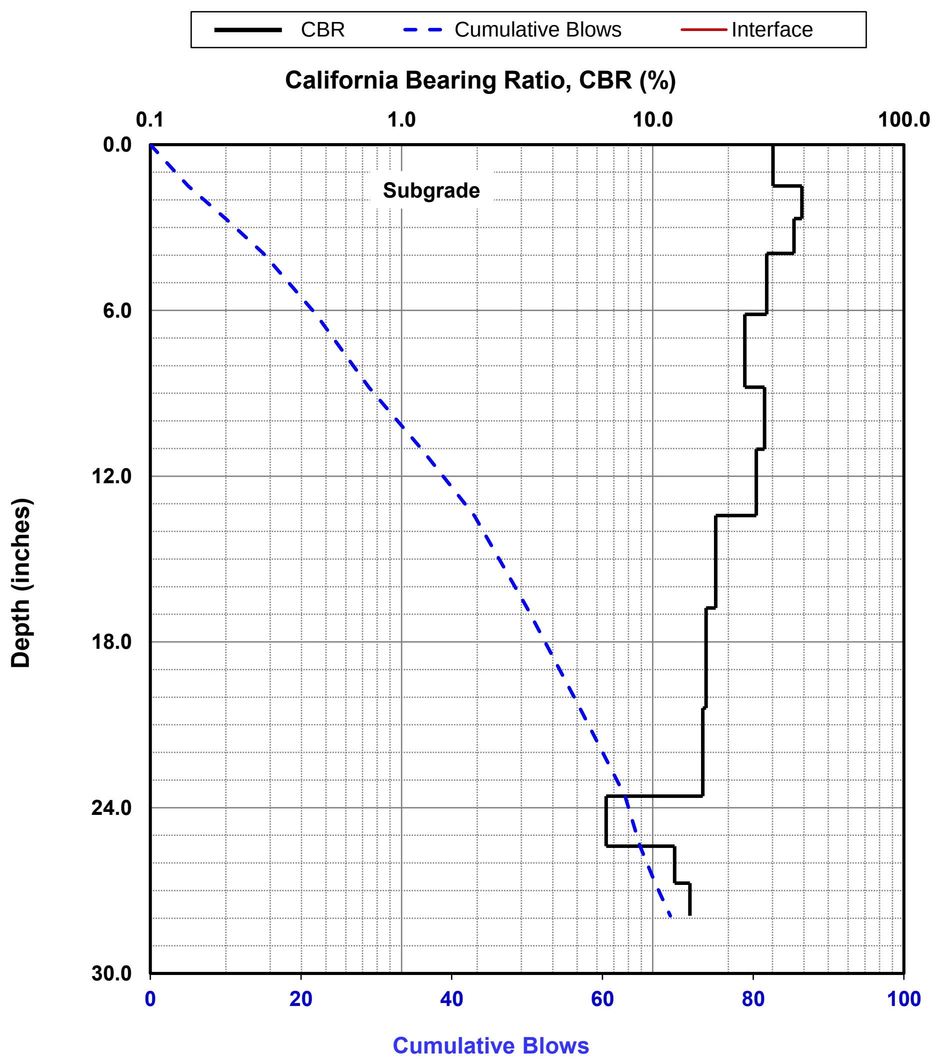
[2] $E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3] $S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2] Powell et al. (1986)

[3] Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name: Iowa DOT STIC

Project ID: SIA-00001

Location: Hwy 100 N. of E Ave., Linn County (Project #5)

Date of Test	11/3/2017	Test ID	PT 4	Operator	DW/JV	ASTM	D6951
Latitude	41.9869270	Longitude		-91.7759170		Elevation (ft)	808
Location	Hwy 100 N. of E Ave	Station		NA			
Comments	Select Subgrade, Fill Area.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg.Top 12 in. of Subgrade	9.1	24.6	19.8	4,585
Avg. Bottom 12 in. of Subgrade	12.7	17.0	15.6	3,585
Ratio of Avg. Top/Bottom Layer	0.7	1.4	1.3	1.3
Std.Dev.Top 12 in. of Subgrade.	3.6	9.9	11.1	2,508
Std. Dev. Bottom 12 in. of Subgrade	6.5	17.7	16.1	3,683

NOTES:

Subgrade is classified as CL

[1] $CBR = 292/DPI^{1.12}$

[1] $CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

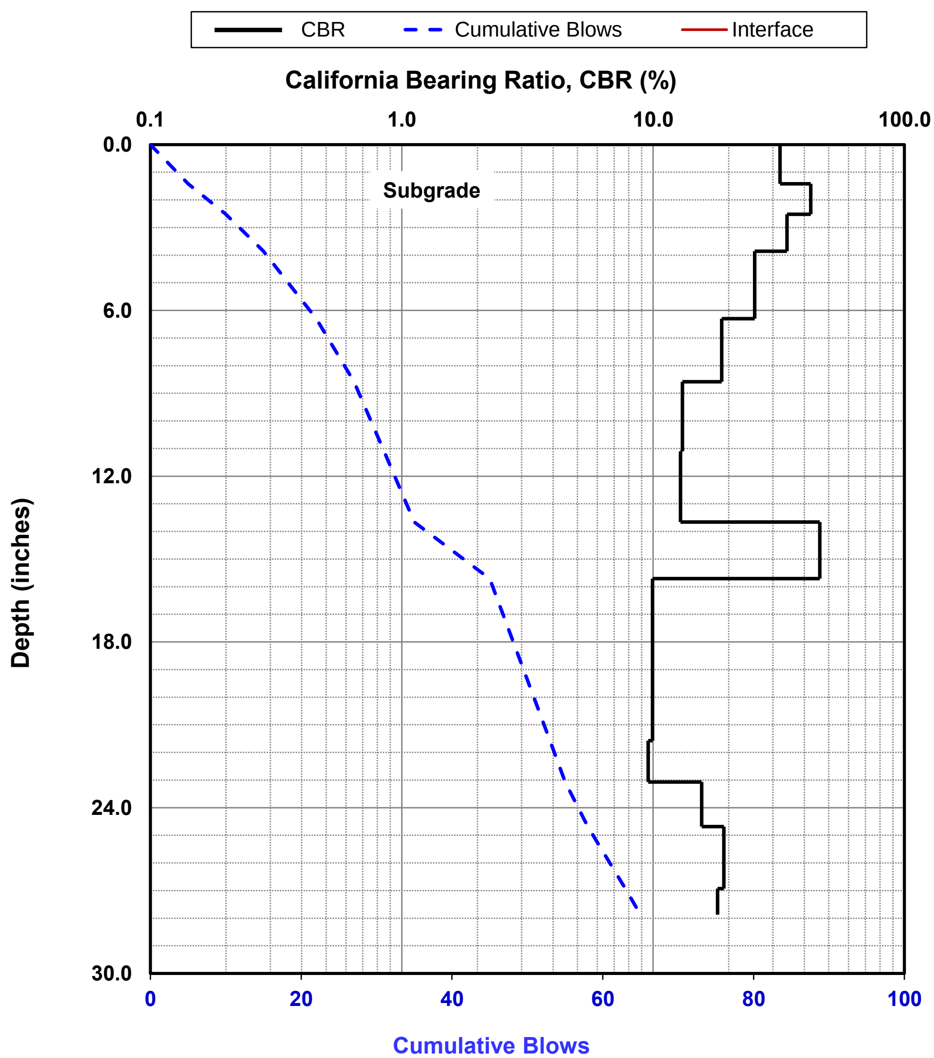
[2] $E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3] $S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2] Powell et al. (1986)

[3] Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 100 N. of E Ave., Linn County (Project #5)

Date of Test	11/3/2017	Test ID	PT 5	Operator	DW/JV	ASTM	D6951
Latitude	41.9856680		Longitude	-91.7760090		Elevation (ft)	793
Location	Hwy 100 N. of E Ave		Station	NA			
Comments	Select Subgrade, Cut Area.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg.Top 12 in. of Subgrade	7.4	31.2	23.1	5,366
Avg. Bottom 12 in. of Subgrade	16.9	12.3	12.7	2,890
Ratio of Avg. Top/Bottom Layer	0.4	2.5	1.8	1.9
Std.Dev.Top 12 in. of Subgrade.	2.7	9.4	10.7	2,413
Std. Dev. Bottom 12 in. of Subgrade	3.6	3.9	6.1	1,356

NOTES:

Subgrade is classified as CL

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

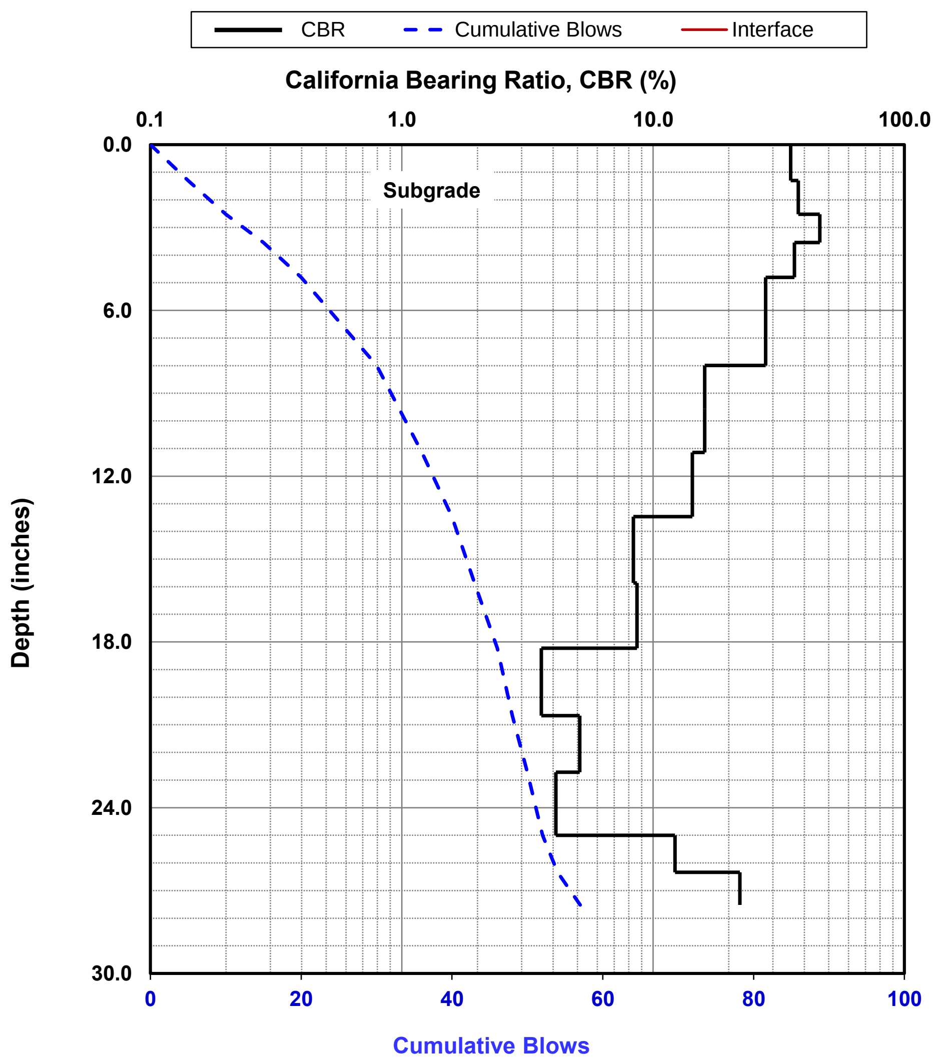
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name: Iowa DOT STIC

Project ID: SIA-00001

Location: Hwy 100 N. of E Ave., Linn County (Project #5)

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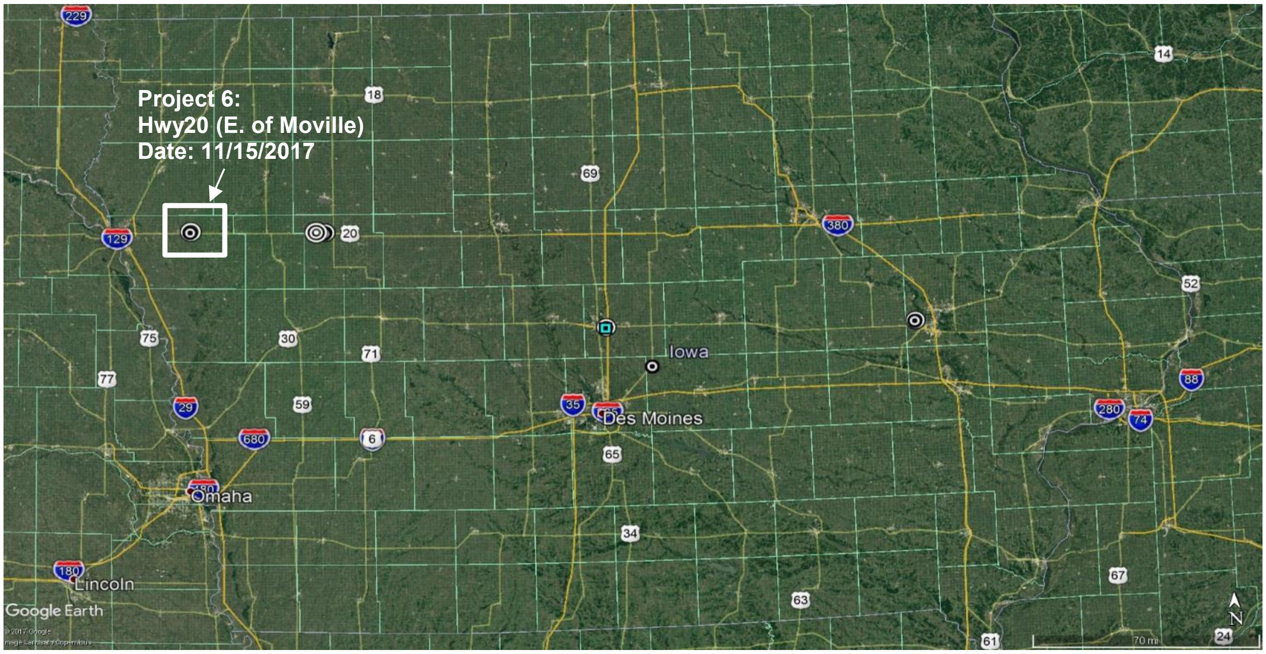
Field Project # 6

Hwy20, E. of Moville, Woodbury, IA

11/15/2017

Select Subgrade

Project Location and Test Locations



Test Locations	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, E. of Moville (Project #6)

Site Conditions and Pictures

Pictures

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, E. of Moville (Project #6)

Summary of Test Results

Summary of Cyclic APLT Test Results

Point #	4 psi cyclic stress @ surface $M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)	8 psi plate cyclic stress @ surface $M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)
1_Cut	8,552	NA	NA	-0.0001	8,425	NA	NA	-0.0006
2_Cut	8,620	NA	NA	-0.0002	8,342	NA	NA	-0.0005
3_Cut	10,748	NA	NA	-0.0002	9,467	NA	NA	0.0000
4_Fill	8,297	NA	NA	0.0000	7,802	NA	NA	0.0001
5_Fill	8,580	NA	NA	-0.0002	7,782	NA	NA	0.0001
AVG	**8,960**	**NA**	**NA**	**(0.0001)**	**8,363**	**NA**	**NA**	**(0.0002)**
COV	11%	NA	NA	-76%	8%	NA	NA	-173%

Point #	13 psi cyclic stress @ surface $M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)	18 psi plate cyclic stress @ surface $M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)
1_Cut	8,659	NA	NA	0.0003	8,502	NA	NA	0.0026
2_Cut	8,442	NA	NA	-0.0001	7,650	NA	NA	0.0027
3_Cut	8,662	NA	NA	0.0004	7,832	NA	NA	0.0057
4_Fill	7,829	NA	NA	0.0004	7,438	NA	NA	0.0018
5_Fill	7,796	NA	NA	0.0003	7,344	NA	NA	0.0018
AVG	**8,277**	**NA**	**NA**	**0.0003**	**7,753**	**NA**	**NA**	**0.0029**
COV	5%	NA	NA	72%	6%	NA	NA	55%

Point #	28 psi cyclic stress @ surface $M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)	38 psi plate cyclic stress @ surface $M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)
1_Cut	7,911	NA	NA	0.0098	7,426	NA	NA	0.0179
2_Cut	6,840	NA	NA	0.0100	6,371	NA	NA	0.0186
3_Cut	7,007	NA	NA	0.0228	6,274	NA	NA	0.0404
4_Fill	7,320	NA	NA	0.0080	7,227	NA	NA	0.0141
5_Fill	6,703	NA	NA	0.0081	6,593	NA	NA	0.0162
AVG	**7,156**	**NA**	**NA**	**0.0118**	**6,778**	**NA**	**NA**	**0.0214**
COV	7%	NA	NA	53%	8%	NA	NA	50%

Summary of Test Results

Summary of AASHTO (2015) universal model parameters

Point #	$k^*_{1(Comp)}$	$k^*_{2(Comp)}$	$k^*_{3(Comp)}$	$M_{r\text{-}Comp}$ R^2(Adj.)	Std. Error (psi)	$M_{r\text{-}Comp(pred)\text{-}BP}$ (psi)	$\sigma_{cyclic\text{-}BP}$ (psi)
1_Cut	633.6	0.106	-1.205	0.911	138	8,658	9.0
2_Cut	648.8	0.078	-1.619	0.957	189	8,611	4.7
3_Cut	737.7	-0.146	-0.801	0.998	64	12,613	2.0
4_Fill	549.6	-0.082	0.104	0.931	102	8,893	2.0
5_Fill	579.1	-0.083	-0.327	0.945	172	9,295	2.0
AVG	**629.8**	**(0.026)**	**-0.770**	**0.949**	**133**	**9,614**	**3.9**
COV	12%	-433%	-0.888	3%	38%	18%	78%

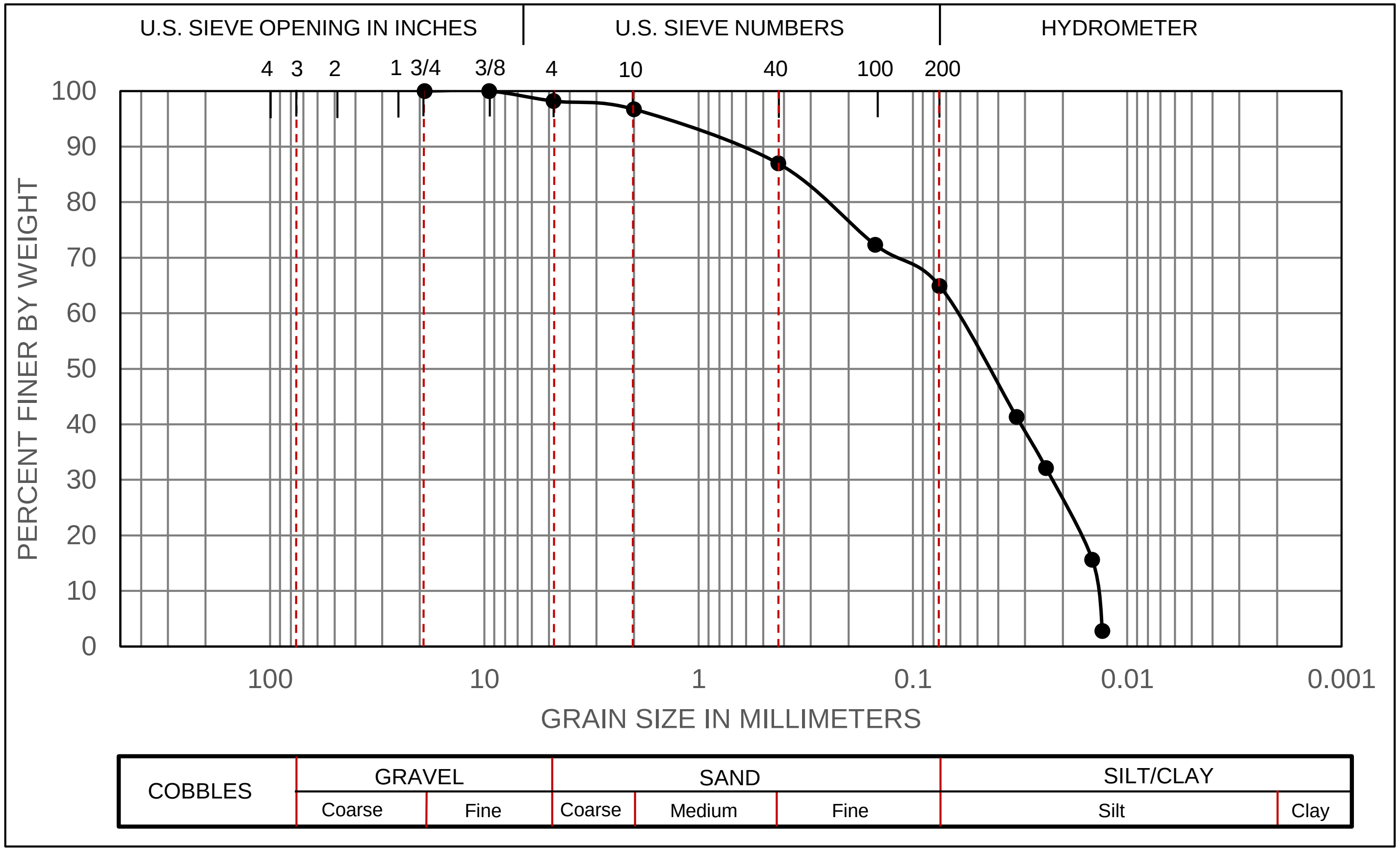
Point #	30 in. static PLT k_u (pci) at δ = 0.05 in.[a]	k_{u1} (pci) at 10 psi[b]	k_{u2} (pci) at 10 psi	Ratio of k_{u2}/k_{u1}
2_Cut	85	92	216	2.4
5_Fill	145	145	272	1.9

[a]per PCA design critera
[b]per AASHTO T222

Summary of DCP and LWD test results

Point #	Subgrade Layer (top 12 in.) Thickness, H_1 (in.)	Avg. CBR (%)	St. Dev CBR (%)	Subgrade Layer (bottom 12 in.) Thickness, H_2 (in.)	Avg. CBR (%)	St. Dev CBR (%)	Ratio CBR_1/ CBR_2	E_{LWD} (psi)
1_Cut	12.0	18.7	23.3	12.0	2.2	0.6	8.7	4,542
2_Cut	12.0	17.6	18.9	12.0	1.5	0.6	11.9	4,800
3_Cut	12.0	13.9	13.3	12.0	2.2	0.6	6.3	3,733
4_Fill	12.0	22.7	18.8	12.0	2.0	0.1	11.5	4,795
5_Fill	12.0	20.0	19.0	12.0	2.5	1.1	8.0	3,836
AVG	**NA**	**NA**	**NA**	**12.0**	**2.1**	**0.6**	**NA**	**4,341**
COV	NA	NA	NA	0%	18%	60%	NA	12%

GRAIN SIZE DISTRIBUTION
ASTM D422/C136



Gradation Summary

% Gravel	1.8
% Sand	33.3
% Silt / % Clay	64.9
D_{10} (mm)	0.014
D_{30} (mm)	0.023
D_{50} (mm)	0.048
D_{60} (mm)	0.066
D_{85} (mm)	0.388
C_u	4.8
C_c	0.6

Atterberg Limits

LL	NP
PL	NP
PI	NP

Classification

AASHTO:	A-4
USCS:	ML

MATERIAL: Select Subgrade
LOCATION: Hwy 20, E. of Moville (Project #6) **TESTED BY:** DW
SAMPLE DATE: 11/15/2017 **TEST DATE:** 9/6/2018

Gradation and Soil Classification Test Results

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, E. of Moville (Project #6)

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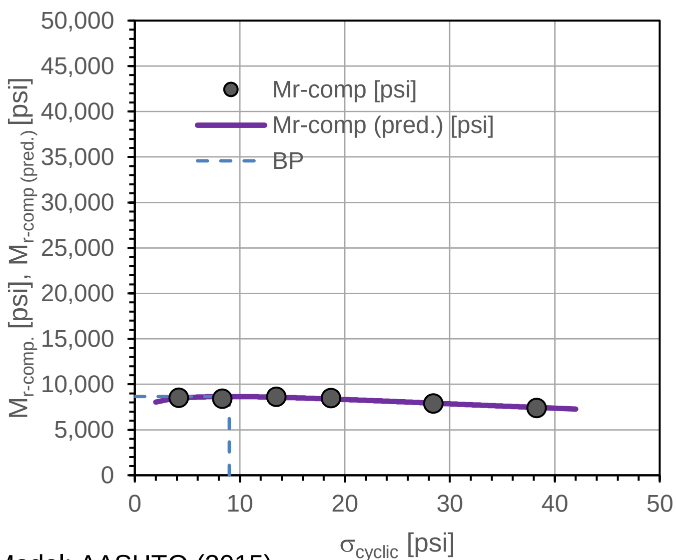
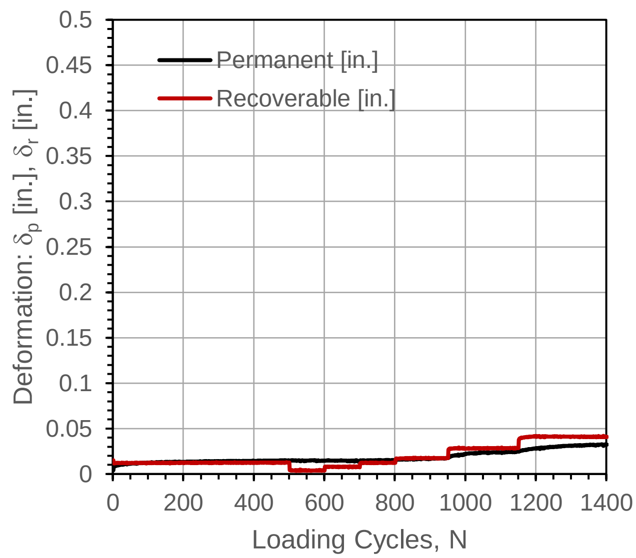
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/15/2017	Time:	11:06:45 AM	Test ID	**HWY20_12_1**
Tested By	DW, JV, HG	Location:	Hwy20	Sta.	NA
Latitude,N:	42.482513	Longitude,W:	95.993118	Elev. (ft):	1389
Comments:	Select subgrade. Cut area.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.48	---	---	0.0147	---	0.128	---
1	100	4.21	8,552	8,465	0.0146	-0.0001	-0.060	Y
2	100	8.35	8,425	8,656	0.0141	-0.0006	-0.166	Y
3	100	13.48	8,659	8,581	0.0150	0.0003	0.188	Y
4	150	18.69	8,502	8,387	0.0174	0.0026	0.373	Y
5	200	28.45	7,911	7,930	0.0246	0.0098	0.488	N
6	250	38.29	7,426	7,452	0.0326	0.0179	0.582	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	633.6	8.54E-08
k^*_2	0.106	7.64E-02
k^*_3	-1.205	2.46E-02
Adj. R^2	0.911	
Std. Error [psi]	138	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	8,658
$\sigma_{cyclic\text{-}BP}$ [psi]	9.0

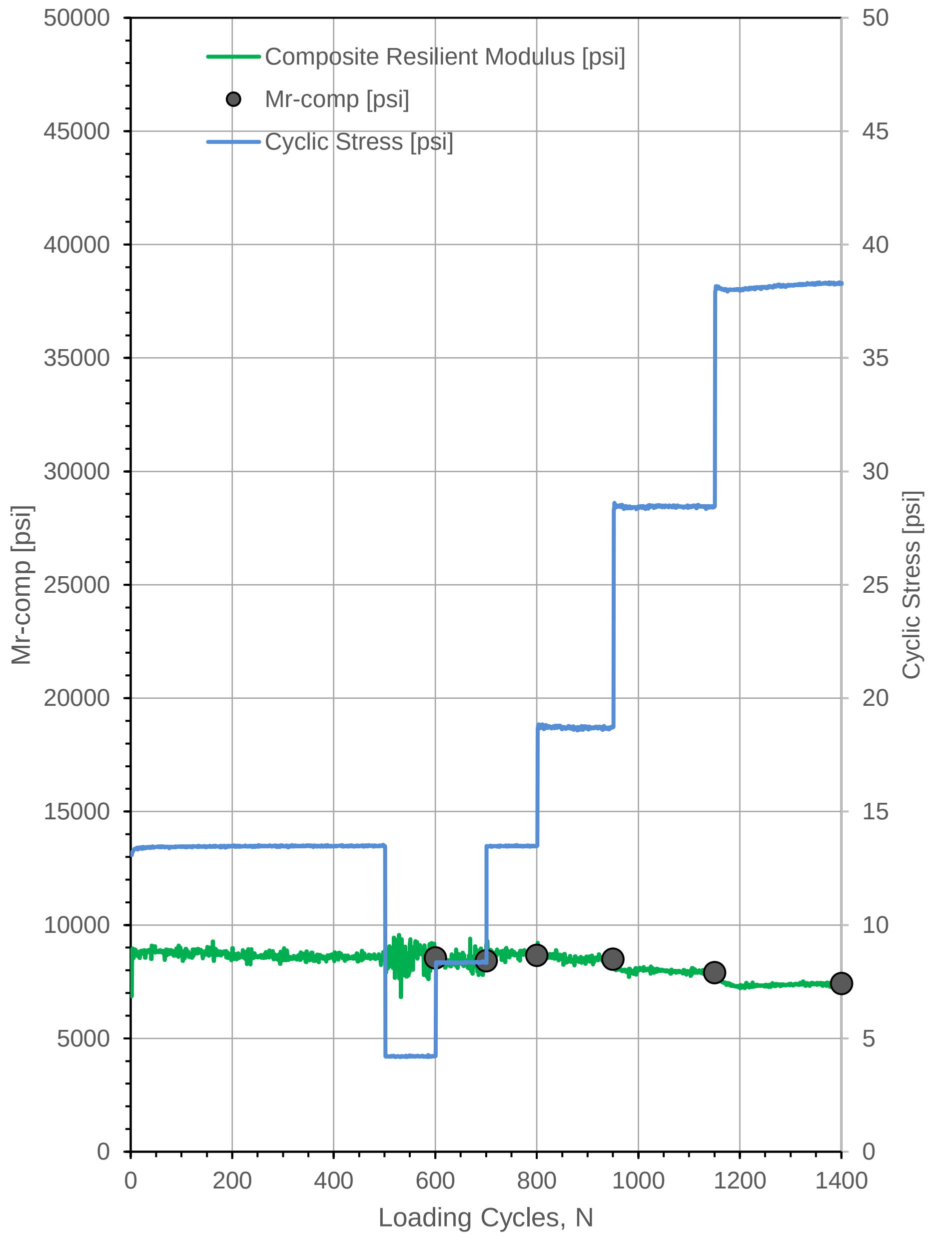
In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, E. of Moville (Project #6)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/15/2017	Time:	11:06:45 AM	Test ID	**HWY20_12_1**
Tested By	DW, JV, HG	Location:	Hwy20	Sta.	NA
Latitude,N:	42.482513	Longitude,W:	95.993118	Elev. (ft):	1389
Comments:	Select subgrade. Cut area.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	8,044
3	8,291
4	8,441
5	8,537
6	8,597
7	8,634
8	8,652
9	8,658
10	8,653
11	8,640
12	8,620
13	8,595
14	8,565
15	8,532
16	8,496
17	8,457
18	8,417
21	8,285
22	8,239
23	8,193
24	8,145
25	8,097
26	8,049
27	8,000
28	7,952
29	7,903
30	7,854
31	7,805
32	7,756
33	7,707
34	7,658
35	7,610
36	7,561
37	7,513
38	7,466
39	7,418
40	7,371



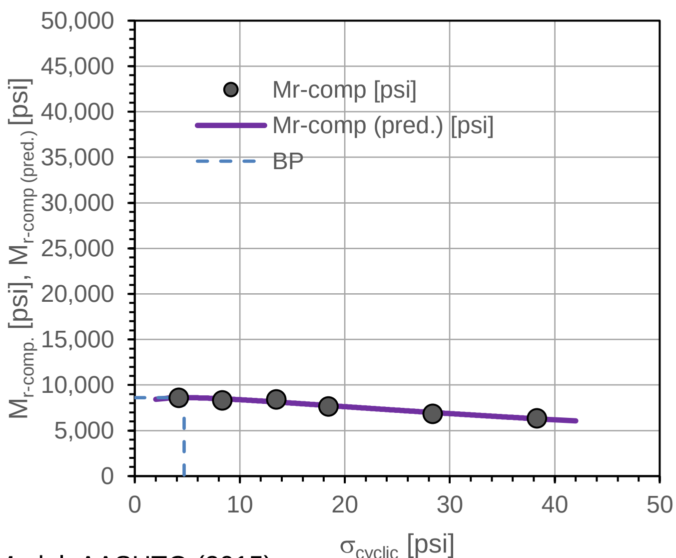
In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

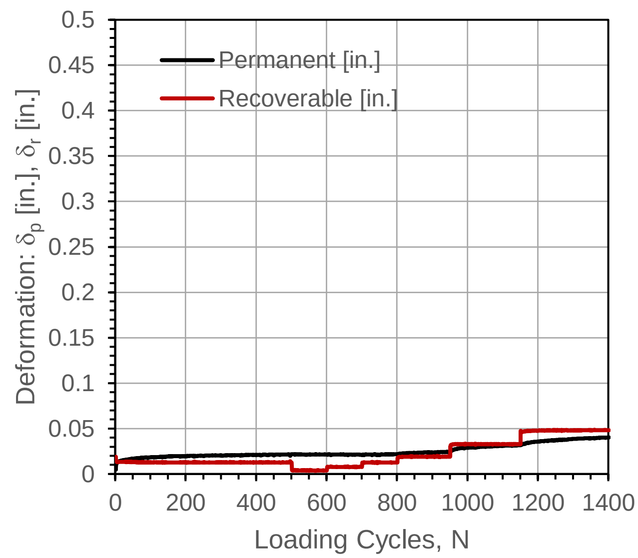
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, E. of Moville (Project #6)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/15/2017	Time:	11:43:50 AM	Test ID	**HWY20_12_2**
Tested By	DW, JV, HG	Location:	Hwy20	Sta.	NA
Latitude,N:	42.482521	Longitude,W:	95.993393	Elev. (ft):	1384
Comments:	Select subgrade. Cut area.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.47	---	---	0.0217	---	0.123	---
1	100	4.20	8,620	8,607	0.0215	-0.0002	-0.104	Y
2	100	8.34	8,342	8,488	0.0212	-0.0005	-0.032	Y
3	100	13.47	8,442	8,137	0.0216	-0.0001	0.153	Y
4	150	18.46	7,650	7,746	0.0244	0.0027	0.445	Y
5	200	28.38	6,840	6,981	0.0317	0.0100	0.452	Y
6	250	38.31	6,371	6,295	0.0403	0.0186	0.537	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	648.8	2.57E-07
k^*_2	0.078	2.69E-01
k^*_3	-1.619	2.99E-02
Adj. R^2	0.957	
Std. Error [psi]	189	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	8,611
$\sigma_{cyclic\text{-}BP}$ [psi]	4.7

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, E. of Moville (Project #6)

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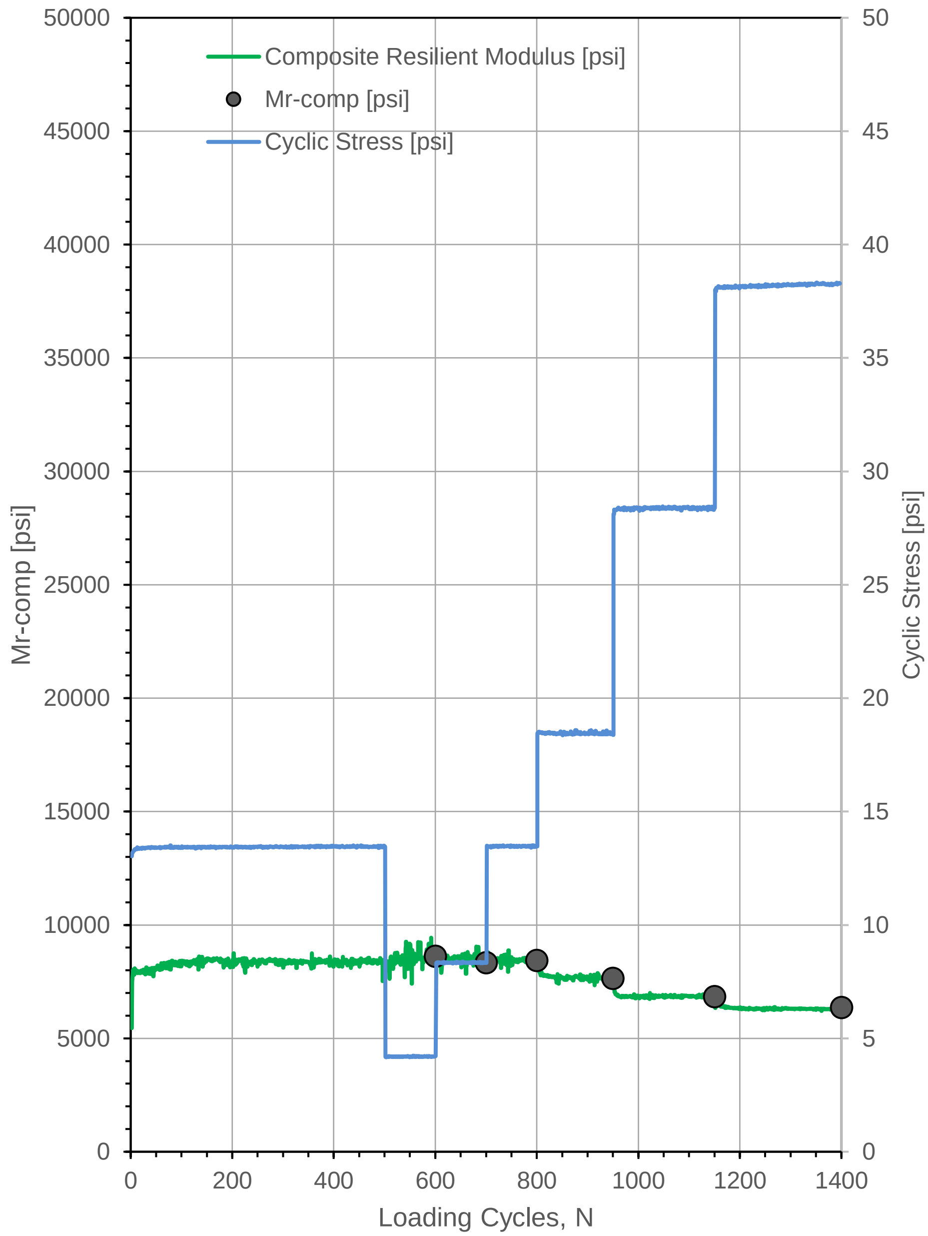
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/15/2017	Time:	11:43:50 AM	Test ID	**HWY20_12_2**
Tested By	DW, JV, HG	Location:	Hwy20	Sta.	NA
Latitude,N:	42.482521	Longitude,W:	95.993393	Elev. (ft):	1384
Comments:	Select subgrade. Cut area.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	8,430
3	8,554
4	8,603
5	8,610
6	8,591
7	8,555
8	8,507
9	8,450
10	8,387
11	8,319
12	8,247
13	8,173
14	8,097
15	8,019
16	7,941
17	7,862
18	7,782
21	7,545
22	7,467
23	7,389
24	7,311
25	7,235
26	7,159
27	7,084
28	7,009
29	6,936
30	6,863
31	6,791
32	6,721
33	6,651
34	6,582
35	6,514
36	6,447
37	6,381
38	6,315
39	6,251
40	6,188



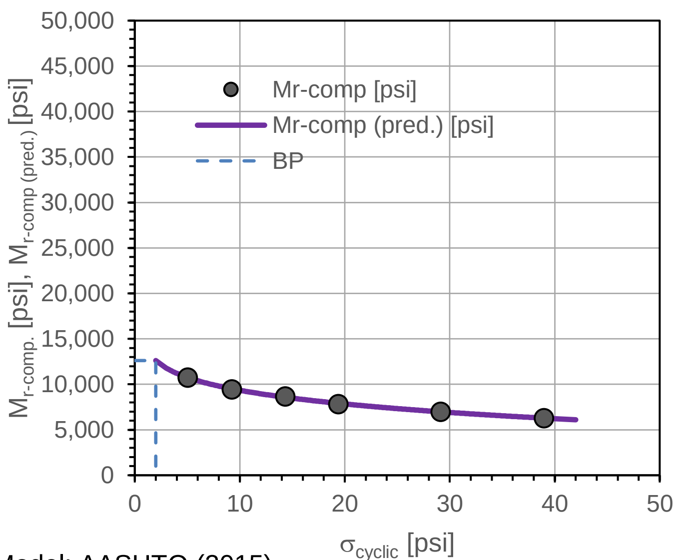
In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

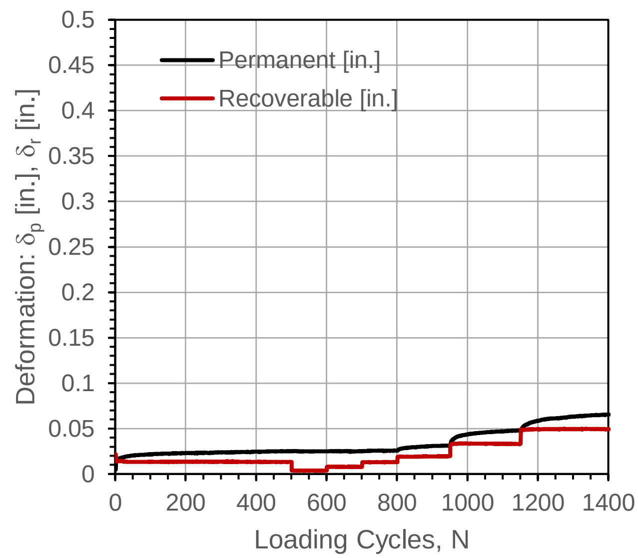
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, E. of Moville (Project #6)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/15/2017	Time:	12:17:13 PM	Test ID	**HWY20_12_3**
Tested By	DW, JV, HG	Location:	Hwy20	Sta.	NA
Latitude,N:	42.482494	Longitude,W:	95.994392	Elev. (ft):	1392
Comments:	Select subgrade. Cut area.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	14.34	---	---	0.0251	---	0.110	---
1	100	5.05	10,748	10,740	0.0249	-0.0002	-0.127	Y
2	100	9.24	9,467	9,507	0.0251	0.0000	-0.045	Y
3	100	14.34	8,662	8,576	0.0255	0.0004	0.365	Y
4	150	19.39	7,832	7,910	0.0308	0.0057	0.499	N
5	200	29.14	7,007	6,974	0.0479	0.0228	0.393	N
6	250	38.97	6,274	6,283	0.0655	0.0404	0.468	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	737.7	7.13E-09
k^*_2	-0.146	6.42E-03
k^*_3	-0.801	1.18E-02
Adj. R^2	0.998	
Std. Error [psi]	64	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	12,613
$\sigma_{cyclic\text{-}BP}$ [psi]	2.0

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, E. of Moville (Project #6)

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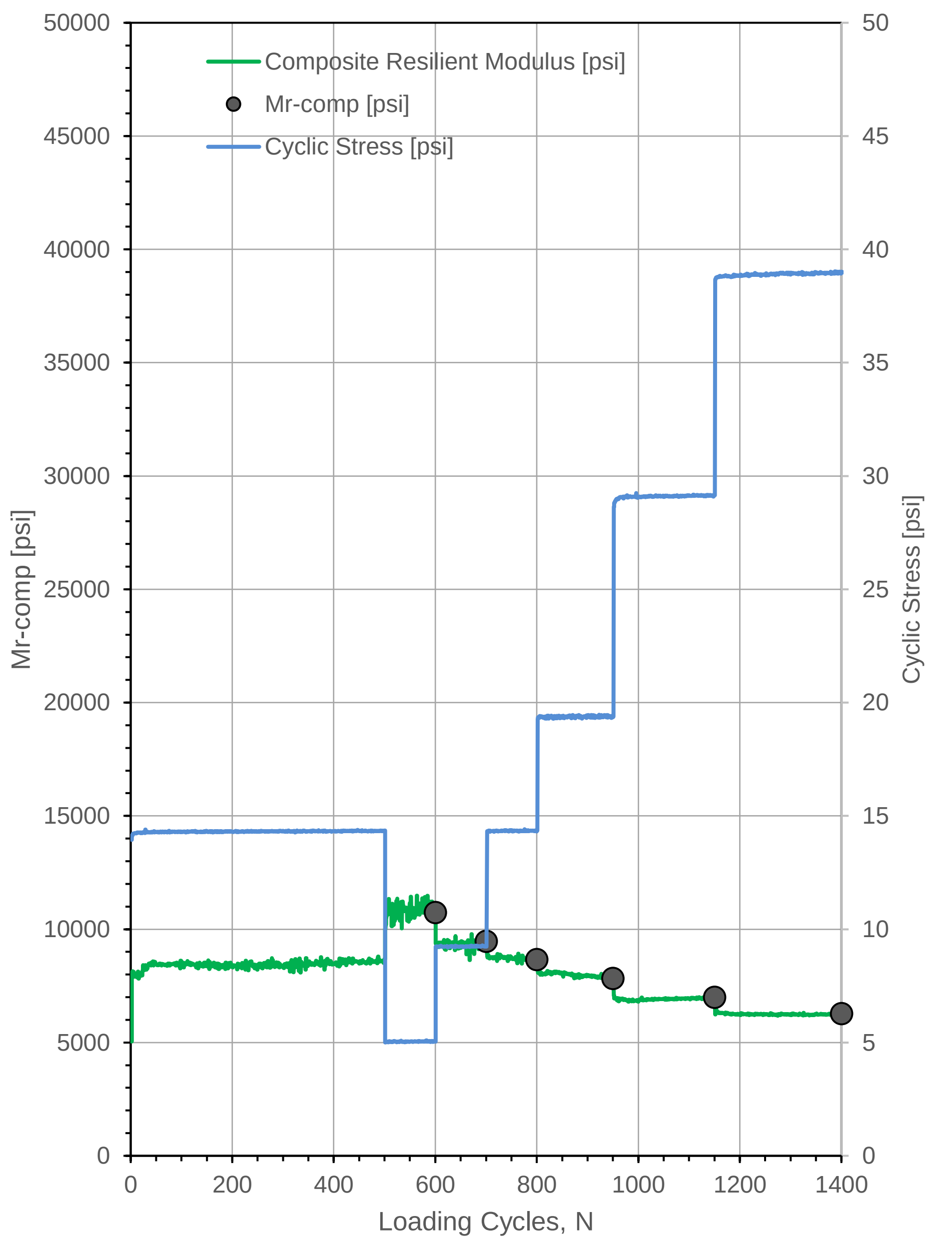
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/15/2017	Time:	12:17:13 PM	Test ID	**HWY20_12_3**
Tested By	DW, JV, HG	Location:	Hwy20	Sta.	NA
Latitude,N:	42.482494	Longitude,W:	95.994392	Elev. (ft):	1392
Comments:	Select subgrade. Cut area.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	12,613
3	11,787
4	11,208
5	10,759
6	10,391
7	10,078
8	9,805
9	9,562
10	9,343
11	9,143
12	8,958
13	8,787
14	8,628
15	8,478
16	8,337
17	8,203
18	8,076
21	7,730
22	7,624
23	7,523
24	7,425
25	7,331
26	7,240
27	7,152
28	7,067
29	6,985
30	6,905
31	6,828
32	6,753
33	6,680
34	6,609
35	6,540
36	6,473
37	6,407
38	6,343
39	6,281
40	6,220



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, E. of Moville (Project #6)

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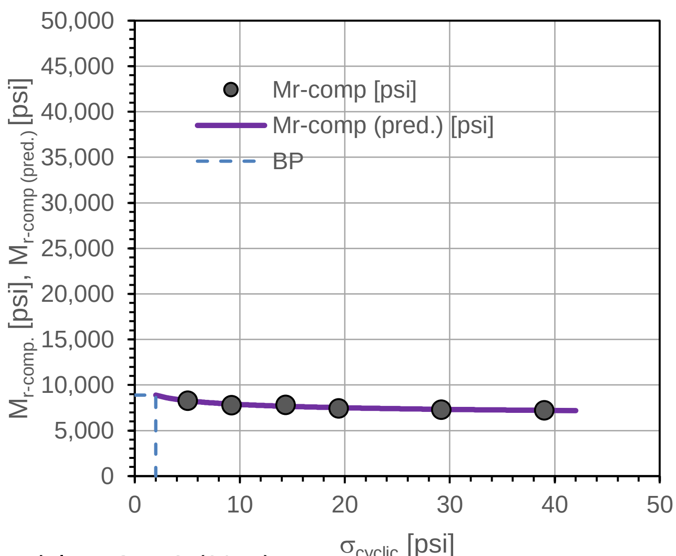
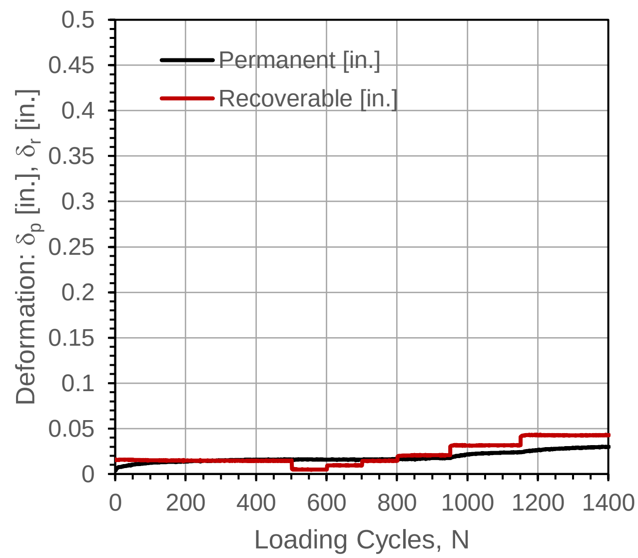
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/15/2017	Time:	12:53:50 PM	Test ID	**HWY20_12_4**
Tested By	DW, JV, HG	Location:	Hwy20	Sta.	NA
Latitude,N:	42.482460	Longitude,W:	95.994949	Elev. (ft):	1386
Comments:	Select subgrade. Fill area.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	14.36	---	---	0.0159	---	0.206	---
1	100	5.04	8,297	8,273	0.0159	0.0000	0.097	Y
2	100	9.24	7,802	7,908	0.0159	0.0001	-0.080	Y
3	100	14.36	7,829	7,666	0.0163	0.0004	0.103	Y
4	150	19.42	7,438	7,515	0.0177	0.0018	0.448	Y
5	200	29.19	7,320	7,332	0.0239	0.0080	0.564	N
6	250	39.02	7,227	7,217	0.0299	0.0141	0.645	N



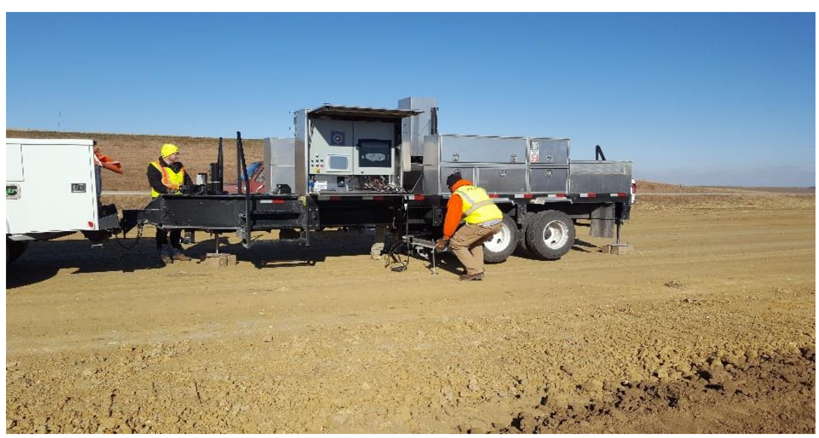


Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	549.6	4.45E-08
k^*_2	-0.082	1.18E-01
k^*_3	0.104	7.12E-01
Adj. R^2	0.931	
Std. Error [psi]	102	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]		8,893
	$\sigma_{cyclic\text{-}BP}$ [psi]	2.0



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, E. of Moville (Project #6)

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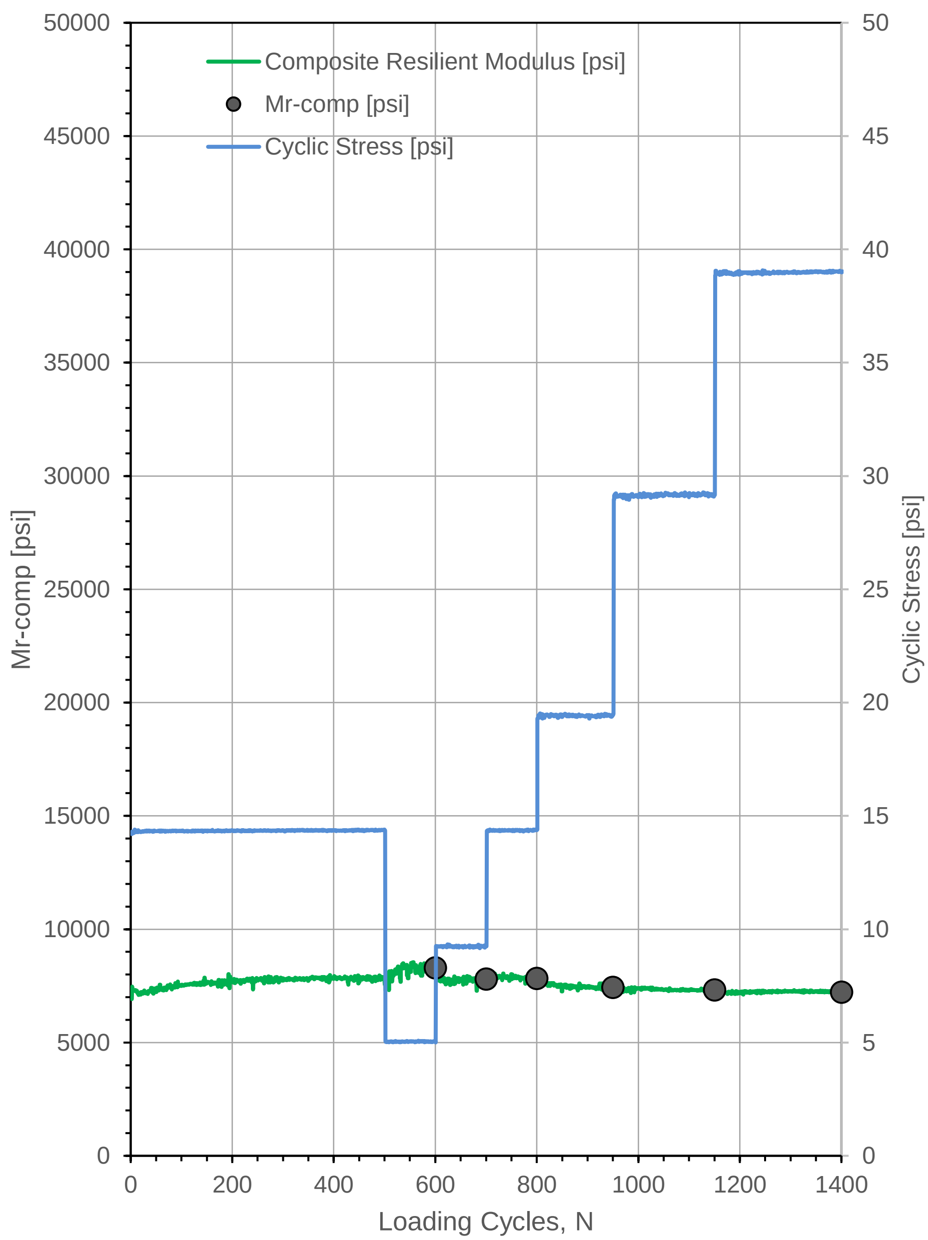
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/15/2017	Time:	12:53:50 PM	Test ID	**HWY20_12_4**
Tested By	DW, JV, HG	Location:	Hwy20	Sta.	NA
Latitude,N:	42.482460	Longitude,W:	95.994949	Elev. (ft):	1386
Comments:	Select subgrade. Fill area.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	8,893
3	8,613
4	8,422
5	8,278
6	8,164
7	8,070
8	7,991
9	7,922
10	7,862
11	7,809
12	7,762
13	7,719
14	7,679
15	7,643
16	7,611
17	7,580
18	7,552
21	7,478
22	7,456
23	7,436
24	7,416
25	7,398
26	7,381
27	7,365
28	7,349
29	7,334
30	7,320
31	7,307
32	7,294
33	7,281
34	7,270
35	7,258
36	7,247
37	7,237
38	7,227
39	7,217
40	7,208



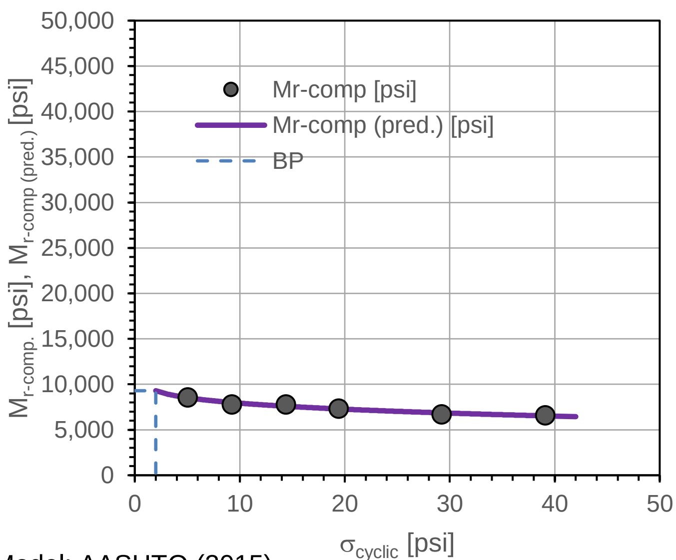
In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

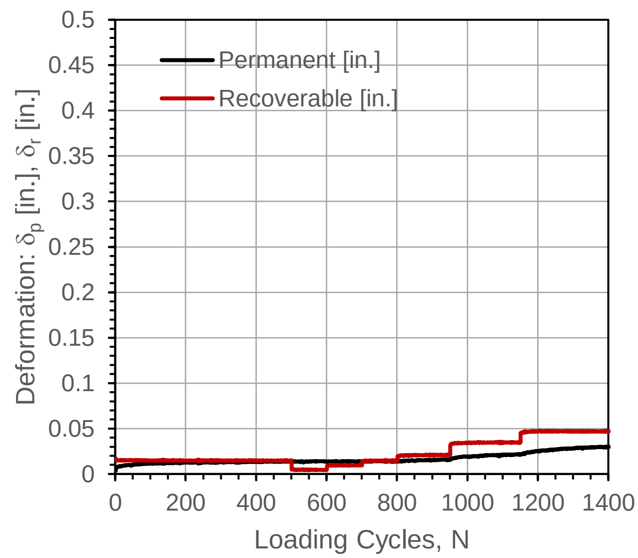
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, E. of Moville (Project #6)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/15/2017	Time:	1:26:33 PM	Test ID	**HWY20_12_5**
Tested By	DW, JV, HG	Location:	Hwy20	Sta.	NA
Latitude,N:	42.482441	Longitude,W:	95.995323	Elev. (ft):	1374
Comments:	Select subgrade. Fill area.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	=$\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	14.39	---	---	0.0138	---	0.138	---
1	100	5.06	8,580	8,521	0.0136	-0.0002	0.044	Y
2	100	9.25	7,782	7,996	0.0139	0.0001	0.081	Y
3	100	14.39	7,796	7,588	0.0141	0.0003	0.037	Y
4	150	19.42	7,344	7,292	0.0156	0.0018	0.481	Y
5	200	29.23	6,703	6,860	0.0219	0.0081	0.430	Y
6	250	39.09	6,593	6,531	0.0300	0.0162	0.602	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	579.1	2.19E-07
k^*_2	-0.083	2.92E-01
k^*_3	-0.327	5.09E-01
Adj. R^2	0.945	
Std. Error [psi]	172	

$M_{r\text{-comp (pred.)-BP}}$ [psi]	9,295
$\sigma_{cyclic\text{-}BP}$ [psi]	2.0

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, E. of Moville (Project #6)

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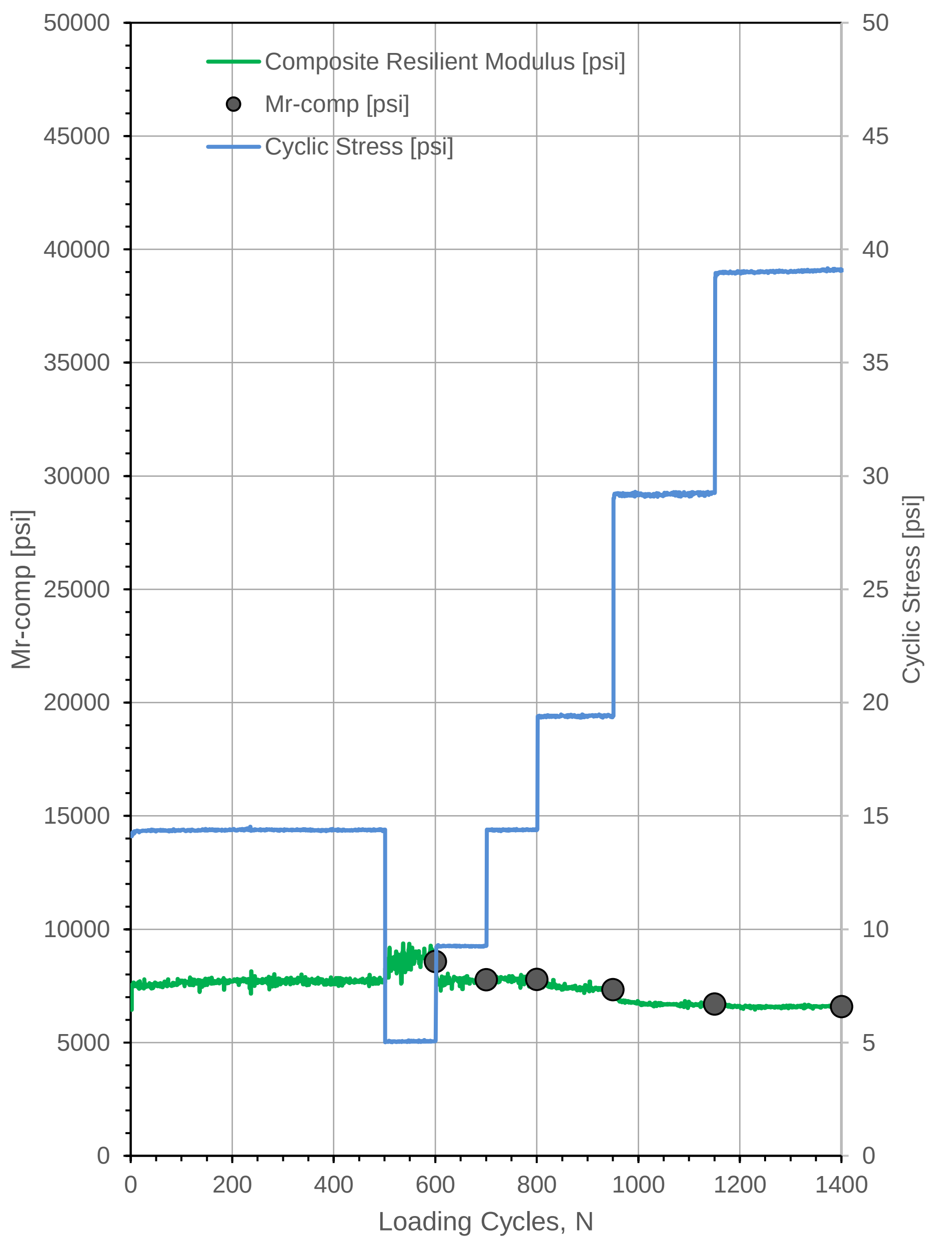
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	11/15/2017	Time:	1:26:33 PM	Test ID	**HWY20_12_5**
Tested By	DW, JV, HG	Location:	Hwy20	Sta.	NA
Latitude,N:	42.482441	Longitude,W:	95.995323	Elev. (ft):	1374
Comments:	Select subgrade. Fill area.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	9,295
3	8,958
4	8,718
5	8,531
6	8,375
7	8,242
8	8,125
9	8,021
10	7,926
11	7,839
12	7,759
13	7,684
14	7,614
15	7,548
16	7,485
17	7,425
18	7,369
21	7,213
22	7,164
23	7,118
24	7,073
25	7,030
26	6,988
27	6,947
28	6,908
29	6,869
30	6,832
31	6,795
32	6,760
33	6,725
34	6,691
35	6,658
36	6,626
37	6,594
38	6,563
39	6,533
40	6,503



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, E. of Moville (Project #6)

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Automated Plate Load Test [APLT]

Test:	In-Situ Static Plate Load Test: Two Loading Cycles.				
Date:	11/15/2017	Time:	3:36:12 PM	Test ID	**Hwy20_30Static_6_2Cut**
Tested By	DW, JV	Location:	Hwy 20 (E. of Moville)	Sta.	NA
Latitude:	42.48249	Longitude:	95.99343	Elev. (ft):	1365
Comments:	Select subgrade. Cut area.				

Cycle	Stage	Load Step	Target Applied Load (lbs)	Target Applied Stress (psi)	Actual Applied Stress (psi)	Deformation (in.) Sensor 1	Sensor 2	Sensor 3	Average Def. (in.)
0	Seating	0	707	1	*1.37*	0.0066	0.0274	0.0220	**0.0187**
Zero load and deformation sensors after applying the seating stress.									
1	Seating	0	0	0	*0.00*	*0.0000*	*0.0000*	*0.0000*	**0.0000**
1	Load	1	1767	2.5	*2.49*	*0.0206*	*0.0428*	*0.0364*	**0.0333**
1	Load	2	3534	5	*4.97*	*0.0423*	*0.0752*	*0.0631*	**0.0602**
1	Load	3	5301	7.5	*7.44*	*0.0628*	*0.1023*	*0.0888*	**0.0847**
1	Load	4	7069	10	*9.93*	*0.0825*	*0.1279*	*0.1157*	**0.1087**
1	Load	5	8836	12.5	*12.41*	*0.1033*	*0.1522*	*0.1394*	**0.1316**
1	Load	6	10603	15	*14.70*	*0.1196*	*0.1725*	*0.1621*	**0.1514**
1	Unload	7	7069	10	*9.94*	*0.1067*	*0.1591*	*0.1482*	**0.1380**
1	Unload	8	3534	5	*4.98*	*0.0856*	*0.1367*	*0.1258*	**0.1160**
1	Unload	9	1767	2.5	*2.49*	*0.0689*	*0.1180*	*0.1080*	**0.0983**
2	Load	10	3534	5	*4.98*	*0.0782*	*0.1271*	*0.1170*	**0.1074**
2	Load	11	7069	10	*9.94*	*0.0996*	*0.1518*	*0.1416*	**0.1310**
2	Load	12	10603	15	*14.86*	*0.1233*	*0.1778*	*0.1670*	**0.1560**
2	Unload	13	1767	2.5	*2.23*	*0.0723*	*0.1228*	*0.1130*	**0.1027**
2	Unload	14	0	0	*0.00*	*0.0499*	*0.0963*	*0.0838*	**0.0767**

Plate Diameter:	*30.0*	in.
Shape factor:	**1.57**	
Material Type:	*A*	A = Cohesive, B = Granular, C = Intermediate
Poisson's ratio:	*0.35*	
Design Stress:	*10.0*	psi
Target Deformation:	*0.05*	in.

AASHTO T222 Method	***k_{u1}* (pci) @ design stress:**	**92**
PCA Design Criteria	***k_u* (pci) @ δ = 0.05 in.:**	**85**

Modulus at target deformation

Stress @ δ = 0.05 in. (psi)	**4.2**
E_1 (psi)	**1,751**
k'_u (pci)	**85**
k_u (pci)	**85**

Modulus at target/design applied stress

First Loading Cycle

δ_1 (in.)	**0.1090**
E_1 (psi)	**1,897**
k'_{u1} (pci)	**92**
k_{u1} (pci)	**92**

Second Loading Cycle

δ_2 (in.)	**0.0421**
E_2 (psi)	**4,468**
k'_{u2} (pci)	**237**
k_{u2} (pci)	**216**
E_2 / E_1 or k_2 / k_1 Ratio	**2.4**

Plate Bending Correction for

$$k'_u \geq 100 \text{ and } 1{,}000 \text{ pci}$$

$$k_u = -39.9178 + 5.5076\,[k'_u]^{0.7019}$$

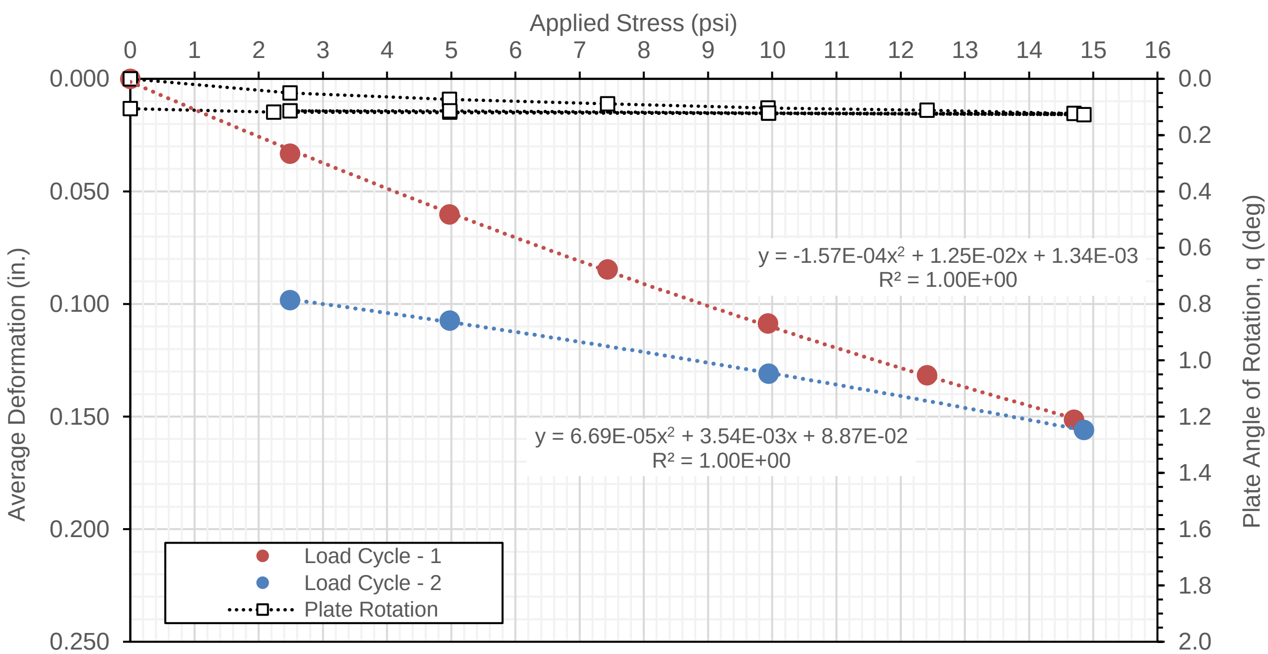
In-situ Modulus of Subgrade Reaction (k) and Elastic Modulus

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, E. of Moville (Project #6)

Polynomial Fit Parameters

First Cycle		*Second Cycle*			
a_1	-1.57E-04	a_1	6.69E-05	θ_{max} (deg)	0.1271
a_2	1.25E-02	a_2	3.54E-03		
R^2	1.00	R^2	1.00		

NOTES:
1. Test performed per AASHTO T222/ASTM D1196.
2. k-value determined using:
   (a) calculated stress at 0.05 in. plate deformation (δ) for first loading cycle, per PCA design guidelines, and
   (b) for a defined target stress and calculating corresponding plate deformations using polynomial fit parameters.



Automated Plate Load Test [APLT]

Test:	In-Situ Static Plate Load Test: Two Loading Cycles.				
Date:	11/15/2017	Time:	2:41:24 PM	Test ID	**Hwy20_30Static_6_5Fill**
Tested By	DW, JV	Location:	Hwy 20 (E. of Moville)	Sta.	NA
Latitude:	42.482430	Longitude:	95.9953450	Elev. (ft):	1371
Comments:	Select subgrade. Fill Area.				

Cycle	Stage	Load Step	Target Applied Load (lbs)	Target Applied Stress (psi)	Actual Applied Stress (psi)	Deformation (in.)			Average Def. (in.)
						Sensor 1	Sensor 2	Sensor 3	
0	Seating	0	707	1	*1.35*	0.0054	0.0055	0.0098	**0.0069**
Zero load and deformation sensors after applying the seating stress.									
1	Seating	0	0	0	*0.00*	*0.0000*	*0.0000*	*0.0000*	**0.0000**
1	Load	1	1767	2.5	*2.51*	*0.0164*	*0.0145*	*0.0207*	**0.0172**
1	Load	2	3534	5	*4.99*	*0.0296*	*0.0321*	*0.0411*	**0.0343**
1	Load	3	5301	7.5	*7.48*	*0.0437*	*0.0489*	*0.0596*	**0.0507**
1	Load	4	7069	10	*9.97*	*0.0565*	*0.0645*	*0.0778*	**0.0663**
1	Load	5	8836	12.5	*12.45*	*0.0705*	*0.0817*	*0.0977*	**0.0833**
1	Load	6	10603	15	*14.69*	*0.0837*	*0.0969*	*0.1153*	**0.0987**
1	Unload	7	7069	10	*9.87*	*0.0739*	*0.0867*	*0.1041*	**0.0882**
1	Unload	8	3534	5	*4.70*	*0.0590*	*0.0695*	*0.0846*	**0.0710**
1	Unload	9	1767	2.5	*2.52*	*0.0501*	*0.0573*	*0.0708*	**0.0594**
2	Load	10	3534	5	*4.99*	*0.0577*	*0.0639*	*0.0792*	**0.0669**
2	Load	11	7069	10	*9.96*	*0.0699*	*0.0822*	*0.0989*	**0.0837**
2	Load	12	10603	15	*14.90*	*0.0847*	*0.1003*	*0.1200*	**0.1017**
2	Unload	13	1767	2.5	*2.33*	*0.0527*	*0.0628*	*0.0769*	**0.0641**
2	Unload	14	0	0	*0.00*	*0.0422*	*0.0446*	*0.0514*	**0.0461**

Plate Diameter:	*30.0*	in.
Shape factor:	**1.57**	
Material Type:	*A*	A = Cohesive, B = Granular, C = Intermediate
Poisson's ratio:	*0.35*	
Design Stress:	*10.0*	psi
Target Deformation:	*0.05*	in.

AASHTO T222 Method
PCA Design Criteria

k_{u1} **(pci) @ design stress:**	**145**
k_u **(pci) @ δ = 0.05 in.:**	**145**

Modulus at target deformation

Stress @ δ = 0.05 in. (psi)	**7.5**
E_1 (psi)	**2,992**
k'_u (pci)	**149**
k_u (pci)	**145**

Plate Bending Correction for

$k'_u \geq 100$ *and* $1{,}000$ *pci*

$$k_u = -39.9178 + 5.5076\,[k'_u]^{0.7019}$$

Modulus at target/design applied stress

First Loading Cycle

δ_1 (in.)	**0.0670**
E_1 (psi)	**2,997**
k'_{u1} (pci)	**149**
k_{u1} (pci)	**145**

Second Loading Cycle

δ_2 (in.)	**0.0318**
E_2 (psi)	**5,624**
k'_{u2} (pci)	**315**
k_{u2} (pci)	**272**
E_2 / E_1 or k_2 / k_1 Ratio	**1.9**

In-situ Modulus of Subgrade Reaction (k) and Elastic Modulus

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 20, E. of Moville (Project #6)

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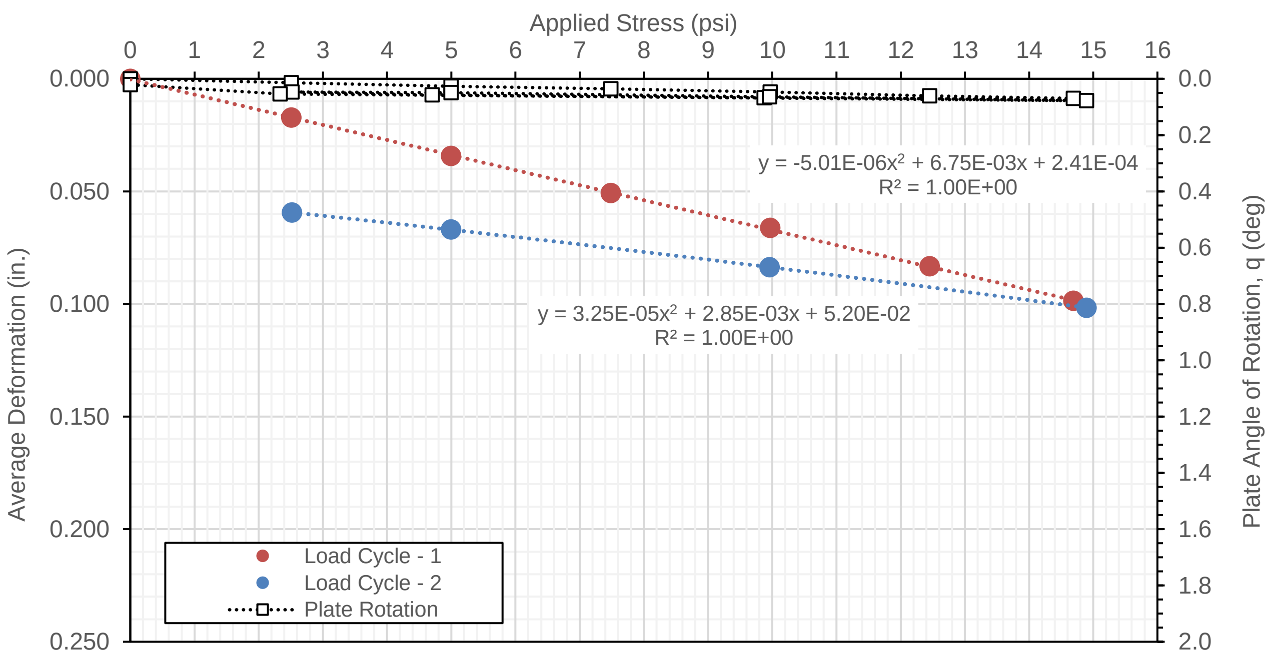
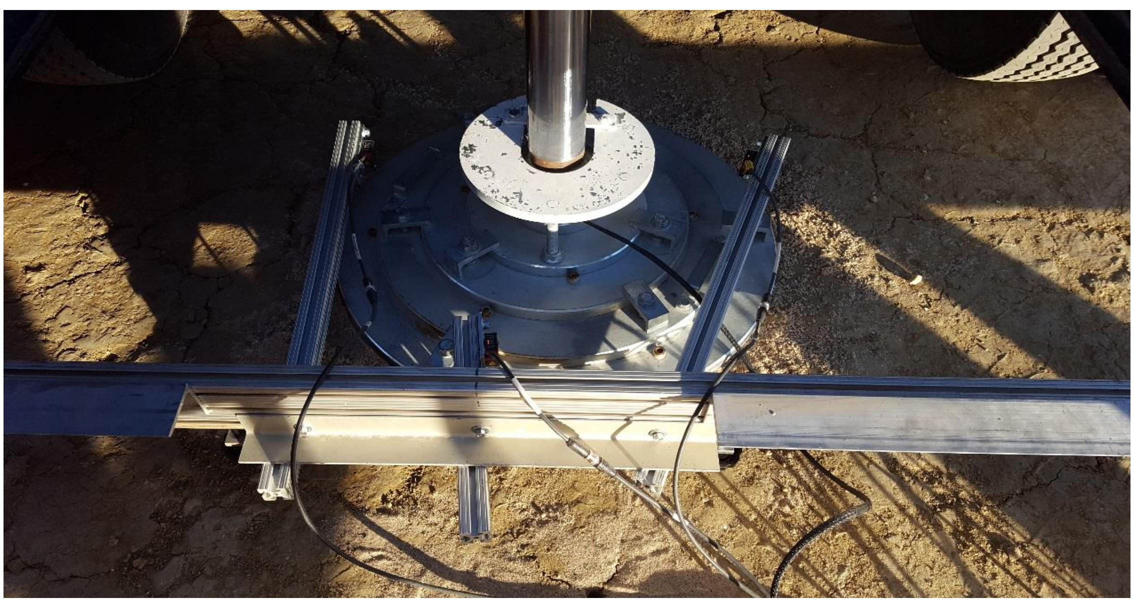
Polynomial Fit Parameters

First Cycle		*Second Cycle*			
a_1	-5.01E-06	a_1	3.25E-05	θ_{max} (deg)	0.0780
a_2	6.75E-03	a_2	2.85E-03		
R^2	1.00	R^2	1.00		

NOTES:
1. Test performed per AASHTO T222/ASTM D1196.
2. k-value determined using:
   (a) calculated stress at 0.05 in. plate deformation (δ) for first loading cycle, per PCA design guidelines, and
   (b) for a defined target stress and calculating corresponding plate deformations using polynomial fit parameters.





Date of Test	11/15/2017	Test ID	PT 1	Operator	DW/JV	ASTM	D6951
Latitude	42.4825130		Longitude	95.9931180		Elevation (ft)	1389
Location	Hwy 20 E. of Moville		Station	NA			
Comments	Select Subgrade, Cut rea.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg.Top 12 in. of Subgrade	11.6	18.7	16.6	3,817
Avg. Bottom 12 in. of Subgrade	40.0	2.2	4.2	910
Ratio of Avg. Top/Bottom Layer	0.3	8.7	4.0	4.2
Std.Dev.Top 12 in. of Subgrade.	13.1	23.3	19.1	4,420
Std. Dev. Bottom 12 in. of Subgrade	4.9	0.6	1.9	403

NOTES:

Subgrade is classified as CL

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

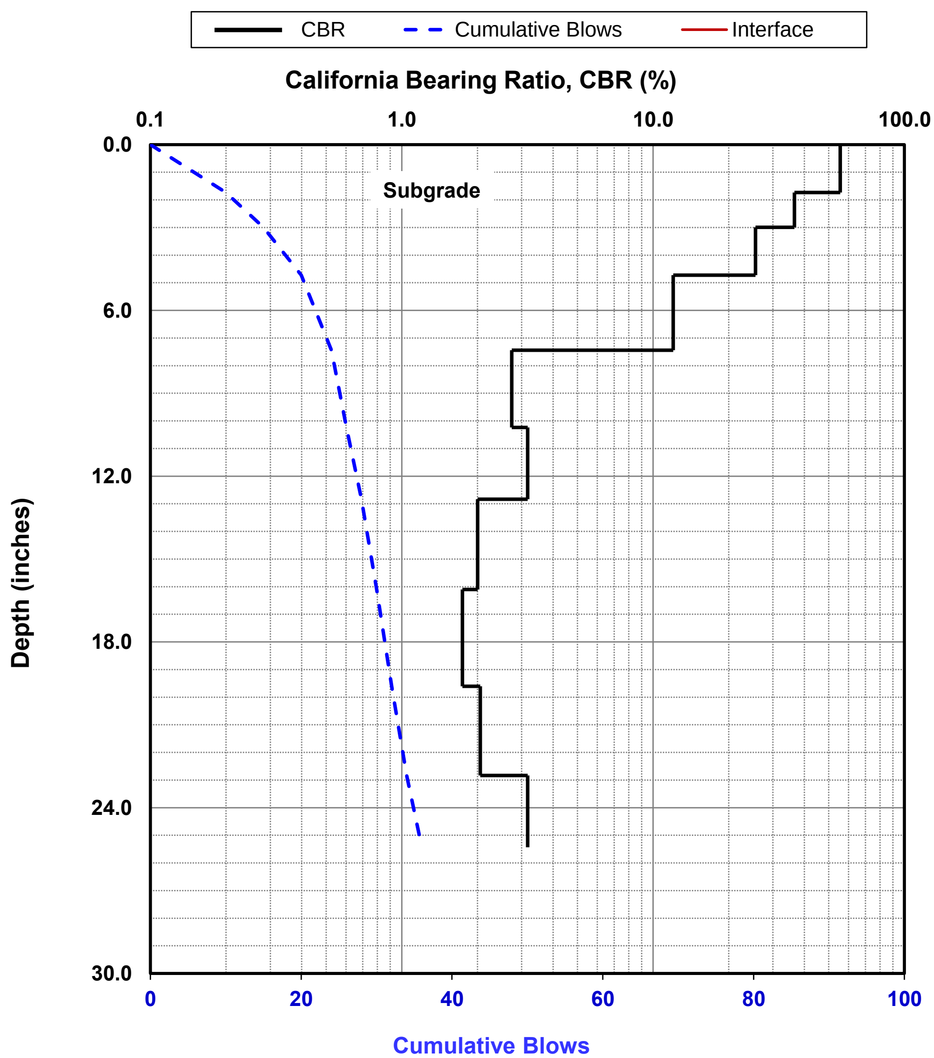
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, E. of Moville (Project #6)

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Date of Test	11/15/2017	Test ID	PT 2	Operator	DW/JV	ASTM	D6951
Latitude	42.4825210		Longitude	95.9933930		Elevation (ft)	1384
Location	Hwy 20 E. of Moville		Station	NA			
Comments	Select Subgrade, Cut rea.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg.Top 12 in. of Subgrade	12.3	17.6	16.0	3,665
Avg. Bottom 12 in. of Subgrade	48.3	1.5	3.3	708
Ratio of Avg. Top/Bottom Layer	0.3	11.9	4.9	5.2
Std.Dev.Top 12 in. of Subgrade.	13.3	18.9	16.7	3,840
Std. Dev. Bottom 12 in. of Subgrade	13.2	0.6	1.9	392

NOTES:

Subgrade is classified as CL

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

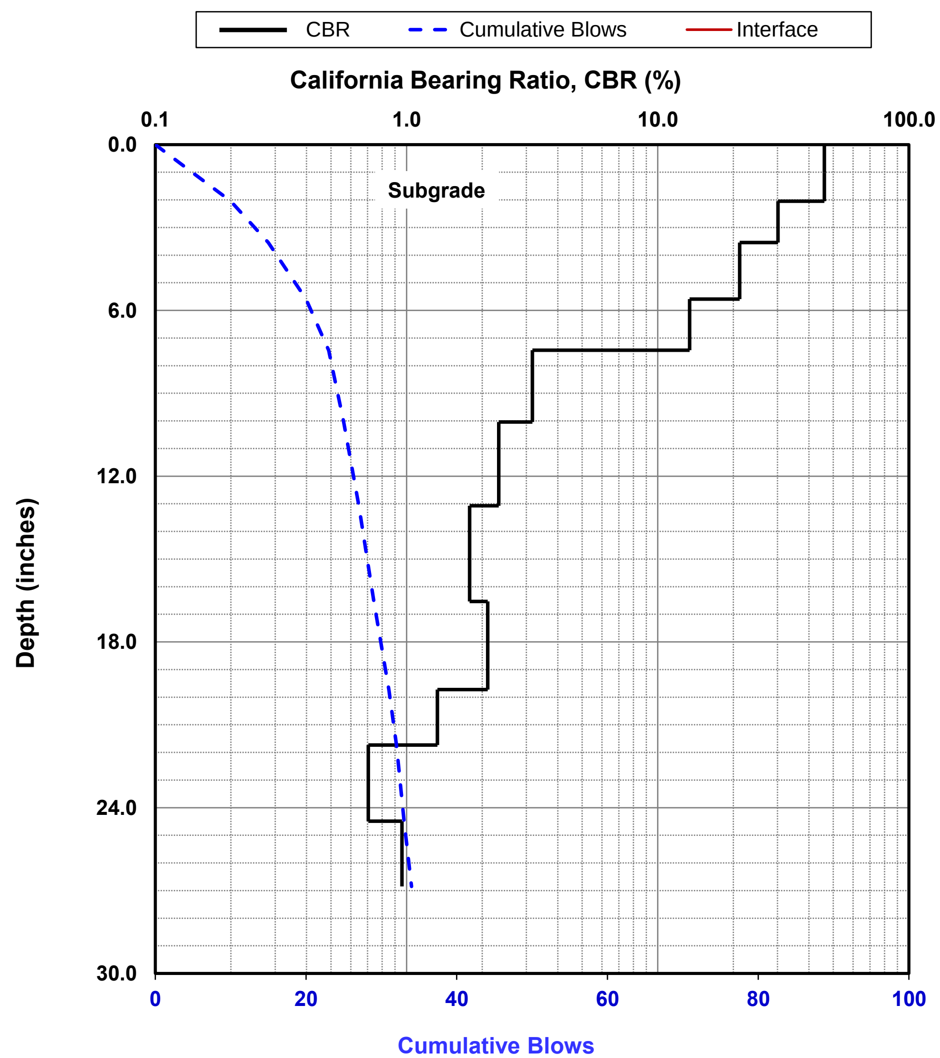
[2]E (ksi) = $(17.6\ CBR^{0.64}) \times 0.1450377$

[3]S_u (psf) = $(3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, E. of Moville (Project #6)

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Date of Test	11/15/2017	Test ID	PT 3	Operator	DW/JV	ASTM	D6951
Latitude	42.4824940		Longitude	95.9943920		Elevation (ft)	1392
Location	Hwy 20 E. of Moville		Station	NA			
Comments	Select Subgrade, Cut rea.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg.Top 12 in. of Subgrade	15.1	13.9	13.8	3,140
Avg. Bottom 12 in. of Subgrade	39.6	2.2	4.2	922
Ratio of Avg. Top/Bottom Layer	0.4	6.3	3.3	3.4
Std.Dev.Top 12 in. of Subgrade.	14.6	13.3	13.4	3,042
Std. Dev. Bottom 12 in. of Subgrade	4.2	0.6	1.7	368

NOTES:

Subgrade is classified as CL

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

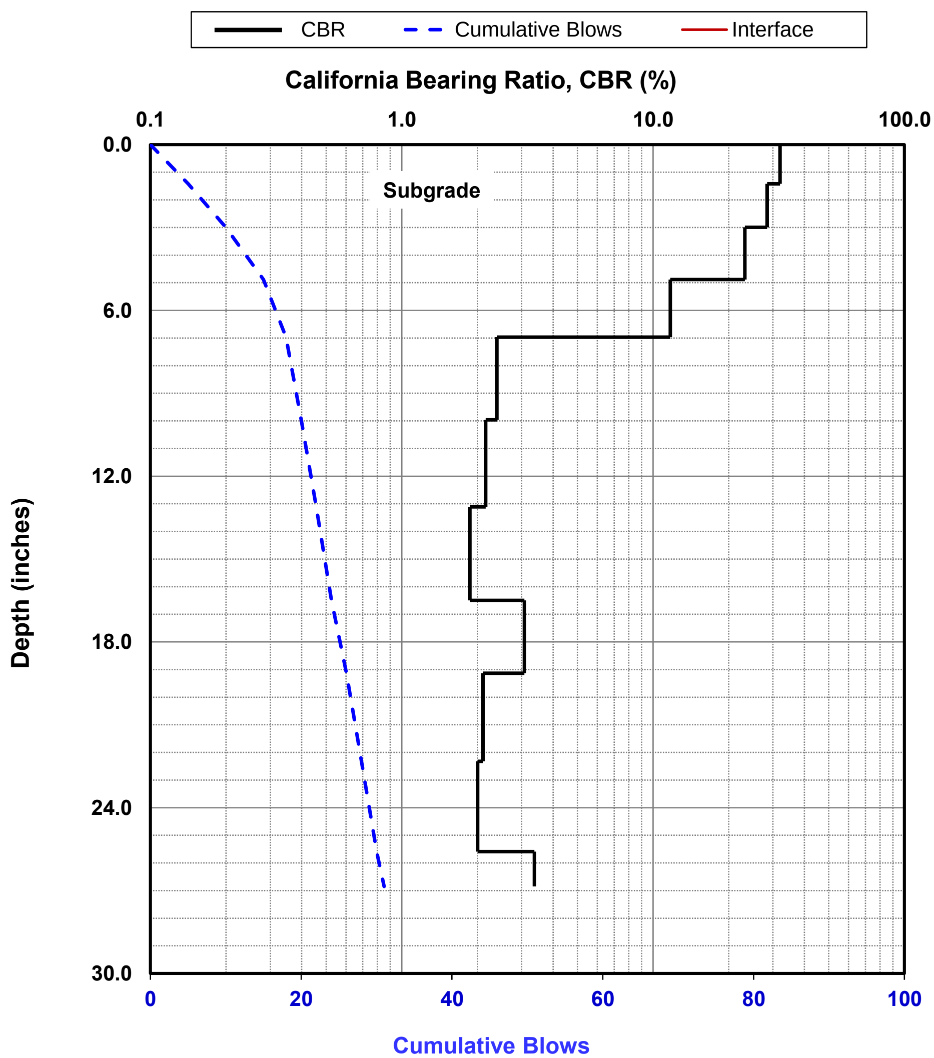
[2]$E\text{ (ksi)} = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\text{ (psf)} = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name: Iowa DOT STIC

Project ID: SIA-00001

Location: Hwy 20, E. of Moville (Project #6)

Date of Test	11/15/2017	Test ID	PT 4	Operator	DW/JV	ASTM	D6951
Latitude	42.4824600	Longitude		95.9949490		Elevation (ft)	1393
Location	Hwy 20 E. of Moville	Station		NA			
Comments	Select Subgrade, fill area.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg.Top 12 in. of Subgrade	9.8	22.7	18.8	4,338
Avg. Bottom 12 in. of Subgrade	41.9	2.0	3.9	857
Ratio of Avg. Top/Bottom Layer	0.2	11.5	4.8	5.1
Std.Dev.Top 12 in. of Subgrade.	8.6	18.8	16.7	3,837
Std. Dev. Bottom 12 in. of Subgrade	1.0	0.1	0.6	117

NOTES:

Subgrade is classified as CL

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

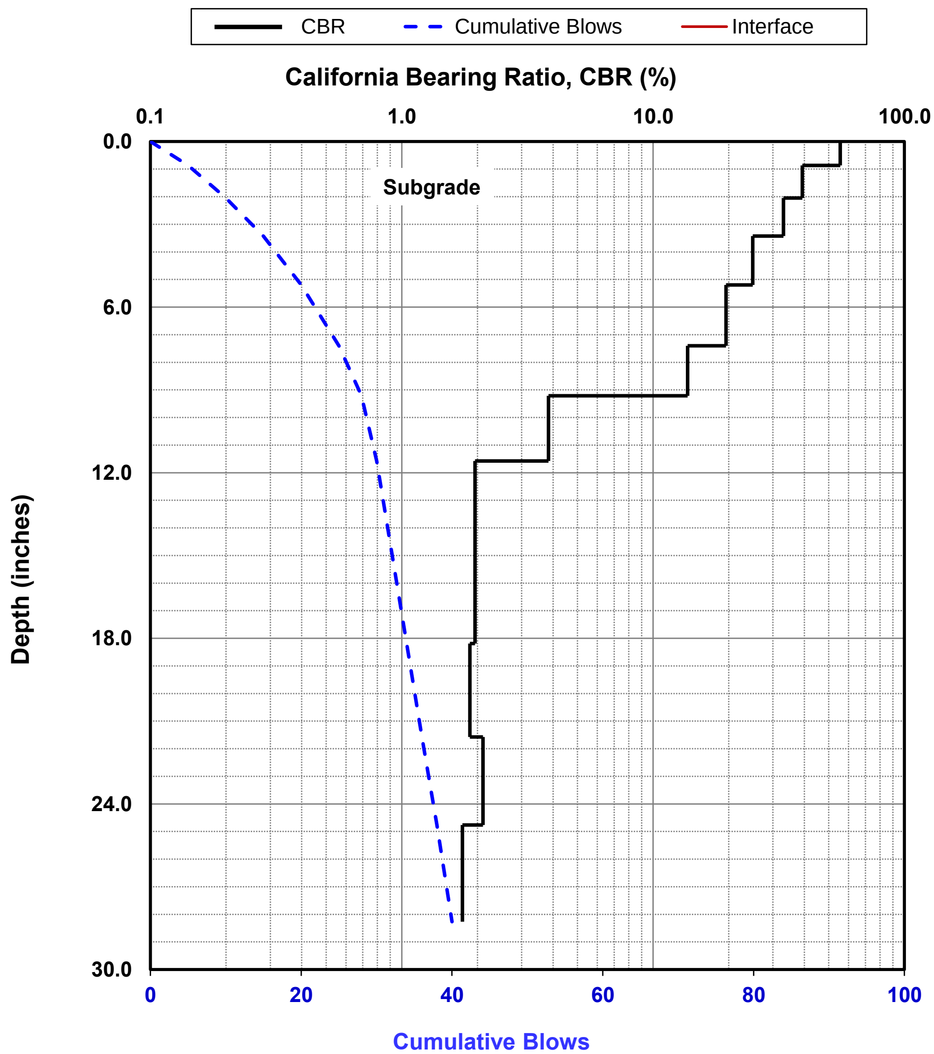
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, E. of Moville (Project #6)

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Date of Test	11/15/2017	Test ID	PT 5	Operator	DW/JV	ASTM	D6951
Latitude	42.4824410		Longitude	95.9953230		Elevation (ft)	1381
Location	Hwy 20 E. of Moville		Station	NA			
Comments	Select Subgrade, fill area.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg.Top 12 in. of Subgrade	10.9	20.0	17.4	4,000
Avg. Bottom 12 in. of Subgrade	37.1	2.5	4.6	1,006
Ratio of Avg. Top/Bottom Layer	0.3	8.0	3.8	4.0
Std.Dev.Top 12 in. of Subgrade.	14.7	19.0	16.8	3,861
Std. Dev. Bottom 12 in. of Subgrade	8.2	1.1	2.7	584

NOTES:

Subgrade is classified as CL

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

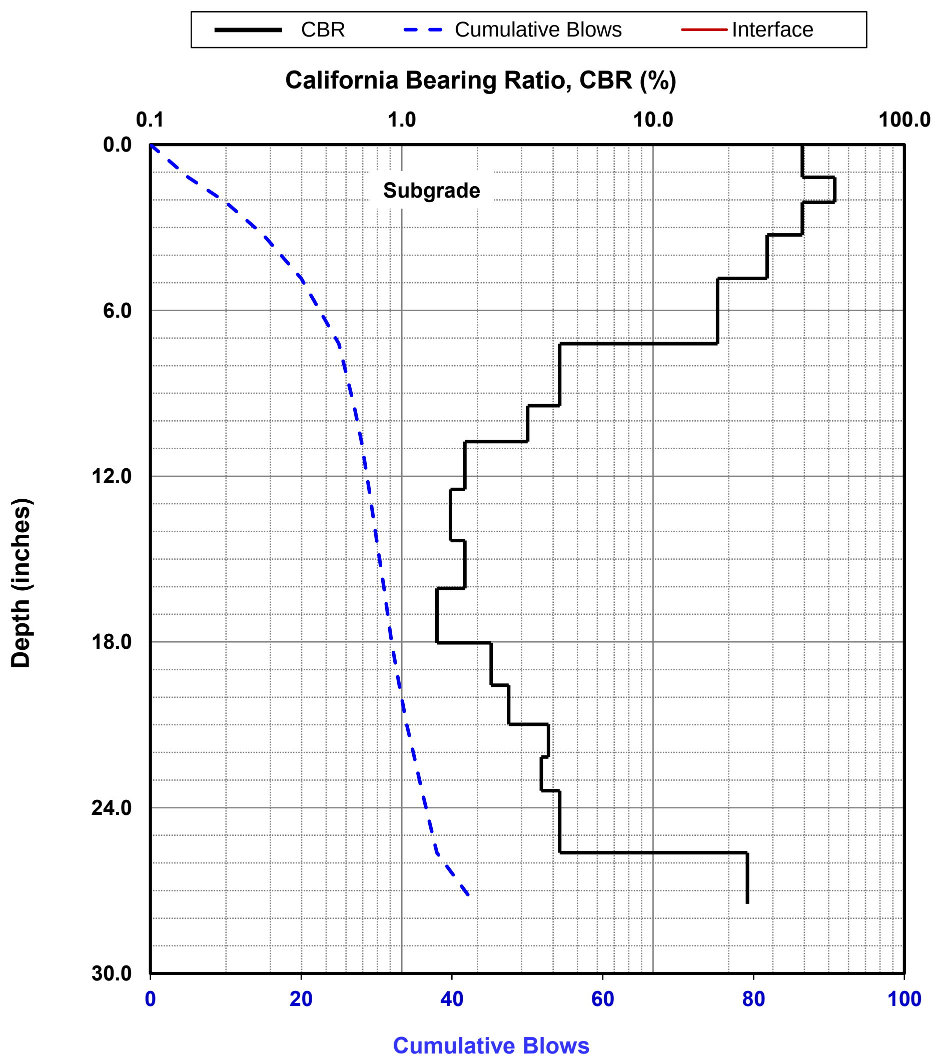
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name: Iowa DOT STIC

Project ID: SIA-00001

Location: Hwy 20, E. of Moville (Project #6)

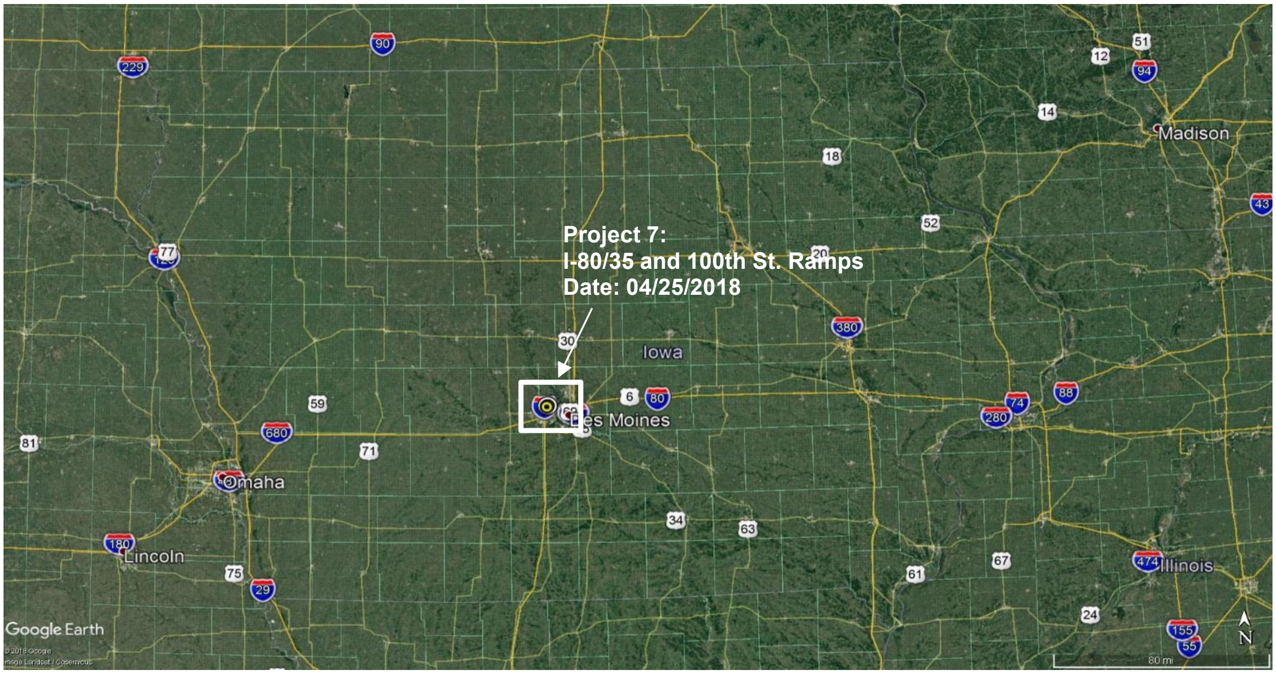
Field Project # 7

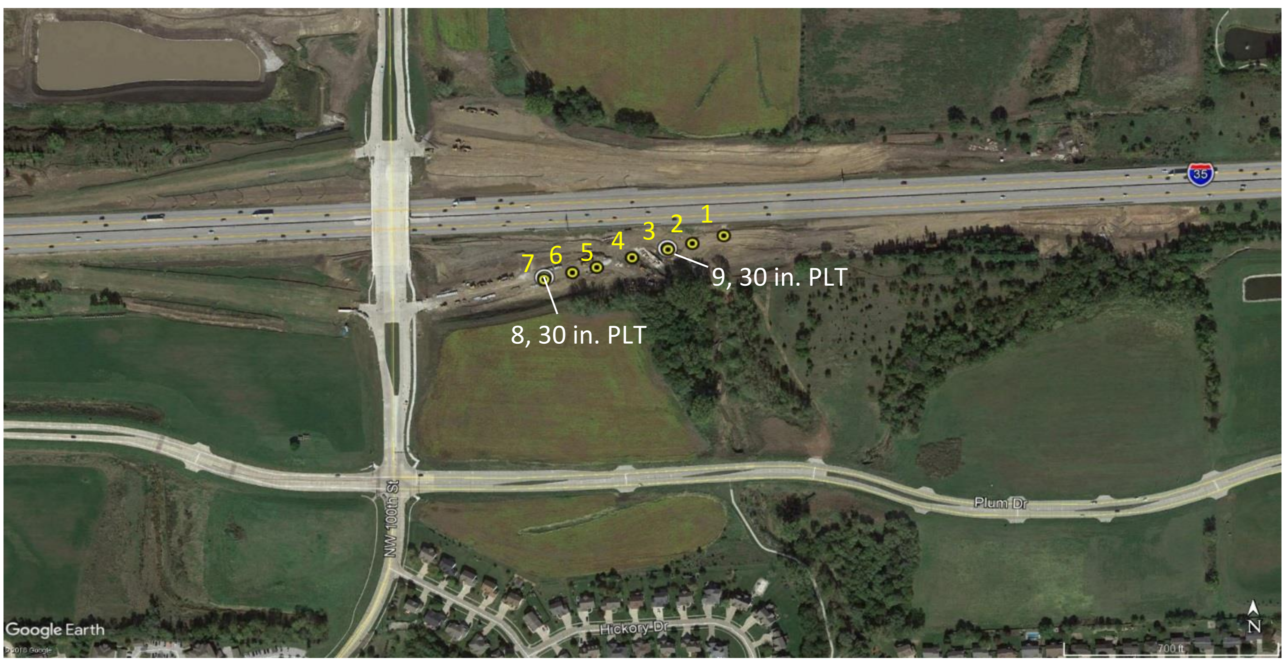
I-80/I-35 and 100th St. Ramp, Polk County, IA

04/25/2018

Modified subbase (crushed limestone) over select subgrade

Project Location and Test Locations





Test Locations	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Polk County I-80/35 and 100th St. Ramps (Project #7)

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Site Conditions and Pictures

Pictures

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Polk County I-80/35 and 100th St. Ramps (Project #7)

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Summary of Test Results

Summary of Cyclic APLT Test Results

Point #	4 psi cyclic stress @ surface				8 psi plate cyclic stress @ surface			
	$M_{r\text{-Comp}}$ (psi)	$M_{r\text{-Base}}$ (psi)	$M_{r\text{-SG}}$ (psi)	$\Delta\delta_p$ ([in.)	$M_{r\text{-Comp}}$ (psi)	$M_{r\text{-Base}}$ (psi)	$M_{r\text{-SG}}$ (psi)	$\Delta\delta_p$ ([in.)
PT1	18,130	18,530	17,130	0.0000	19,116	20,883	16,059	0.0002
PT2	12,776	21,681	5,772	0.0003	13,875	26,334	5,590	0.0004
PT3	10,419	20,497	4,053	0.0000	9,671	18,356	3,898	0.0003
PT4	15,047	24,618	7,065	0.0000	15,135	25,380	6,961	-0.0001
PT5	24,094	28,687	17,283	-0.0001	23,857	27,563	18,231	-0.0003
PT6	17,942	19,550	15,053	-0.0002	19,344	22,648	14,307	-0.0001
PT7	18,901	17,007	23,683	0.0001	20,272	19,283	22,417	0.0003
AVG	**16,759**	**21,510**	**12,863**	**0.0000**	**17,324**	**22,921**	**12,495**	**0.0001**
COV	27%	19%	57%	1342%	27%	16%	57%	302%

Point #	13 psi cyclic stress @ surface				18 psi plate cyclic stress @ surface			
	$M_{r\text{-Comp}}$ (psi)	$M_{r\text{-Base}}$ (psi)	$M_{r\text{-SG}}$ (psi)	$\Delta\delta_p$ ([in.)	$M_{r\text{-Comp}}$ (psi)	$M_{r\text{-Base}}$ (psi)	$M_{r\text{-SG}}$ (psi)	$\Delta\delta_p$ ([in.)
PT1	20,254	23,334	15,555	0.0008	19,277	22,516	14,458	0.0096
PT2	14,502	29,955	5,365	0.0008	13,512	28,091	4,974	0.0049
PT3	9,800	19,817	3,702	0.0009	8,518	16,873	3,284	0.0104
PT4	16,092	29,778	6,658	0.0004	15,463	29,605	6,170	0.0039
PT5	25,398	31,217	17,584	-0.0001	24,518	30,428	16,752	0.0043
PT6	19,522	23,572	13,852	0.0006	17,924	21,492	12,905	0.0075
PT7	23,481	23,655	23,039	0.0013	22,073	22,142	21,934	0.0061
AVG	**18,436**	**25,904**	**12,251**	**0.0007**	**17,326**	**24,449**	**11,497**	**0.0067**
COV	29%	17%	59%	64%	31%	21%	60%	39%

Point #	28 psi cyclic stress @ surface				38 psi plate cyclic stress @ surface			
	$M_{r\text{-Comp}}$ (psi)	$M_{r\text{-Base}}$ (psi)	$M_{r\text{-SG}}$ (psi)	$\Delta\delta_p$ ([in.)	$M_{r\text{-Comp}}$ (psi)	$M_{r\text{-Base}}$ (psi)	$M_{r\text{-SG}}$ (psi)	$\Delta\delta_p$ ([in.)
PT1	15,685	18,077	12,137	0.0515	13,989	15,961	10,914	0.0924
PT2	11,954	26,238	4,177	0.0224	10,819	24,900	3,617	0.0434
PT3	6,682	13,601	2,509	0.0548	5,701	12,210	2,039	0.1047
PT4	13,661	28,154	5,069	0.0160	12,400	26,799	4,391	0.0301
PT5	22,628	29,109	14,642	0.0193	21,837	28,631	13,737	0.0345
PT6	14,662	17,298	10,840	0.0356	13,311	15,779	9,747	0.0656
PT7	20,592	21,249	19,307	0.0255	19,418	20,160	17,945	0.0455
AVG	**15,123**	**21,961**	**9,812**	**0.0321**	**13,925**	**20,634**	**8,913**	**0.0594**
COV	35%	27%	63%	49%	39%	30%	66%	49%

Summary of Test Results

Summary of AASHTO (2015) universal model parameters

$M_{r\text{-}Comp}$							
Point #	**$k^*_{1(Comp)}$**	**$k^*_{2(Comp)}$**	**$k^*_{3(Comp)}$**	**R^2(Adj.)**	**Std. Error (psi)**	**$M_{r\text{-}Comp(pred)\text{-}BP}$ (psi)**	**$\sigma_{cyclic\text{-}BP}$ (psi)**
PT1	1,644.0	0.352	-3.501	0.940	572	19,938	10.5
PT2	1,118.5	0.308	-2.883	0.963	253	14,171	11.2
PT3	866.4	0.167	-3.273	0.967	340	10,334	5.0
PT4	1,221.8	0.221	-2.245	0.906	400	15,836	10.2
PT5	1,802.9	0.126	-1.242	0.768	558	24,767	10.6
PT6	1,611.8	0.305	-3.377	0.963	475	19,375	9.3
PT7	1,612.4	0.337	-2.371	0.762	731	22,311	15.5
AVG	**1,411.1**	**0.260**	**-2.699**	**0.895**	**476**	**18,105**	**10.3**
COV	24%	34%	-0.299	10%	34%	27%	30%

$M_{r\text{-}Base}$					
Point #	**$k^*_{1(Base)}$**	**$k^*_{2(Base(}$**	**$k^*_{3(Base)}$**	**R^2(Adj.)**	**Std. Error (psi)**
PT1	1,865.4	0.522	-4.385	0.917	773
PT2	2,071.4	0.481	-3.185	0.894	876
PT3	1,619.1	0.123	-2.655	0.901	1,012
PT4	1,982.7	0.282	-1.709	0.711	982
PT5	2,072.3	0.117	-0.793	0.174	677
PT6	1,930.7	0.443	-4.163	0.936	732
PT7	1,543.4	0.453	-2.748	0.816	900
AVG	**1,869.3**	**0.346**	**-2.805**	**0.764**	**850**
COV	11%	50%	-0.455	36%	15%

$M_{r\text{-}SG}$					
Point #	**$k^*_{1(SG)}$**	**$k^*_{2(SG)}$**	**$k^*_{3(SG)}$**	**R^2(Adj.)**	**Std. Error (psi)**
PT1	1,398.4	0.046	-3.853	0.989	249
PT2	843.8	0.325	-12.267	0.998	40
PT3	771.0	0.439	-16.297	0.998	38
PT4	1,178.7	0.403	-13.182	0.994	83
PT5	1,884.9	0.247	-5.309	0.949	388
PT6	1,300.7	0.085	-4.321	0.991	201
PT7	2,037.6	0.124	-3.218	0.937	552
AVG	**1,345.0**	**0.238**	**-8.350**	**0.979**	**222**
COV	36%	66%	-0.645	3%	87%

AASHTO 2015 Universal Model:

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

Summary of Test Results

Summary of Static PLT results

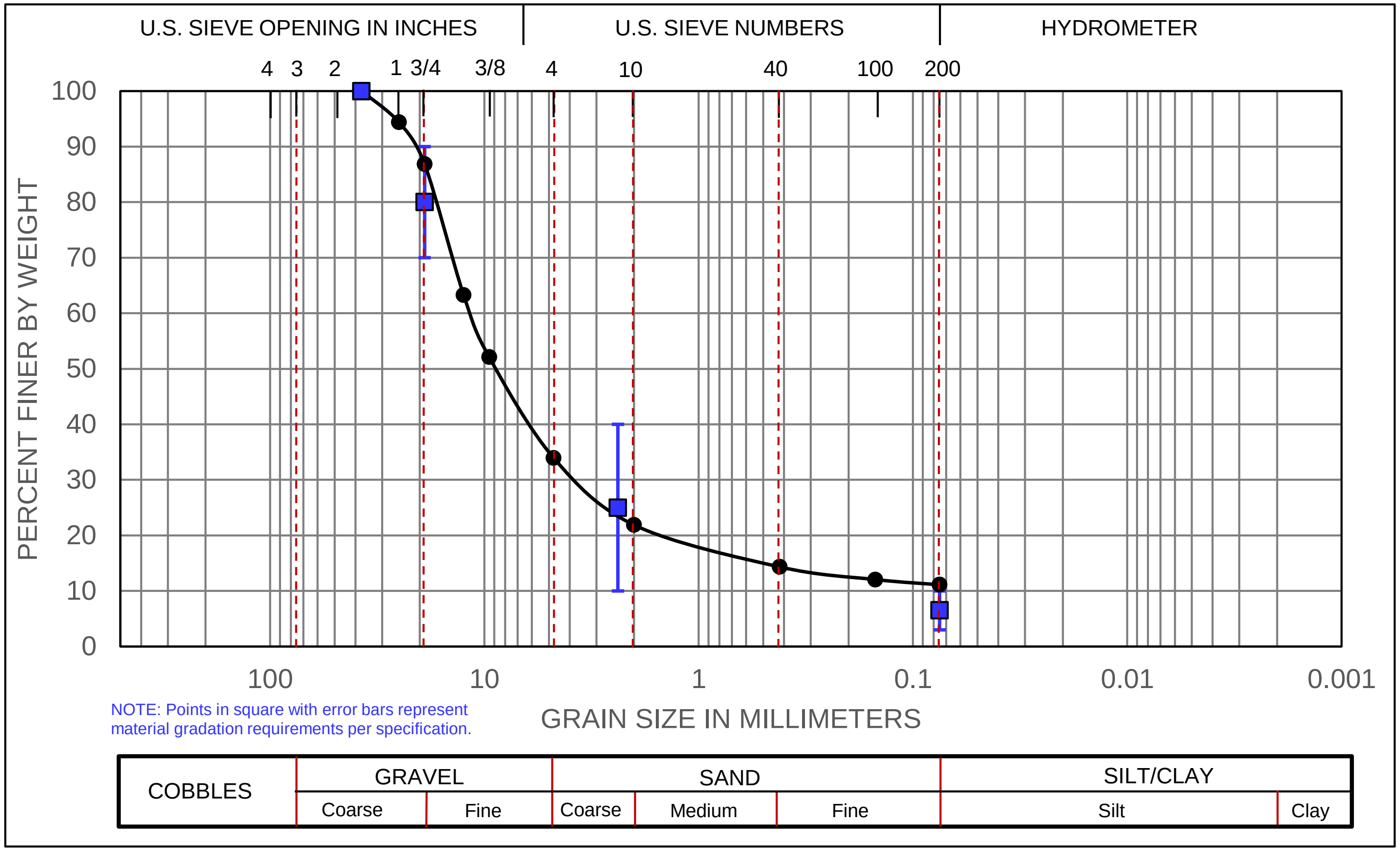
Point #	30 in. static PLT: k_u (pci) at δ = 0.05 in.[a]	k_{u1} (pci) at 10 psi[b]	k_{u2} (pci) at 10 psi	Ratio of k_{u2}/k_{u1}	
PT8	246	284	450	1.6	Same as PT7
PT9	47	39	129	3.3	Sane as PT3

[a]per PCA design critera
[b]per AASHTO T222

Summary of DCP test results

Point #	Subbase Layer Thickness, H_1 (in.)	Subbase Layer Avg. CBR (%)	Subbase Layer St. Dev CBR (%)	Subgrade Layer Thickness, H_2 (in.)	Subgrade Layer Avg. CBR (%)	Subgrade Layer St. Dev CBR (%)	Ratio CBR_1/CBR_2
PT1	12.0	20.3	10.3	12.0	5.0	3.2	4.1
PT2	12.0	22.3	9.7	12.0	11.8	5.9	1.9
PT3 / PT9	12.0	19.5	13.7	12.0	9.4	12.5	2.1
PT4	12.0	32.5	14.7	12.0	19.2	12.5	1.7
PT5	12.0	34.5	10.6	12.0	15.1	6.2	2.3
PT6	12.0	29.0	11.4	12.0	8.1	7.9	3.6
PT7 / PT8	12.0	36.5	16.5	12.0	14.9	6.9	2.5
AVG	**12.0**	**27.8**	**12.4**	**12.0**	**11.9**	**7.9**	**2.6**
COV	**0%**	**25%**	**21%**	**0%**	**41%**	**44%**	**35%**

GRAIN SIZE DISTRIBUTION
ASTM D422/C136



Gradation Summary

% Gravel	66.1
% Sand	22.8
% Fines	11.1
D_{10} (mm)	NA
D_{30} (mm)	3.851
D_{50} (mm)	8.947
D_{60} (mm)	11.616
D_{85} (mm)	18.495
C_u	NA
C_c	NA

Atterberg Limits

LL	NP
PL	NP
PI	NP

Classification

AASHTO:	A-1-a
USCS:	GP-GM

MATERIAL: Crushed Limestone (Iowa DOT Gradation 4123 - Modified Subbase)

LOCATION: Polk County I-80/35 and 100th St. Ramps (Project #7) **TESTED BY:** DW

SAMPLE DATE: 4/25/2018 **TEST DATE:** 9/7/2018

Gradation and Soil Classification Test Results

Project Name: Iowa DOT STIC

Project ID: SIA-00001

Location: Polk County I-80/35 and 100th St. Ramps (Project #7)

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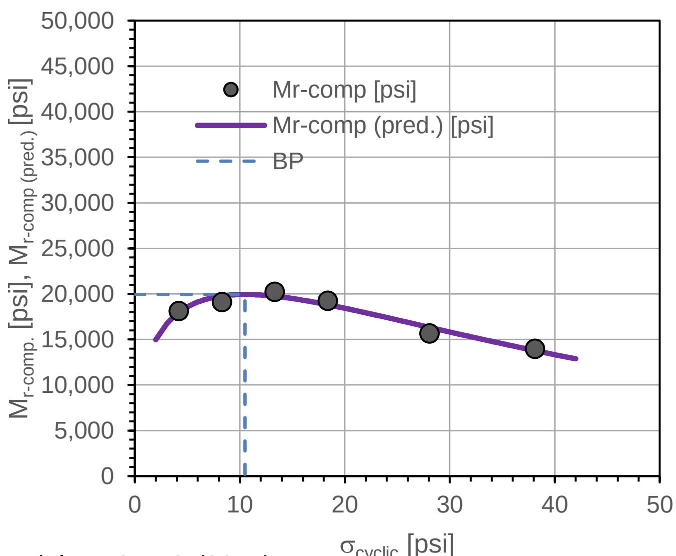
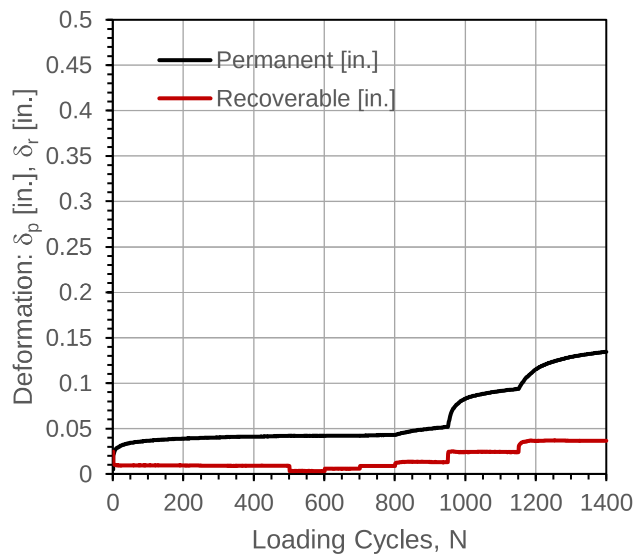
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	4/25/2018	Time:	10:19:55 AM	Test ID	**STIC_7_12_pt1**
Tested By	DW, HG	Location:	I-80/35 100th St.	Sta.	4508 + 00
Latitude,N:	41.651440	Longitude,W:	93.751991	Elev. (ft):	913
Comments:	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.33	---	---	0.0420	---	0.118	---
1	100	4.21	18,130	17,970	0.0420	0.0000	-0.041	Y
2	100	8.29	19,116	19,777	0.0422	0.0002	0.221	Y
3	100	13.33	20,254	19,743	0.0428	0.0008	0.398	Y
4	150	18.38	19,277	18,811	0.0517	0.0096	0.756	N
5	200	28.06	15,685	16,332	0.0935	0.0515	0.501	N
6	250	38.13	13,989	13,774	0.1344	0.0924	0.667	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	1,644.0	4.35E-07
k^*_2	0.352	2.05E-02
k^*_3	-3.501	8.58E-03
Adj. R^2	0.940	
Std. Error [psi]	572	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]		19,938
	$\sigma_{cyclic\text{-}BP}$ [psi]	10.5

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Polk County I-80/35 and 100th St. Ramps (Project #7)

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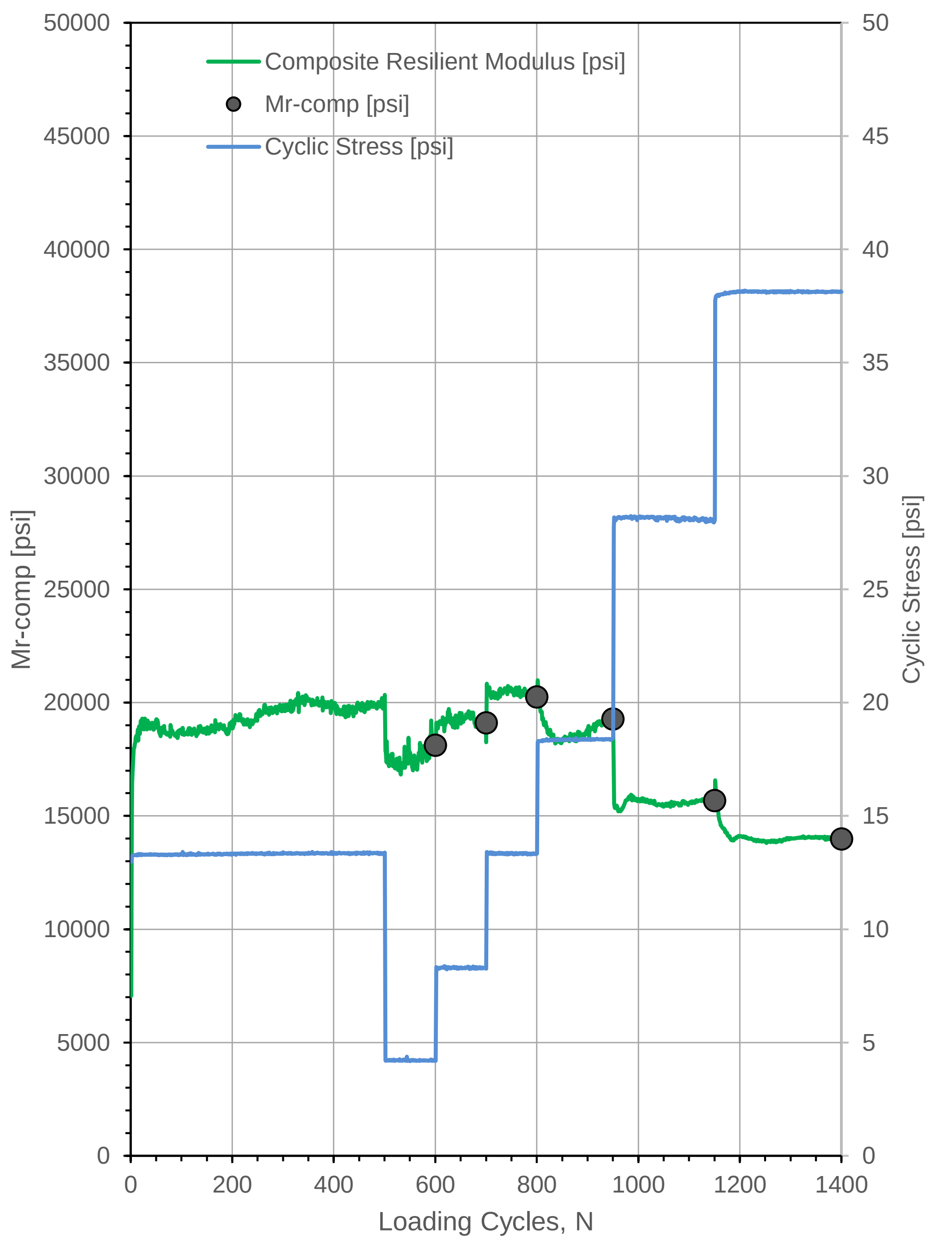
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	4/25/2018	Time:	10:19:55 AM	Test ID	**STIC_7_12_pt1**
Tested By	DW, HG	Location:	I-80/35 100th St.	Sta.	4508 + 00
Latitude,N:	41.651440	Longitude,W:	93.751991	Elev. (ft):	913
Comments:	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	14,976
3	16,659
4	17,784
5	18,564
6	19,109
7	19,482
8	19,726
9	19,869
10	19,932
11	19,931
12	19,878
13	19,783
14	19,653
15	19,495
16	19,313
17	19,113
18	18,896
21	18,182
22	17,928
23	17,670
24	17,409
25	17,145
26	16,880
27	16,614
28	16,349
29	16,084
30	15,821
31	15,560
32	15,300
33	15,044
34	14,790
35	14,538
36	14,291
37	14,046
38	13,805
39	13,567
40	13,334



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Polk County I-80/35 and 100th St. Ramps (Project #7)

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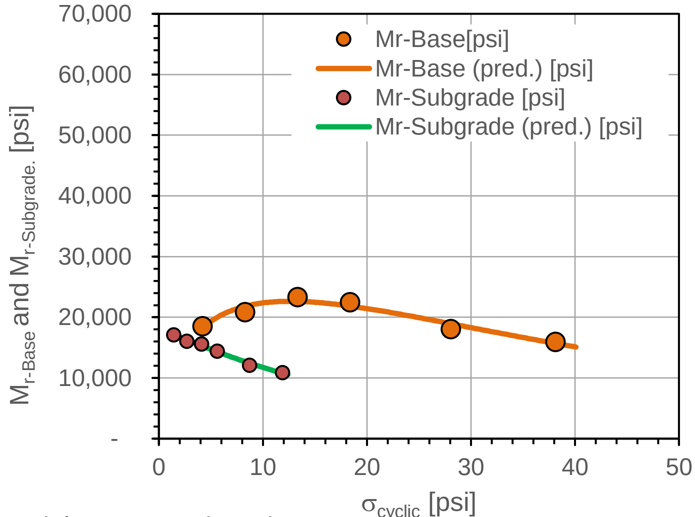
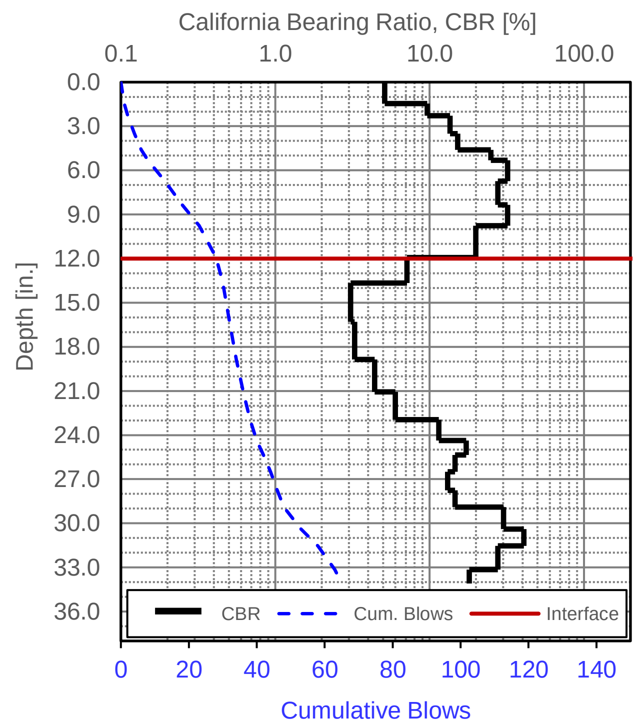
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	4/25/2018	Time:	10:19:55 AM	Test ID	**STIC_7_12_pt1**
Tested By	DW, HG	Location:	I-80/35 100th St.	Sta.	4508 + 00
Latitude,N:	41.651440	Longitude,W:	93.751991	Elev. (ft):	913
Comments:	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.				

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	13.33	---	---	---	---	---	---
1	100	4.21	18,530	18,312	1.43	17,130	17,101	1.08
2	100	8.29	20,883	21,813	2.68	16,059	16,284	1.30
3	100	13.33	23,334	22,619	4.13	15,555	15,301	1.50
4	100	18.38	22,516	21,849	5.62	14,458	14,313	1.56
5	100	28.06	18,077	18,943	8.70	12,137	12,450	1.49
6	100	38.13	15,961	15,687	11.89	10,914	10,792	1.46

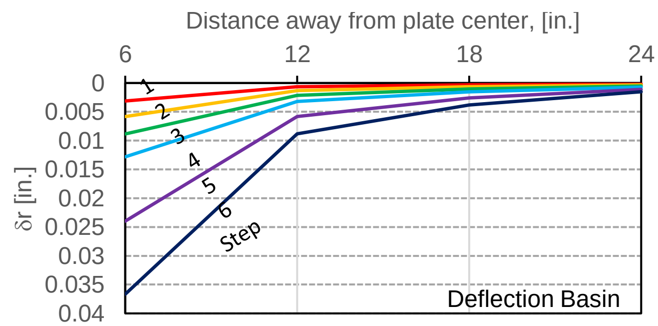




Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1 (Base)	1865.4	7.35E-07
k^*_2 (Base)	0.522	1.18E-02
k^*_3 (Base)	-4.385	7.81E-03
Adj. R^2	0.917	
Std. Error [psi]	773	
k^*_1 (Subgrade)	1398.4	4.49E-06
k^*_2 (Subgrade)	0.046	5.61E-01
k^*_3 (Subgrade)	-3.853	1.86E-02
Adj. R^2	0.989	
Std. Error [psi]	249	



In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Polk County I-80/35 and 100th St. Ramps (Project #7)

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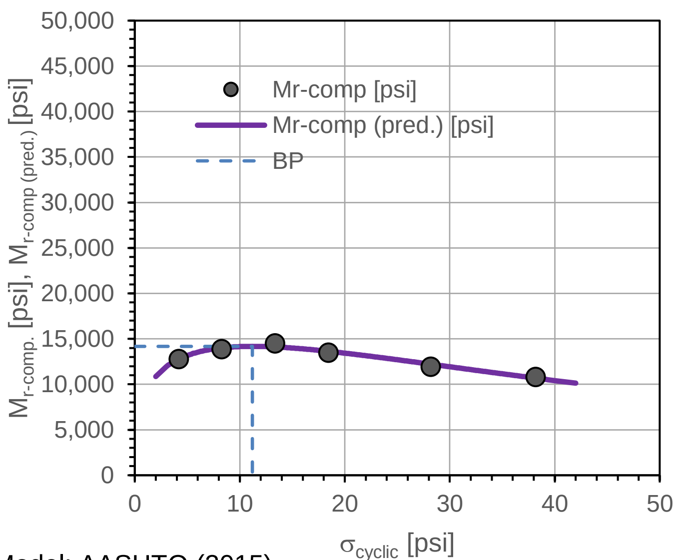
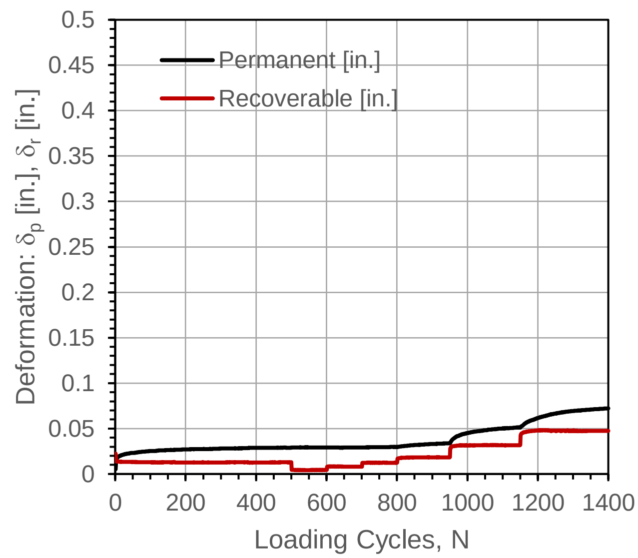
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	4/25/2018	Time:	10:58:25 AM	Test ID	**STIC_7_12_pt2**
Tested By	DW, HG	Location:	I-80/35 100th St.	Sta.	4507 + 05
Latitude,N:	41.651367	Longitude,W:	93.752365	Elev. (ft):	911
Comments:	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.38	---	---	0.0289	---	0.117	---
1	100	4.20	12,776	12,785	0.0292	0.0003	0.174	Y
2	100	8.29	13,875	14,008	0.0292	0.0004	0.068	Y
3	100	13.38	14,502	14,107	0.0297	0.0008	0.359	Y
4	150	18.44	13,512	13,629	0.0338	0.0049	0.648	N
5	200	28.19	11,954	12,213	0.0512	0.0224	0.492	N
6	250	38.17	10,819	10,683	0.0722	0.0434	0.605	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	1,118.5	1.08E-07
k^*_2	0.308	7.03E-03
k^*_3	-2.883	3.37E-03
Adj. R^2	0.963	
Std. Error [psi]	253	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	14,171
$\sigma_{cyclic\text{-}BP}$ [psi]	11.2

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Polk County I-80/35 and 100th St. Ramps (Project #7)

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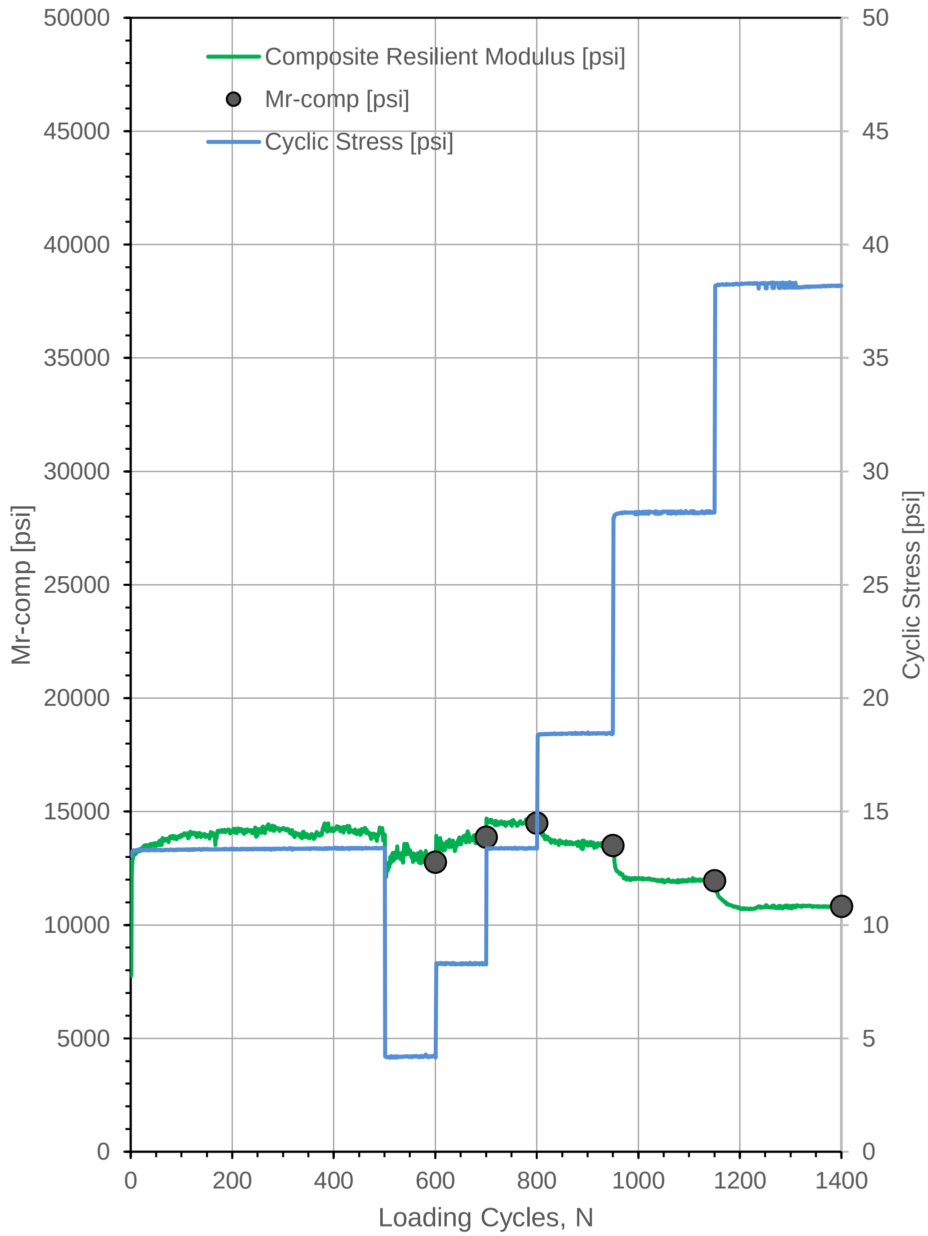
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	4/25/2018	Time:	10:58:25 AM	Test ID	**STIC_7_12_pt2**
Tested By	DW, HG	Location:	I-80/35 100th St.	Sta.	4507 + 05
Latitude,N:	41.651367	Longitude,W:	93.752365	Elev. (ft):	911
Comments:	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	10,858
3	11,941
4	12,667
5	13,176
6	13,538
7	13,794
8	13,969
9	14,083
10	14,146
11	14,170
12	14,162
13	14,126
14	14,069
15	13,993
16	13,902
17	13,798
18	13,683
21	13,292
22	13,151
23	13,005
24	12,856
25	12,705
26	12,552
27	12,397
28	12,242
29	12,086
30	11,931
31	11,775
32	11,620
33	11,465
34	11,312
35	11,159
36	11,008
37	10,858
38	10,709
39	10,562
40	10,417



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Polk County I-80/35 and 100th St. Ramps (Project #7)

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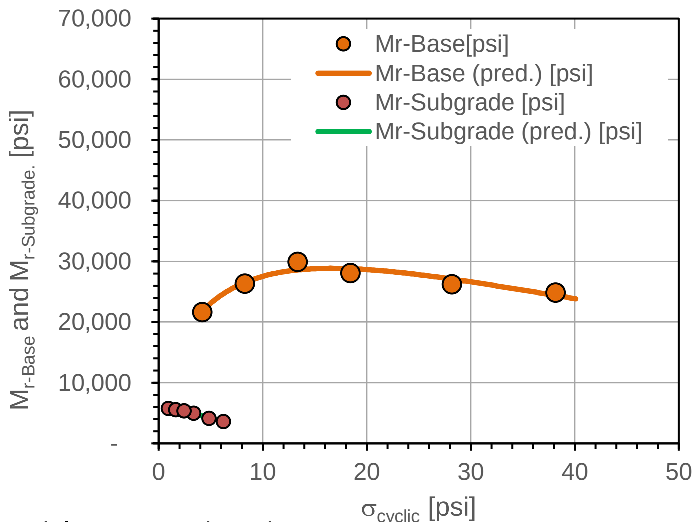
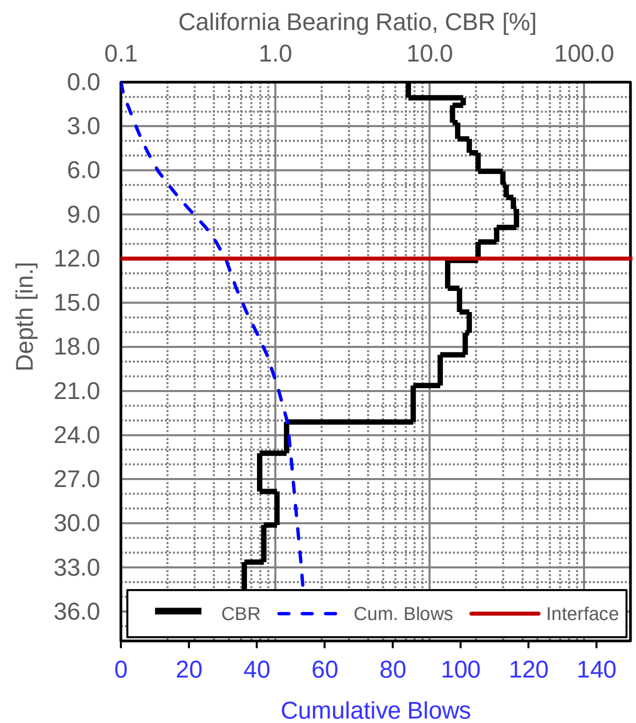
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	4/25/2018	Time:	10:58:25 AM	Test ID	**STIC_7_12_pt2**
Tested By	DW, HG	Location:	I-80/35 100th St.	Sta.	4507 + 05
Latitude,N:	41.651367	Longitude,W:	93.752365	Elev. (ft):	911
Comments:	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.				

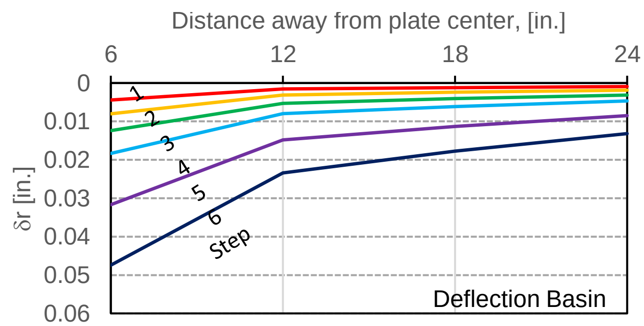
Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	13.38	---	---	---	---	---	---
1	100	4.20	21,681	21,788	0.93	5,772	5,760	3.76
2	100	8.29	26,334	26,518	1.65	5,590	5,632	4.71
3	100	13.38	29,955	28,587	2.45	5,365	5,343	5.58
4	100	18.44	28,091	28,793	3.36	4,974	4,934	5.65
5	100	28.19	26,238	27,076	4.85	4,177	4,224	6.28
6	100	38.17	24,900	24,375	6.23	3,617	3,601	6.88





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
$k^*_{1\ (Base)}$	2071.4	3.89E-07
$k^*_{2\ (Base)}$	0.481	8.51E-03
$k^*_{3\ (Base)}$	-3.185	1.10E-02
Adj. R^2	0.894	
Std. Error [psi]	876	
$k^*_{1\ (Subgrade)}$	843.8	4.08E-06
$k^*_{2\ (Subgrade)}$	0.325	6.98E-03
$k^*_{3\ (Subgrade)}$	-12.267	7.88E-04
Adj. R^2	0.998	
Std. Error [psi]	40	

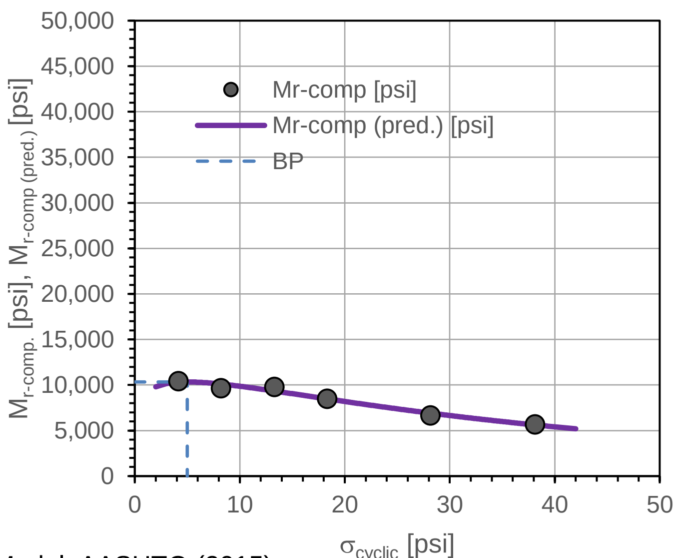
In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

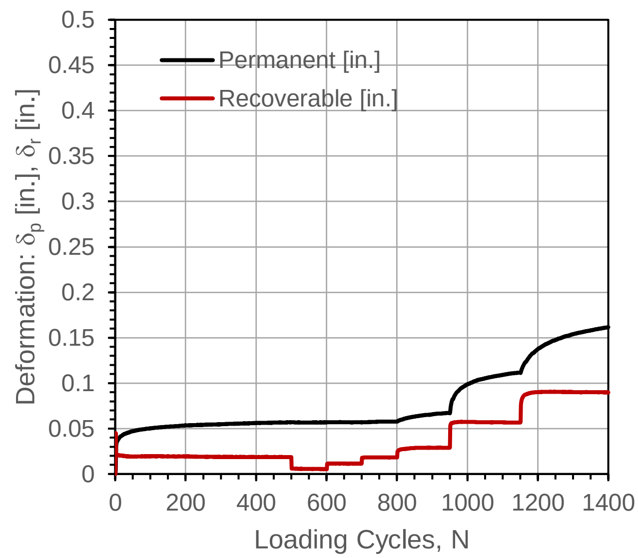
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Polk County I-80/35 and 100th St. Ramps (Project #7)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	4/25/2018	Time:	11:36:17 AM	Test ID	**STIC_7_12_pt3**
Tested By	DW, HG	Location:	I-80/35 100th St.	Sta.	4506 + 20
Latitude,N:	41.651310	Longitude,W:	93.752655	Elev. (ft):	912
Comments:	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.29	---	---	0.0568	---	0.148	---
1	100	4.16	10,419	10,307	0.0568	0.0000	-0.372	Y
2	100	8.21	9,671	10,108	0.0571	0.0003	0.403	Y
3	100	13.29	9,800	9,340	0.0577	0.0009	0.685	N
4	150	18.32	8,518	8,477	0.0673	0.0104	0.816	N
5	200	28.16	6,682	6,911	0.1117	0.0548	1.377	N
6	250	38.12	5,701	5,619	0.1616	0.1047	2.279	N





Model: AASHTO (2015)

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

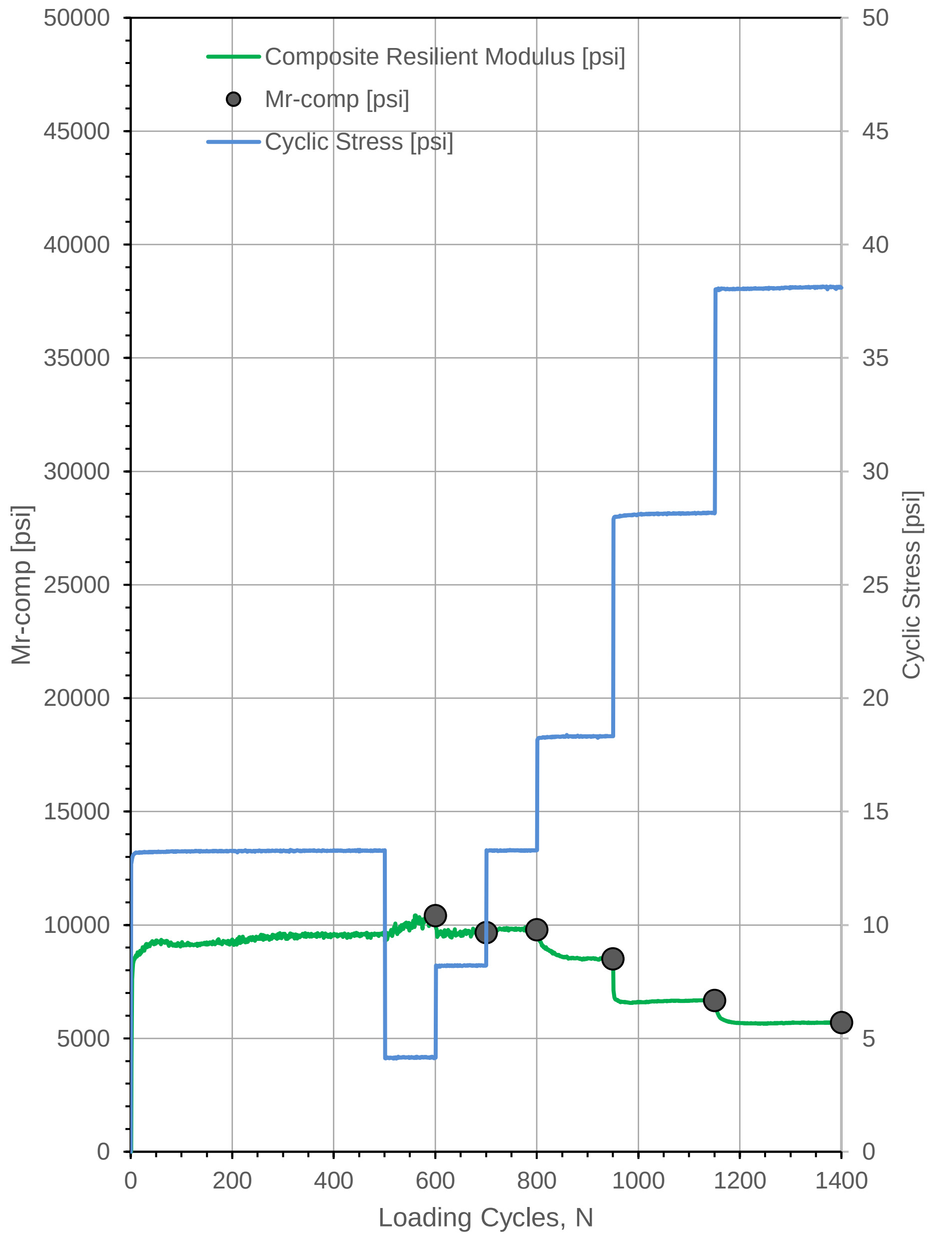
Parameter	Value	P-Value
k^*_1	866.4	8.67E-07
k^*_2	0.167	1.58E-01
k^*_3	-3.273	1.50E-02
Adj. R^2	0.967	
Std. Error [psi]	340	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	10,334
$\sigma_{cyclic\text{-}BP}$ [psi]	5.0

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	4/25/2018	Time:	11:36:17 AM	Test ID	**STIC_7_12_pt3**
Tested By	DW, HG	Location:	I-80/35 100th St.	Sta.	4506 + 20
Latitude,N:	41.651310	Longitude,W:	93.752655	Elev. (ft):	912
Comments:	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	9,813
3	10,148
4	10,294
5	10,334
6	10,307
7	10,236
8	10,133
9	10,008
10	9,867
11	9,715
12	9,554
13	9,389
14	9,219
15	9,048
16	8,875
17	8,703
18	8,531
21	8,025
22	7,861
23	7,699
24	7,540
25	7,384
26	7,231
27	7,081
28	6,934
29	6,791
30	6,650
31	6,512
32	6,378
33	6,246
34	6,118
35	5,992
36	5,870
37	5,750
38	5,633
39	5,519
40	5,408



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Polk County I-80/35 and 100th St. Ramps (Project #7)

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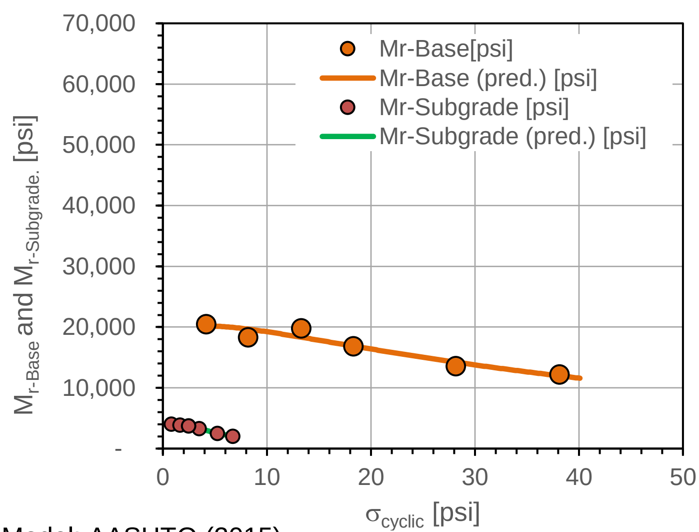
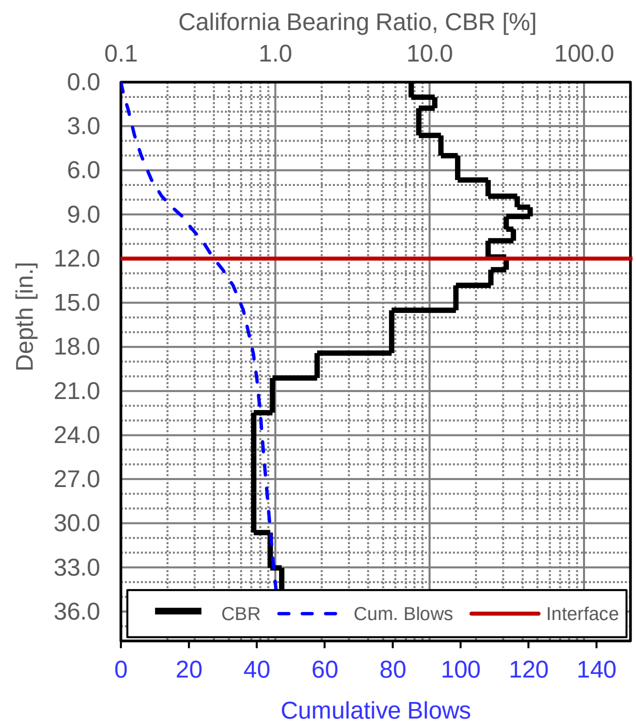
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	4/25/2018	Time:	11:36:17 AM	Test ID	**STIC_7_12_pt3**
Tested By	DW, HG	Location:	I-80/35 100th St.	Sta.	4506 + 20
Latitude,N:	41.651310	Longitude,W:	93.752655	Elev. (ft):	912
Comments:	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.				

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	13.29	---	---	---	---	---	---
1	100	4.16	20,497	20,152	0.80	4,053	4,044	5.06
2	100	8.21	18,356	19,666	1.64	3,898	3,941	4.71
3	100	13.29	19,817	18,333	2.49	3,702	3,666	5.35
4	100	18.32	16,873	16,877	3.50	3,284	3,258	5.14
5	100	28.16	13,601	14,222	5.24	2,509	2,551	5.42
6	100	38.12	12,210	11,979	6.73	2,039	2,024	5.99

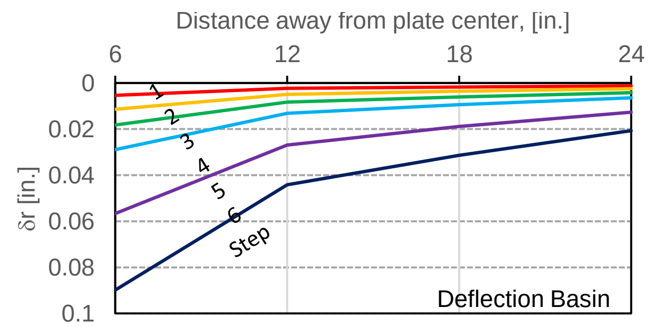




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\ (Base)}$	1619.1	2.38E-06
$k^*_{2\ (Base)}$	0.123	4.35E-01
$k^*_{3\ (Base)}$	-2.655	7.52E-02
Adj. R^2	0.901	
Std. Error [psi]	1012	
$k^*_{1\ (Subgrade)}$	771.0	7.66E-06
$k^*_{2\ (Subgrade)}$	0.439	5.13E-03
$k^*_{3\ (Subgrade)}$	-16.297	5.77E-04
Adj. R^2	0.998	
Std. Error [psi]	38	



In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Polk County I-80/35 and 100th St. Ramps (Project #7)

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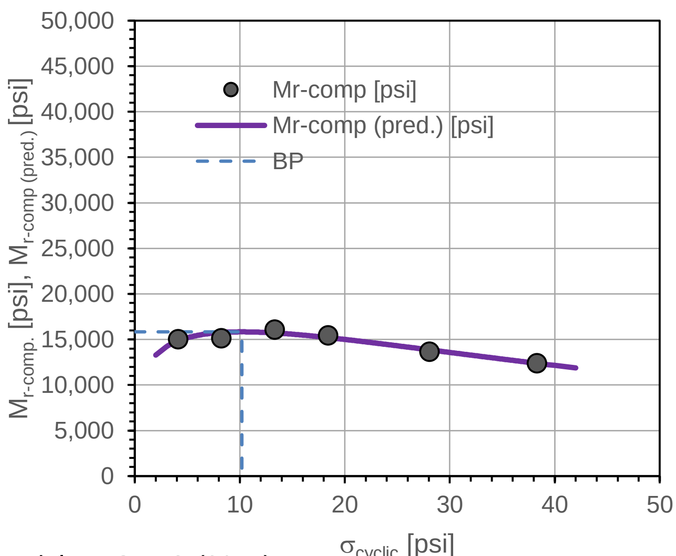
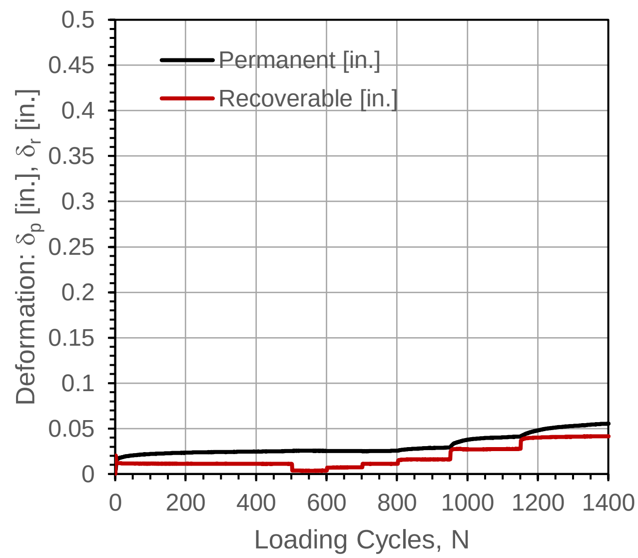
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	4/25/2018	Time:	12:11:18 PM	Test ID	**STIC_7_12_pt4**
Tested By	DW, HG	Location:	I-80/35 100th St.	Sta.	4505 + 00
Latitude,N:	41.651234	Longitude,W:	93.753082	Elev. (ft):	915
Comments:	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.32	---	---	0.0253	---	0.148	---
1	100	4.12	15,047	14,845	0.0253	0.0000	-0.372	Y
2	100	8.25	15,135	15,768	0.0252	-0.0001	0.403	Y
3	100	13.32	16,092	15,716	0.0257	0.0004	0.685	N
4	150	18.41	15,463	15,206	0.0292	0.0039	0.816	N
5	200	28.07	13,661	13,860	0.0413	0.0160	1.377	N
6	250	38.31	12,400	12,381	0.0554	0.0301	2.279	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	1,221.8	2.65E-07
k^*_2	0.221	3.88E-02
k^*_3	-2.245	1.60E-02
Adj. R^2	0.906	
Std. Error [psi]	400	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]		15,836
	$\sigma_{cyclic\text{-}BP}$ [psi]	10.2

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Polk County I-80/35 and 100th St. Ramps (Project #7)

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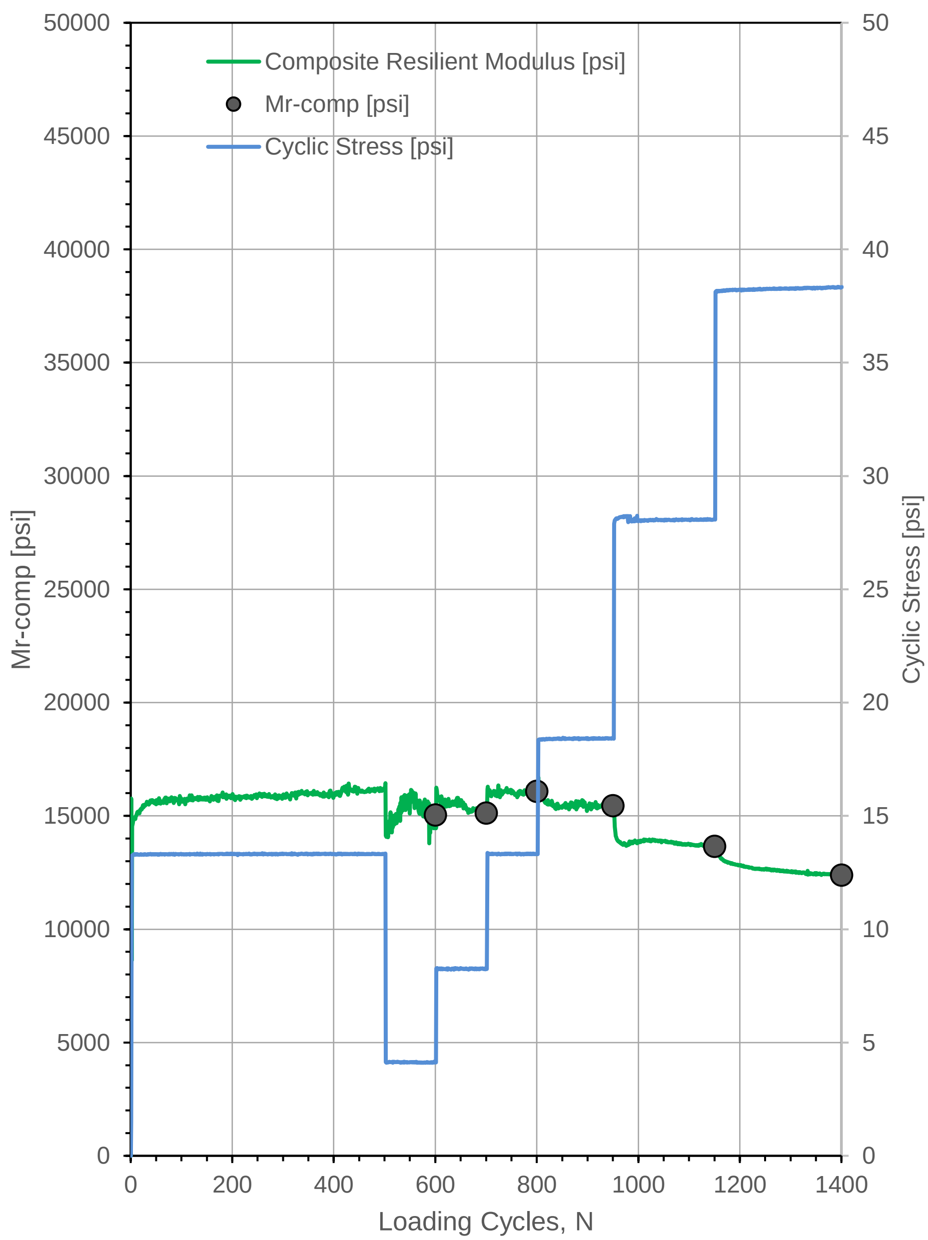
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	4/25/2018	Time:	12:11:18 PM	Test ID	**STIC_7_12_pt4**
Tested By	DW, HG	Location:	I-80/35 100th St.	Sta.	4505 + 00
Latitude,N:	41.651234	Longitude,W:	93.753082	Elev. (ft):	915
Comments:	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	13,294
3	14,203
4	14,789
5	15,184
6	15,454
7	15,634
8	15,748
9	15,811
10	15,835
11	15,827
12	15,792
13	15,737
14	15,665
15	15,578
16	15,480
17	15,372
18	15,256
21	14,871
22	14,734
23	14,594
24	14,452
25	14,309
26	14,163
27	14,017
28	13,871
29	13,724
30	13,577
31	13,430
32	13,284
33	13,139
34	12,994
35	12,850
36	12,707
37	12,566
38	12,425
39	12,286
40	12,148



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Polk County I-80/35 and 100th St. Ramps (Project #7)

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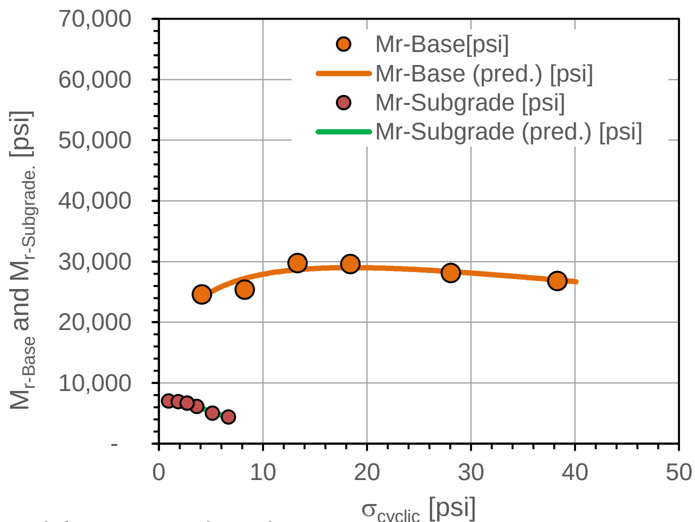
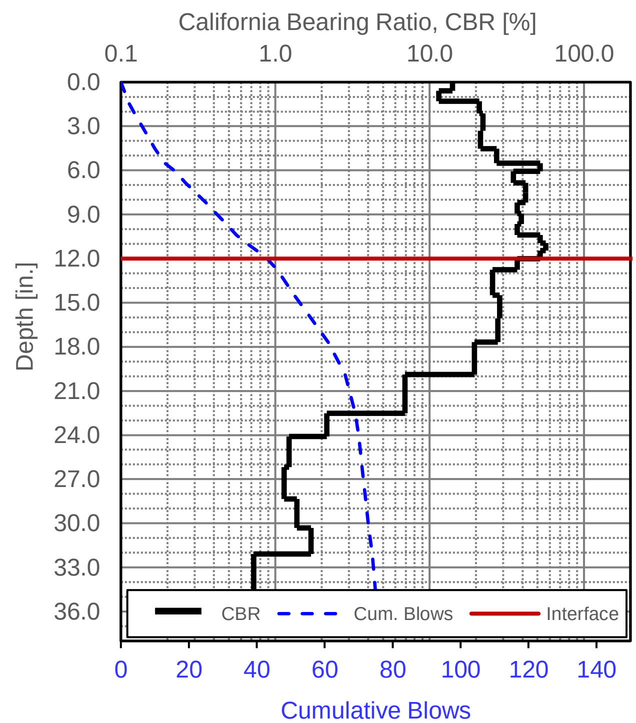
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	4/25/2018	Time:	12:11:18 PM	Test ID	**STIC_7_12_pt4**
Tested By	DW, HG	Location:	I-80/35 100th St.	Sta.	4505 + 00
Latitude,N:	41.651234	Longitude,W:	93.753082	Elev. (ft):	915
Comments:	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.				

Step	N	$\sigma_{cyclic\_surface}$ [psi]	M_{r-Base}[psi]	$M_{r-Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r-Subgrade}$ [psi]	$M_{r-Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	13.32	---	---	---	---	---	---
1	100	4.12	24,618	24,025	0.94	7,065	7,080	3.48
2	100	8.25	25,380	27,219	1.85	6,961	6,976	3.65
3	100	13.32	29,778	28,667	2.73	6,658	6,609	4.47
4	100	18.41	29,605	29,003	3.64	6,170	6,104	4.80
5	100	28.07	28,154	28,355	5.16	5,069	5,203	5.55
6	100	38.31	26,799	26,957	6.70	4,391	4,338	6.10

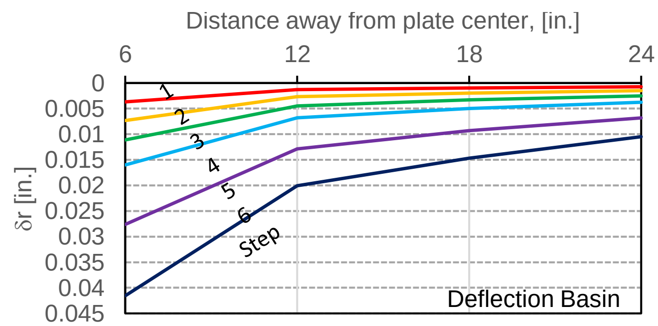




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\ (Base)}$	1982.7	8.87E-07
$k^*_{2\ (Base)}$	0.282	6.70E-02
$k^*_{3\ (Base)}$	-1.709	1.00E-01
Adj. R^2	0.711	
Std. Error [psi]	982	
$k^*_{1\ (Subgrade)}$	1178.7	1.67E-05
$k^*_{2\ (Subgrade)}$	0.403	1.72E-02
$k^*_{3\ (Subgrade)}$	-13.182	2.79E-03
Adj. R^2	0.994	
Std. Error [psi]	83	



In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Polk County I-80/35 and 100th St. Ramps (Project #7)

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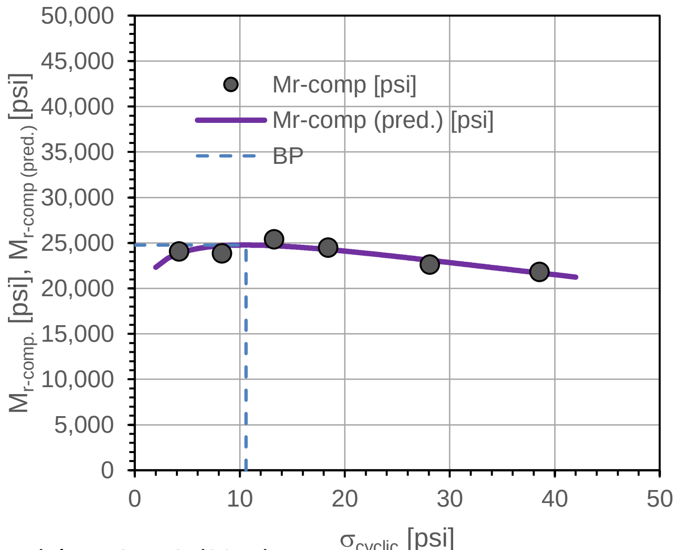
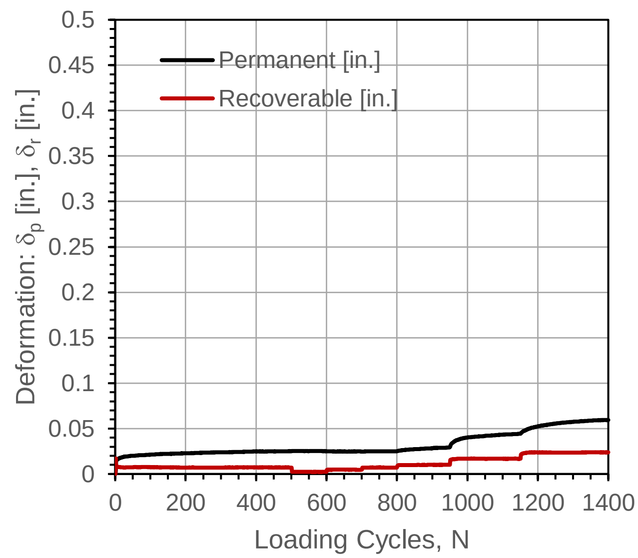
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	4/25/2018	Time:	12:48:05 PM	Test ID	**STIC_7_12_pt5**
Tested By	DW, HG	Location:	I-80/35 100th St.	Sta.	4503 + 80
Latitude,N:	41.651142	Longitude,W:	93.753502	Elev. (ft):	909
Comments:	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.27	---	---	0.0250	---	0.148	---
1	100	4.24	24,094	23,860	0.0249	-0.0001	-0.372	Y
2	100	8.32	23,857	24,692	0.0247	-0.0003	0.403	Y
3	100	13.27	25,398	24,690	0.0250	-0.0001	0.685	N
4	150	18.41	24,518	24,272	0.0294	0.0043	0.816	N
5	200	28.10	22,628	23,092	0.0443	0.0193	1.377	N
6	250	38.54	21,837	21,694	0.0595	0.0345	2.279	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	1,802.9	1.89E-07
k^*_2	0.126	1.30E-01
k^*_3	-1.242	6.54E-02
Adj. R^2	0.768	
Std. Error [psi]	558	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	24,767
$\sigma_{cyclic\text{-}BP}$ [psi]	10.6

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Polk County I-80/35 and 100th St. Ramps (Project #7)

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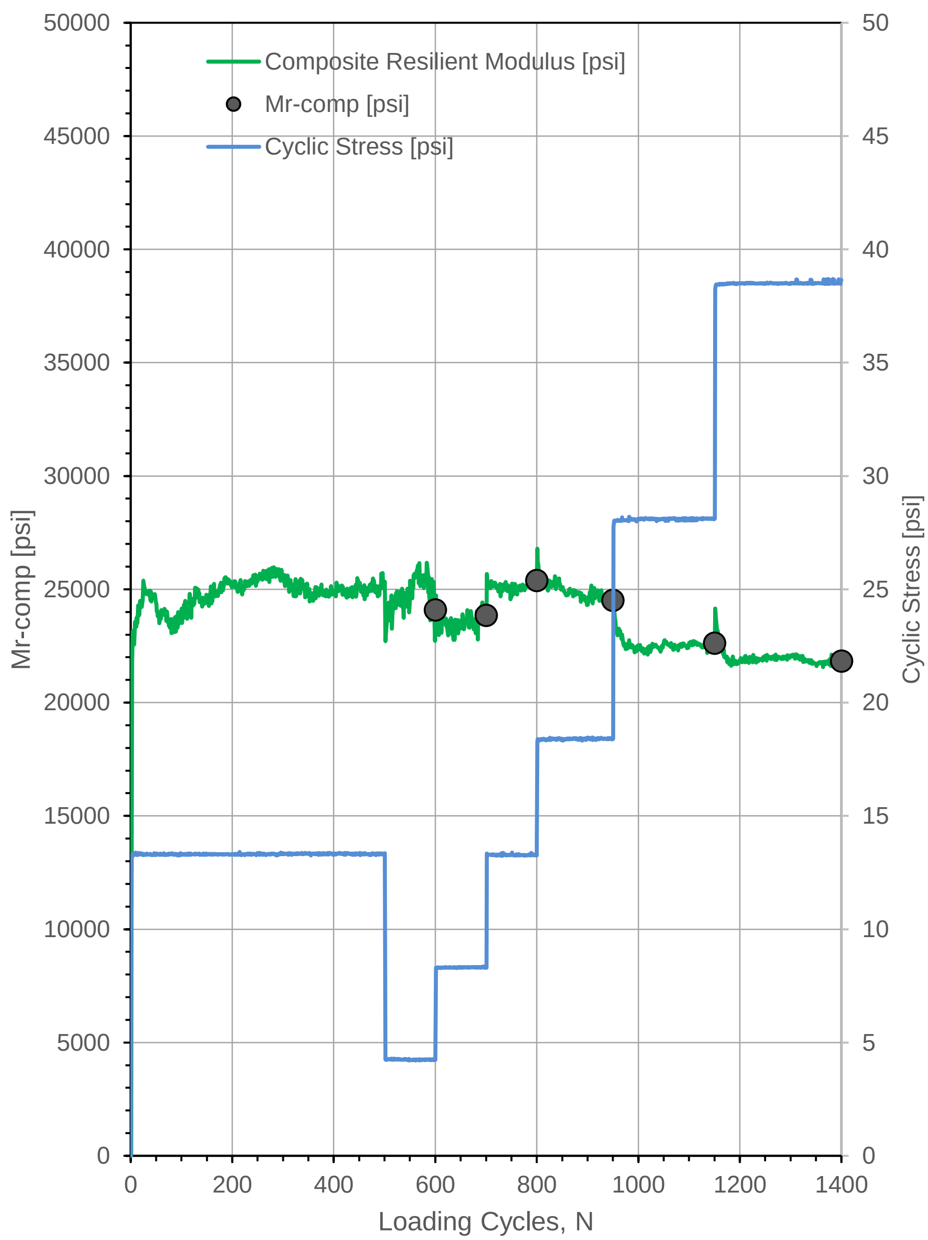
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	4/25/2018	Time:	12:48:05 PM	Test ID	**STIC_7_12_pt5**
Tested By	DW, HG	Location:	I-80/35 100th St.	Sta.	4503 + 80
Latitude,N:	41.651142	Longitude,W:	93.753502	Elev. (ft):	909
Comments:	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	22,337
3	23,207
4	23,759
5	24,129
6	24,383
7	24,554
8	24,666
9	24,733
10	24,763
11	24,765
12	24,744
13	24,704
14	24,648
15	24,579
16	24,499
17	24,410
18	24,313
21	23,987
22	23,869
23	23,747
24	23,623
25	23,496
26	23,368
27	23,237
28	23,106
29	22,973
30	22,840
31	22,706
32	22,572
33	22,437
34	22,303
35	22,168
36	22,034
37	21,900
38	21,766
39	21,633
40	21,501



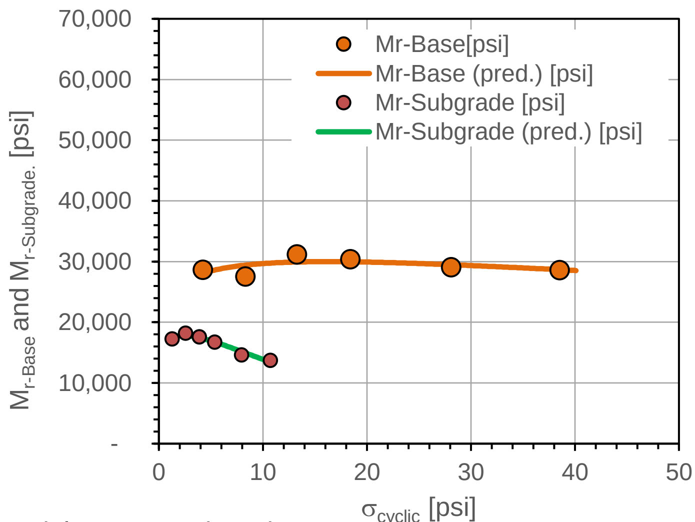
In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

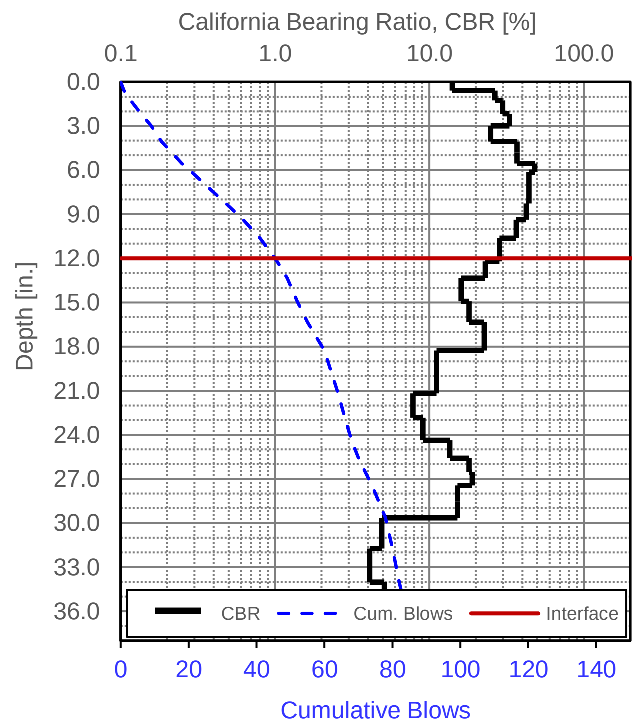
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Polk County I-80/35 and 100th St. Ramps (Project #7)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	4/25/2018	Time:	12:48:05 PM	Test ID	**STIC_7_12_pt5**
Tested By	DW, HG	Location:	I-80/35 100th St.	Sta.	4503 + 80
Latitude,N:	41.651142	Longitude,W:	93.753502	Elev. (ft):	909
Comments:	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.				

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	13.27	---	---	---	---	---	---
1	100	4.24	28,687	28,075	1.27	17,283	17,539	1.66
2	100	8.32	27,563	29,418	2.57	18,231	17,804	1.51
3	100	13.27	31,217	29,929	3.89	17,584	17,461	1.78
4	100	18.41	30,428	29,964	5.36	16,752	16,755	1.82
5	100	28.10	29,109	29,484	7.94	14,642	15,196	1.99
6	100	38.54	28,631	28,664	10.71	13,737	13,447	2.08

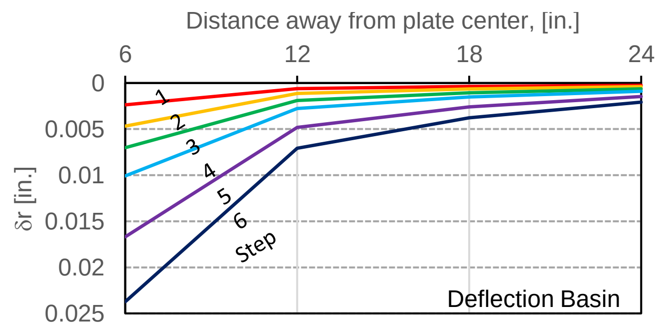




Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1 (Base)	2072.3	7.55E-07
k^*_2 (Base)	0.117	3.18E-01
k^*_3 (Base)	-0.793	3.44E-01
Adj. R^2	0.174	
Std. Error [psi]	677	
k^*_1 (Subgrade)	1884.9	1.37E-05
k^*_2 (Subgrade)	0.247	8.95E-02
k^*_3 (Subgrade)	-5.309	2.53E-02
Adj. R^2	0.949	
Std. Error [psi]	388	



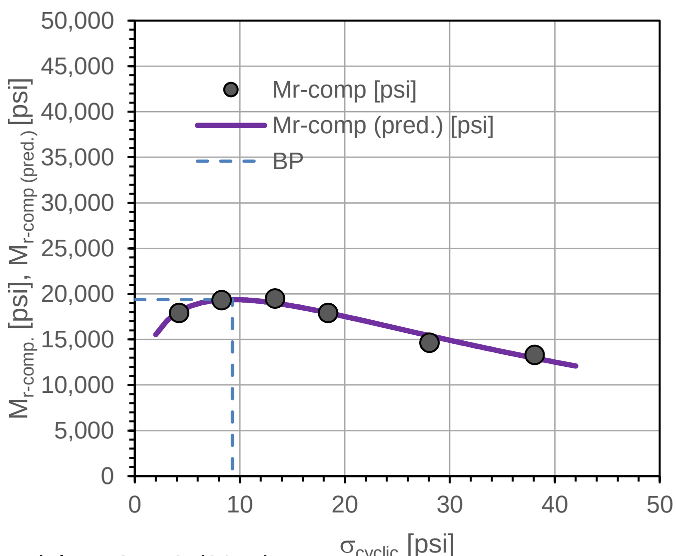
In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

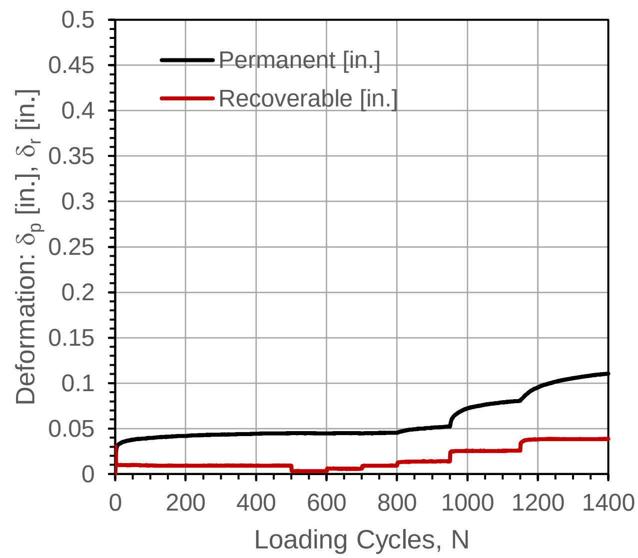
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Polk County I-80/35 and 100th St. Ramps (Project #7)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	4/25/2018	Time:	1:25:00 PM	Test ID	**STIC_7_12_pt6**
Tested By	DW, HG	Location:	I-80/35 100th St.	Sta.	4503 + 00
Latitude,N:	41.651093	Longitude,W:	93.753792	Elev. (ft):	917
Comments:	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.36	---	---	0.0448	---	0.148	---
1	100	4.22	17,942	18,061	0.0446	-0.0002	-0.372	Y
2	100	8.28	19,344	19,340	0.0447	-0.0001	0.403	Y
3	100	13.36	19,522	18,989	0.0455	0.0006	0.685	N
4	150	18.42	17,924	17,916	0.0523	0.0075	0.816	N
5	200	28.09	14,662	15,407	0.0804	0.0356	1.377	N
6	250	38.10	13,311	12,946	0.1104	0.0656	2.279	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	1,611.8	3.93E-07
k^*_2	0.305	2.74E-02
k^*_3	-3.377	8.61E-03
Adj. R^2	0.963	
Std. Error [psi]	475	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	19,375
$\sigma_{cyclic\text{-}BP}$ [psi]	9.3

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Polk County I-80/35 and 100th St. Ramps (Project #7)

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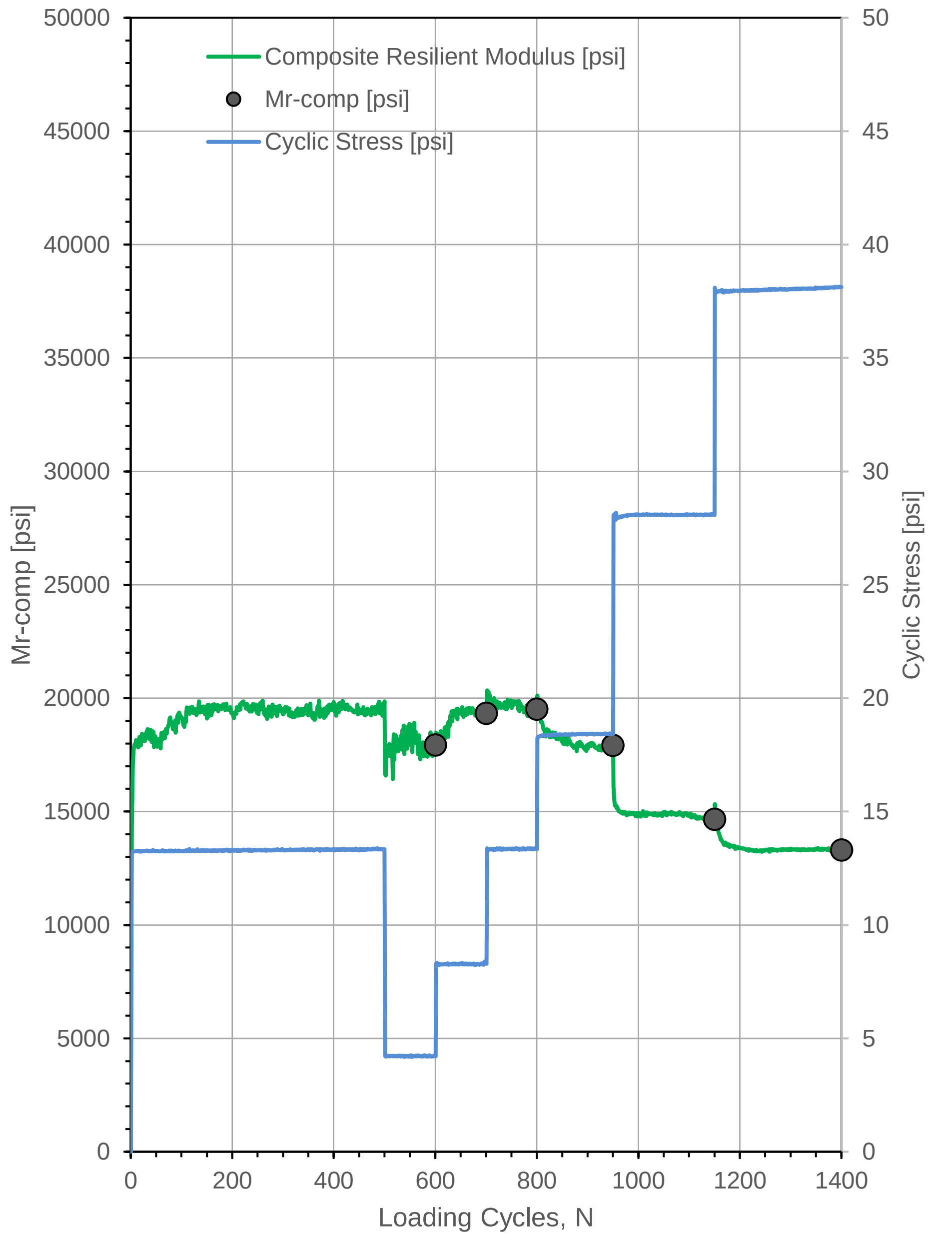
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	4/25/2018	Time:	1:25:00 PM	Test ID	**STIC_7_12_pt6**
Tested By	DW, HG	Location:	I-80/35 100th St.	Sta.	4503 + 00
Latitude,N:	41.651093	Longitude,W:	93.753792	Elev. (ft):	917
Comments:	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	15,540
3	16,981
4	17,905
5	18,519
6	18,922
7	19,176
8	19,317
9	19,372
10	19,361
11	19,296
12	19,188
13	19,047
14	18,877
15	18,686
16	18,477
17	18,253
18	18,018
21	17,267
22	17,007
23	16,745
24	16,482
25	16,218
26	15,954
27	15,691
28	15,430
29	15,171
30	14,914
31	14,659
32	14,407
33	14,159
34	13,914
35	13,672
36	13,434
37	13,199
38	12,969
39	12,742
40	12,519



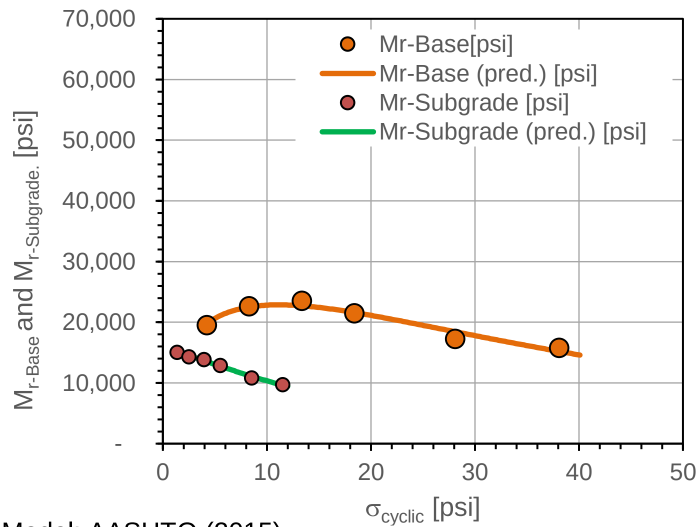
In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

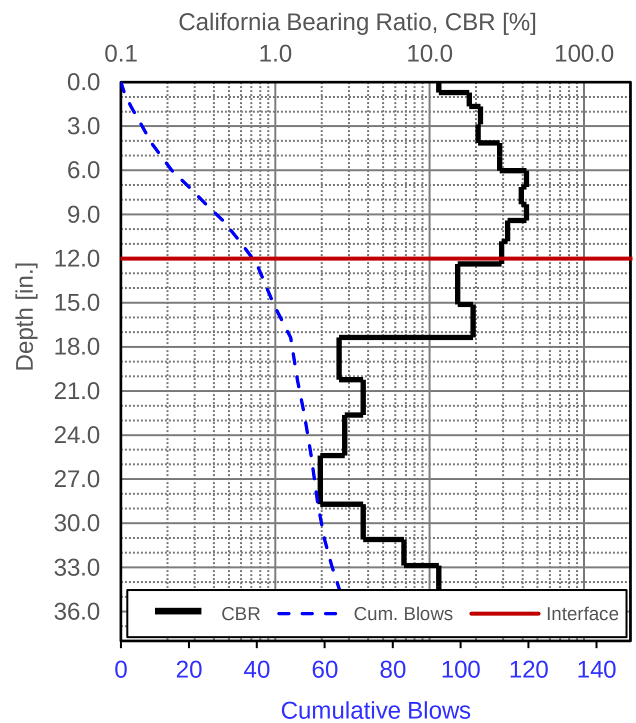
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Polk County I-80/35 and 100th St. Ramps (Project #7)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	4/25/2018	Time:	1:25:00 PM	Test ID	**STIC_7_12_pt6**
Tested By	DW, HG	Location:	I-80/35 100th St.	Sta.	4503 + 00
Latitude,N:	41.651093	Longitude,W:	93.753792	Elev. (ft):	917
Comments:	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.				

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	13.36	---	---	---	---	---	---
1	100	4.22	19,550	19,773	1.36	15,053	15,026	1.30
2	100	8.28	22,648	22,504	2.52	14,307	14,484	1.58
3	100	13.36	23,572	22,717	3.97	13,852	13,669	1.70
4	100	18.42	21,492	21,604	5.52	12,905	12,770	1.67
5	100	28.09	17,298	18,450	8.53	10,840	11,104	1.60
6	100	38.10	15,779	15,194	11.51	9,747	9,643	1.62

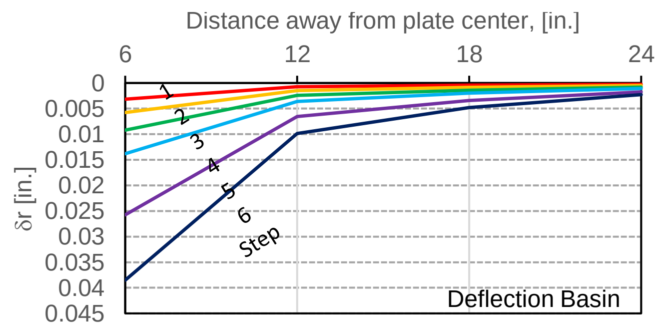




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\ (Base)}$	1930.7	8.59E-07
$k^*_{2\ (Base)}$	0.443	2.17E-02
$k^*_{3\ (Base)}$	-4.163	1.06E-02
Adj. R^2	0.936	
Std. Error [psi]	732	
$k^*_{1\ (Subgrade)}$	1300.7	3.87E-06
$k^*_{2\ (Subgrade)}$	0.085	2.78E-01
$k^*_{3\ (Subgrade)}$	-4.321	1.17E-02
Adj. R^2	0.991	
Std. Error [psi]	201	



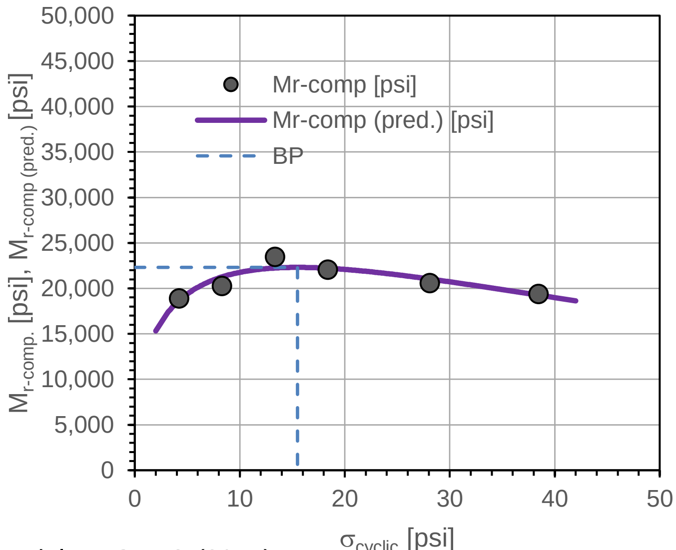
In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

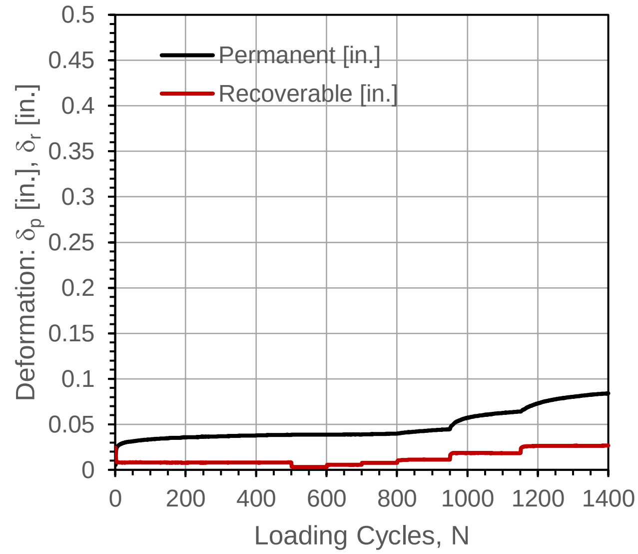
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Polk County I-80/35 and 100th St. Ramps (Project #7)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	4/25/2018	Time:	1:59:56 PM	Test ID	**STIC_7_12_pt7**
Tested By	DW, HG	Location:	I-80/35 100th St.	Sta.	4502 + 00
Latitude,N:	41.651028	Longitude,W:	93.754128	Elev. (ft):	930
Comments:	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.36	---	---	0.0385	---	0.148	---
1	100	4.24	18,901	18,673	0.0386	0.0001	-0.372	Y
2	100	8.30	20,272	21,259	0.0387	0.0003	0.403	Y
3	100	13.36	23,481	22,243	0.0398	0.0013	0.685	N
4	150	18.40	22,073	22,210	0.0445	0.0061	0.816	N
5	200	28.12	20,592	21,029	0.0640	0.0255	1.377	N
6	250	38.47	19,418	19,255	0.0839	0.0455	2.279	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	1,612.4	6.67E-07
k^*_2	0.337	3.44E-02
k^*_3	-2.371	3.63E-02
Adj. R^2	0.762	
Std. Error [psi]	731	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	22,311
$\sigma_{cyclic\text{-}BP}$ [psi]	15.5

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Polk County I-80/35 and 100th St. Ramps (Project #7)

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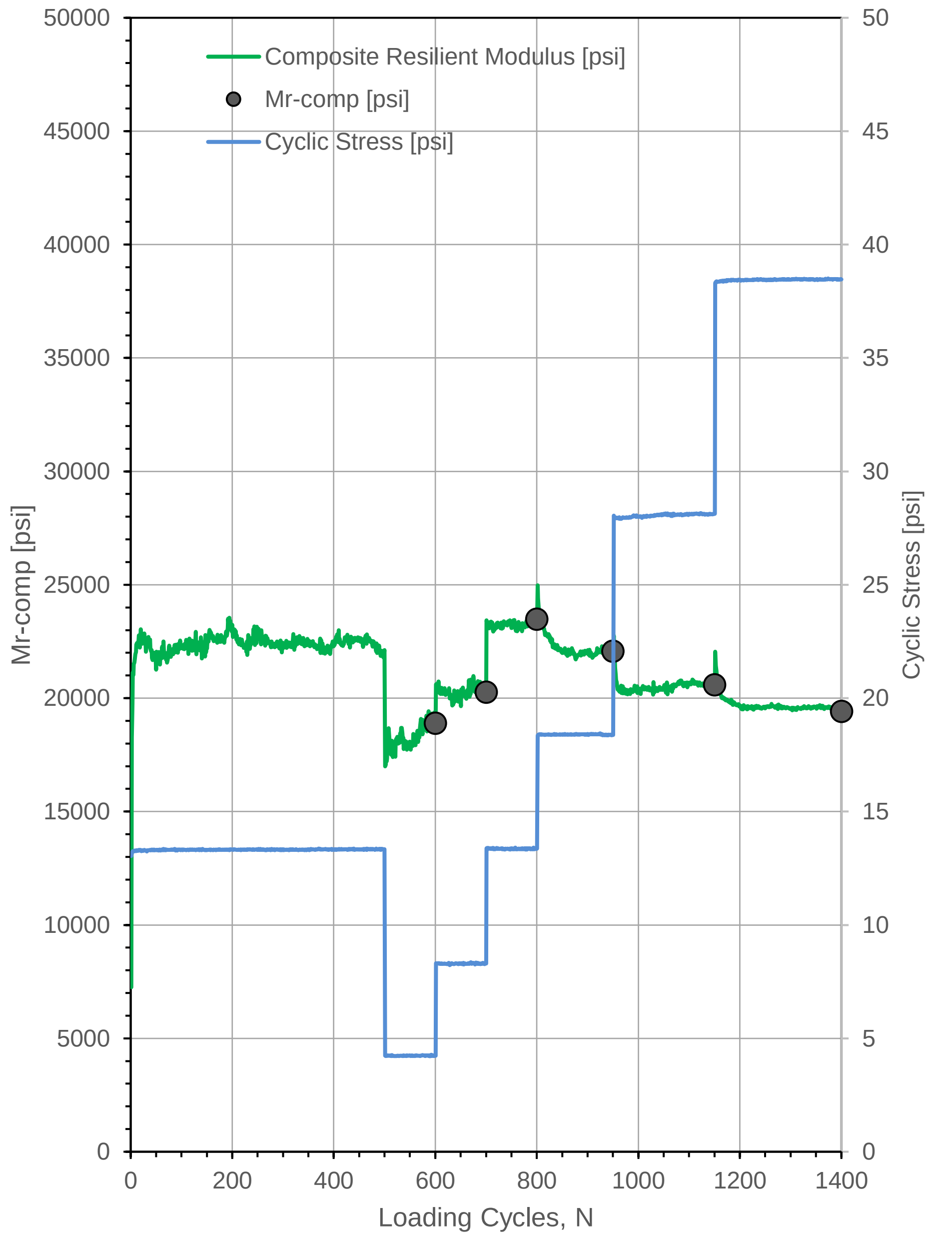
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	4/25/2018	Time:	1:59:56 PM	Test ID	**STIC_7_12_pt7**
Tested By	DW, HG	Location:	I-80/35 100th St.	Sta.	4502 + 00
Latitude,N:	41.651028	Longitude,W:	93.754128	Elev. (ft):	930
Comments:	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.				

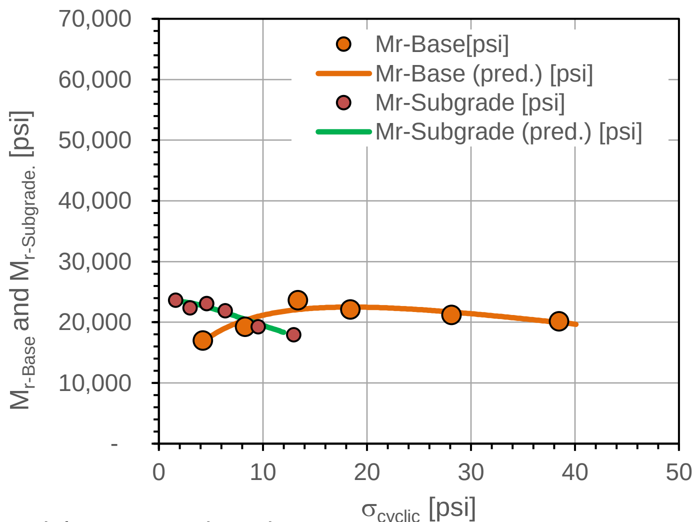
σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	15,320
3	17,132
4	18,419
5	19,381
6	20,120
7	20,695
8	21,145
9	21,495
10	21,764
11	21,967
12	22,115
13	22,217
14	22,279
15	22,307
16	22,307
17	22,281
18	22,234
21	21,990
22	21,882
23	21,762
24	21,633
25	21,497
26	21,353
27	21,203
28	21,047
29	20,888
30	20,724
31	20,557
32	20,388
33	20,216
34	20,043
35	19,868
36	19,692
37	19,515
38	19,338
39	19,161
40	18,984

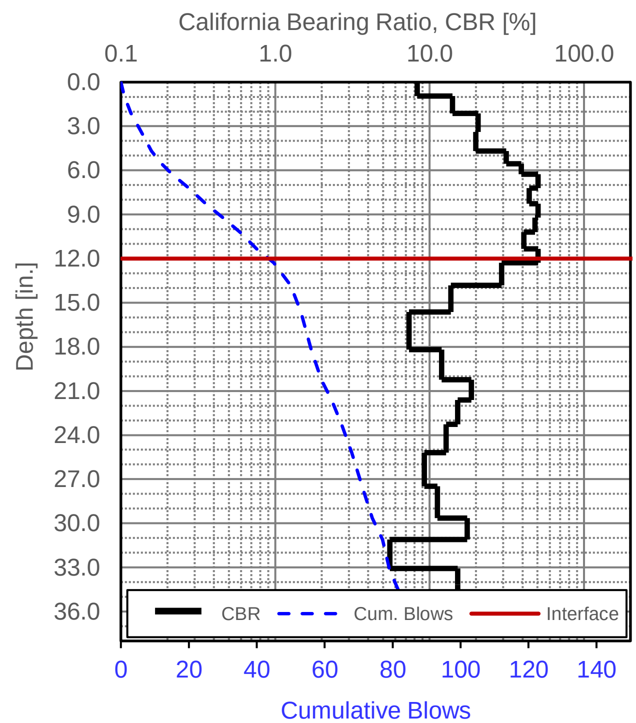


Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	4/25/2018	Time:	1:59:56 PM	Test ID	**STIC_7_12_pt7**
Tested By	DW, HG	Location:	I-80/35 100th St.	Sta.	4502 + 00
Latitude,N:	41.651028	Longitude,W:	93.754128	Elev. (ft):	930
Comments:	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.				

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	13.36	---	---	---	---	---	---
1	100	4.24	17,007	16,787	1.61	23,683	23,429	0.72
2	100	8.30	19,283	20,349	3.01	22,417	23,197	0.86
3	100	13.36	23,655	22,094	4.62	23,039	22,523	1.03
4	100	18.40	22,142	22,503	6.39	21,934	21,577	1.01
5	100	28.12	21,249	21,691	9.54	19,307	19,755	1.10
6	100	38.47	20,160	19,974	12.97	17,945	17,813	1.12

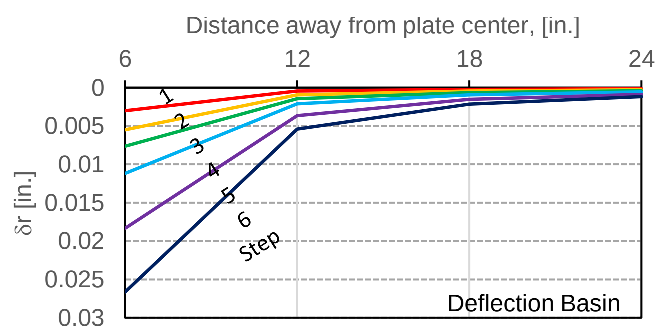




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\ (Base)}$	1543.4	1.18E-06
$k^*_{2\ (Base)}$	0.453	2.56E-02
$k^*_{3\ (Base)}$	-2.748	3.97E-02
Adj. R^2	0.816	
Std. Error [psi]	900	
$k^*_{1\ (Subgrade)}$	2037.6	8.88E-06
$k^*_{2\ (Subgrade)}$	0.124	2.92E-01
$k^*_{3\ (Subgrade)}$	-3.218	5.82E-02
Adj. R^2	0.937	
Std. Error [psi]	552	



In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Polk County I-80/35 and 100th St. Ramps (Project #7)

Automated Plate Load Test [APLT]

Test:	In-Situ Static Plate Load Test: Two Loading Cycles.				
Date:	4/25/2018	Time:	3:18:05 PM	Test ID	STIC_7_static_30in_pt8
Tested By	DW, JV	Location:	EB, Center	Sta.	NA
Latitude:	41.65104	Longitude:	93.75413	Elev. (ft):	918
Comments:	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.				

Cycle	Stage	Load Step	Target Applied Load (lbs)	Target Applied Stress (psi)	Actual Applied Stress (psi)	Deformation (in.) Sensor 1	Sensor 2	Sensor 3	Average Def. (in.)
0	Seating	0	707	1	1.26	0.0043	0.0030	0.0017	0.0030
Zero load and deformation sensors after applying the seating stress.									
1	Seating	0	0	0	0.00	0.0000	0.0000	0.0000	0.0000
1	Load	1	1767	2.5	2.41	0.0076	0.0037	0.0087	0.0067
1	Load	2	3534	5	4.89	0.0133	0.0101	0.0138	0.0124
1	Load	3	5301	7.5	7.44	0.0205	0.0181	0.0188	0.0191
1	Load	4	7069	10	9.85	0.0348	0.0299	0.0251	0.0300
1	Load	5	8836	12.5	12.35	0.0487	0.0441	0.0362	0.0430
1	Load	6	10603	15	14.87	0.0623	0.0581	0.0484	0.0563
1	Unload	7	7069	10	9.70	0.0570	0.0518	0.0424	0.0504
1	Unload	8	3534	5	4.61	0.0461	0.0432	0.0347	0.0413
1	Unload	9	1767	2.5	2.45	0.0398	0.0356	0.0281	0.0345
2	Load	10	3534	5	4.89	0.0438	0.0400	0.0325	0.0388
2	Load	11	7069	10	9.85	0.0542	0.0485	0.0399	0.0475
2	Load	12	10603	15	14.90	0.0663	0.0606	0.0508	0.0592
2	Unload	13	1767	2.5	2.55	0.0430	0.0387	0.0316	0.0378
2	Unload	14	0	0	0.00	0.0307	0.0292	0.0229	0.0276

Plate Diameter:	30.0	in.
Shape factor:	2.67	
Material Type:	B	A = Cohesive, B = Granular, C = Intermediate
Poisson's ratio:	0.35	
Design Stress:	10.0	psi
Target Deformation:	0.05	in.

AASHTO T222 Method
PCA Design Criteria

k_{u1} (pci) @ design stress:	284
k_u (pci) @ δ = 0.05 in.:	246

Modulus at target deformation

Stress @ δ = 0.05 in. (psi)	13.9
E_1 (psi)	8,648
k'_u (pci)	278
k_u (pci)	246

Plate Bending Correction for

$k'_u \geq 100$ *and* $1{,}000$ *pci*

$k_u = -39.9178 + 5.5076\,[k'_u]^{0.7019}$

Modulus at target/design applied stress

First Loading Cycle

δ_1 (in.)	0.0301
E_1 (psi)	9,967
k'_{u1} (pci)	332
k_{u1} (pci)	284

Second Loading Cycle

δ_2 (in.)	0.0167
E_2 (psi)	15,791
k'_{u2} (pci)	598
k_{u2} (pci)	450
E_2 / E_1 or k_2 / k_1 Ratio	1.6

In-situ Modulus of Subgrade Reaction (k) and Elastic Modulus

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Polk County I-80/35 and 100th St. Ramps (Project #7)

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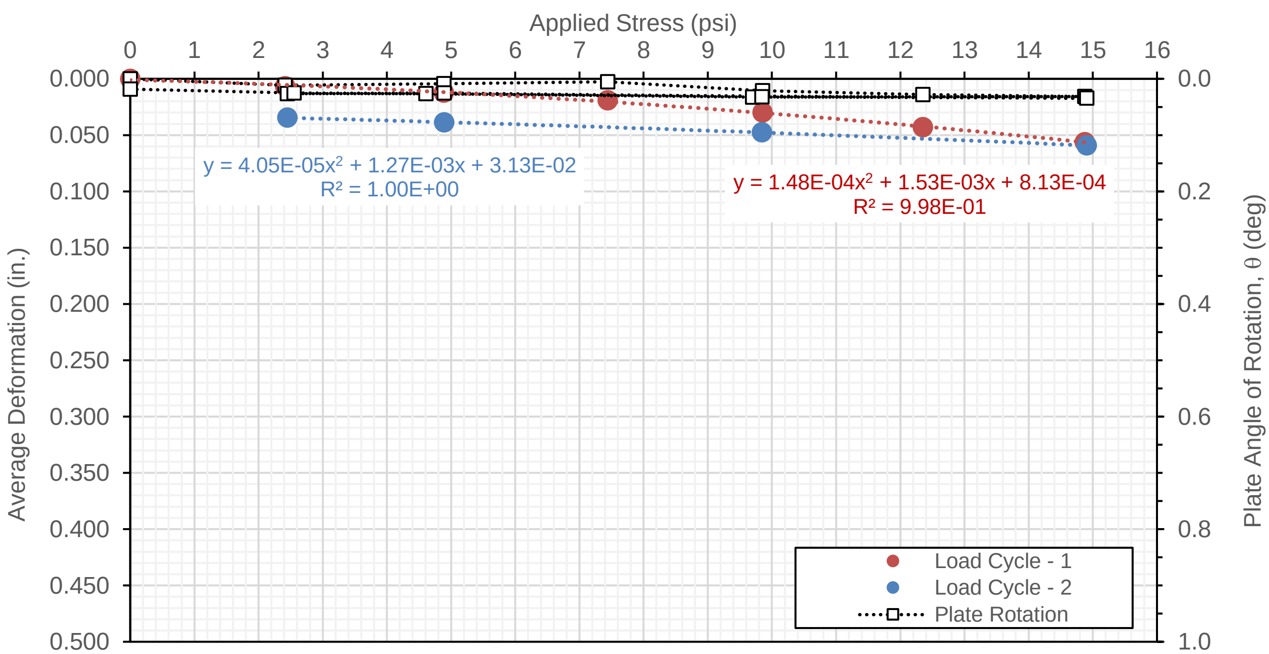
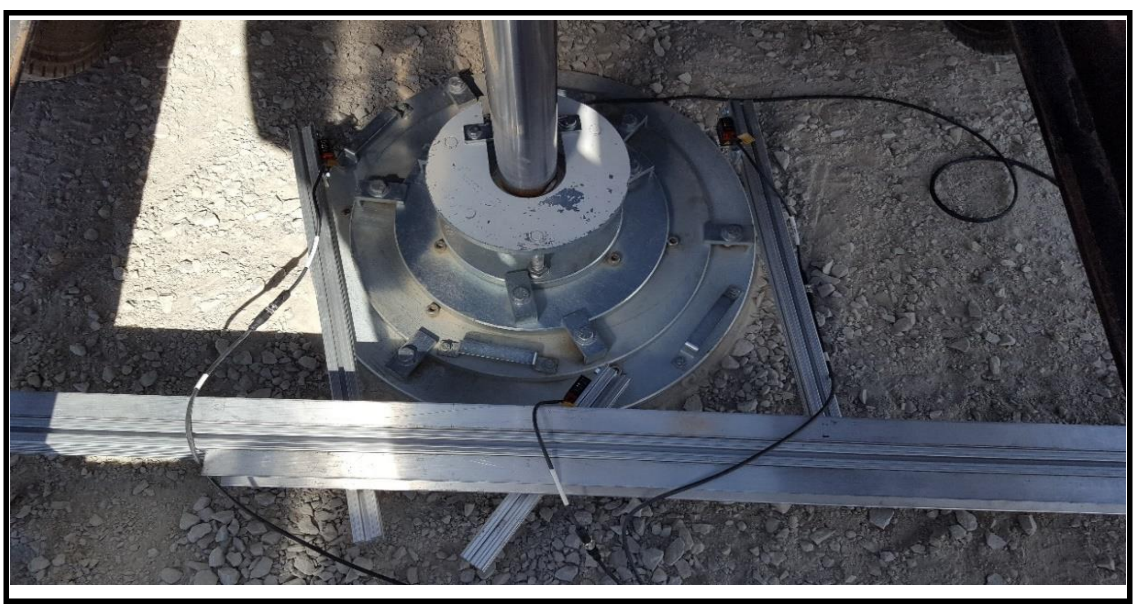
Polynomial Fit Parameters

First Cycle		*Second Cycle*			
a_1	1.48E-04	a_1	4.05E-05	θ_{max} (deg)	0.0344
a_2	1.53E-03	a_2	1.27E-03		
R^2	1.00	R^2	1.00		

NOTES:
1. Test performed per AASHTO T222/ASTM D1196.
2. k-value determined using:
   (a) calculated stress at 0.05 in. plate deformation (δ) for first loading cycle, per PCA design guidelines, and
   (b) for a defined target stress and calculating corresponding plate deformations using polynomial fit parameters.





Automated Plate Load Test [APLT]

Test:	In-Situ Static Plate Load Test: Two Loading Cycles.				
Date:	4/25/2018	Time:	4:07:29 PM	Test ID	STIC_7_static_30in_pt8
Tested By	DW, JV	Location:	EB, Center	Sta.	NA
Latitude:	41.65131	Longitude:	93.75267	Elev. (ft):	910
Comments:	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.				

Cycle	Stage	Load Step	Target Applied Load (lbs)	Target Applied Stress (psi)	Actual Applied Stress (psi)	Deformation (in.) Sensor 1	Sensor 2	Sensor 3	Average Def. (in.)
0	Seating	0	707	1	1.26	0.0165	0.0147	0.0160	0.0157
Zero load and deformation sensors after applying the seating stress.									
1	Seating	0	0	0	0.00	0.0000	0.0000	0.0000	0.0000
1	Load	1	1767	2.5	2.48	0.0529	0.0453	0.0502	0.0495
1	Load	2	3534	5	4.98	0.1198	0.1054	0.1150	0.1134
1	Load	3	5301	7.5	7.45	0.1858	0.1680	0.1795	0.1778
1	Load	4	7069	10	9.93	0.2601	0.2408	0.2542	0.2517
1	Load	5	8836	12.5	12.40	0.3399	0.3175	0.3346	0.3307
1	Load	6	10603	15	14.89	0.4246	0.3997	0.4202	0.4149
1	Unload	7	7069	10	9.83	0.3950	0.3724	0.3922	0.3866
1	Unload	8	3534	5	4.97	0.3439	0.3258	0.3443	0.3380
1	Unload	9	1767	2.5	2.50	0.3049	0.2877	0.3042	0.2989
2	Load	10	3534	5	4.97	0.3206	0.3035	0.3198	0.3146
2	Load	11	7069	10	9.92	0.3714	0.3521	0.3694	0.3643
2	Load	12	10603	15	14.88	0.4466	0.4246	0.4466	0.4393
2	Unload	13	1767	2.5	2.51	0.3266	0.3113	0.3297	0.3225
2	Unload	14	0	0	0.00	0.3006	0.2881	0.3039	0.2975

Plate Diameter:	30.0	in.
Shape factor:	2.67	
Material Type:	B	A = Cohesive, B = Granular, C = Intermediate
Poisson's ratio:	0.35	
Design Stress:	10.0	psi
Target Deformation:	0.05	in.

AASHTO T222 Method
PCA Design Criteria

k_{u1} (pci) @ design stress:	39
k_u (pci) @ δ = 0.05 in.:	47

Modulus at target deformation

Stress @ δ = 0.05 in. (psi)	2.3
E_1 (psi)	1,637
k'_u (pci)	47
k_u (pci)	47

Plate Bending Correction for

$k'_u \geq 100$ *and* $1{,}000$ *pci*

$$k_u = -39.9178 + 5.5076\,[k'_u]^{0.7019}$$

Modulus at target/design applied stress

First Loading Cycle

δ_1 (in.)	0.2546
E_1 (psi)	1,379
k'_{u1} (pci)	39
k_{u1} (pci)	39

Second Loading Cycle

δ_2 (in.)	0.0759
E_2 (psi)	4,545
k'_{u2} (pci)	132
k_{u2} (pci)	129
E_2 / E_1 or k_2 / k_1 Ratio	3.3

In-situ Modulus of Subgrade Reaction (k) and Elastic Modulus

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Polk County I-80/35 and 100th St. Ramps (Project #7)

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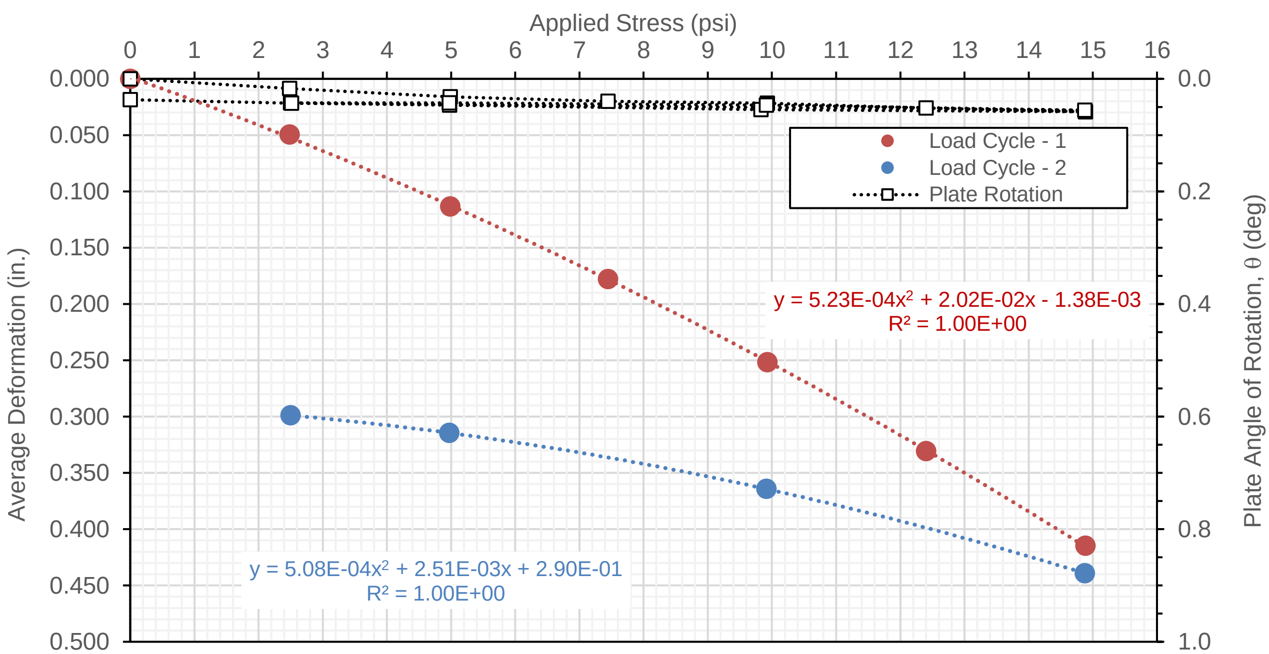
Polynomial Fit Parameters

First Cycle		*Second Cycle*			
a_1	5.23E-04	a_1	5.08E-04	θ_{max} (deg)	0.0586
a_2	2.02E-02	a_2	2.51E-03		
R^2	1.00	R^2	1.00		

NOTES:
1. Test performed per AASHTO T222/ASTM D1196.
2. k-value determined using:
   (a) calculated stress at 0.05 in. plate deformation (δ) for first loading cycle, per PCA design guidelines, and
   (b) for a defined target stress and calculating corresponding plate deformations using polynomial fit parameters.



Date of Test	4/25/2018	Test ID	STIC_7_12_pt1	Operator	DW/HG	ASTM	D6951
Latitude, N	41.6514400	Longitude, W	93.7519910	Elevation (ft)	913		
Location	I-80/35 100th St.	Station	4508 + 00				
Comments	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	10.8	20.3	17.5	4,030
Avg. Subgrade Layer (top 12 in.)	26.3	5.0	7.1	1,586
Ratio of Avg. Top/Bottom Layer	0.4	4.1	2.5	2.5
Std.Dev.Subbase Layer	11.5	10.3	11.4	2,578
Std. Dev. Subgrade Layer (top 12 in.)	6.1	3.2	5.3	1,171

NOTES:

Subgrade is assumed as sandy clay.

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

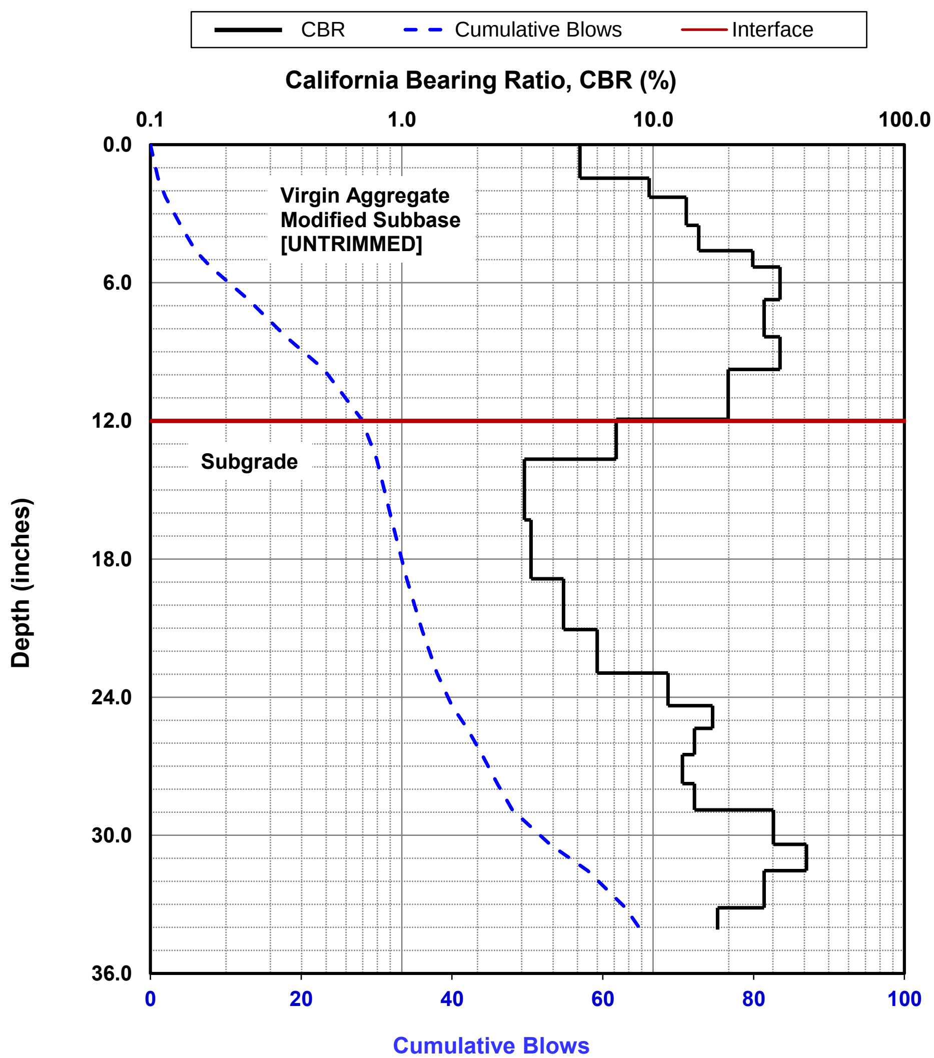
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Polk County I-80/35 and 100th St. Ramps (Project #7)

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Date of Test	4/25/2018	Test ID	STIC_7_12_pt2	Operator	DW/HG	ASTM	D6951
Latitude, N	41.6513670		Longitude, W	93.7523650		Elevation (ft)	911
Location	I-80/35 100th St.		Station	4507 + 05			
Comments	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	9.9	22.3	18.6	4,294
Avg. Subgrade Layer (top 12 in.)	17.5	11.8	12.4	2,816
Ratio of Avg. Top/Bottom Layer	0.6	1.9	1.5	1.5
Std.Dev.Subbase Layer	6.9	9.7	11.0	2,478
Std. Dev. Subgrade Layer (top 12 in.)	14.9	5.9	8.0	1,780

NOTES:

Subgrade is assumed as sandy clay.

[1]CBR = 292/DPI$^{1.12}$

[1]CBR = 1/(0.017019DPI)^2

for CL soils with CBR < 10

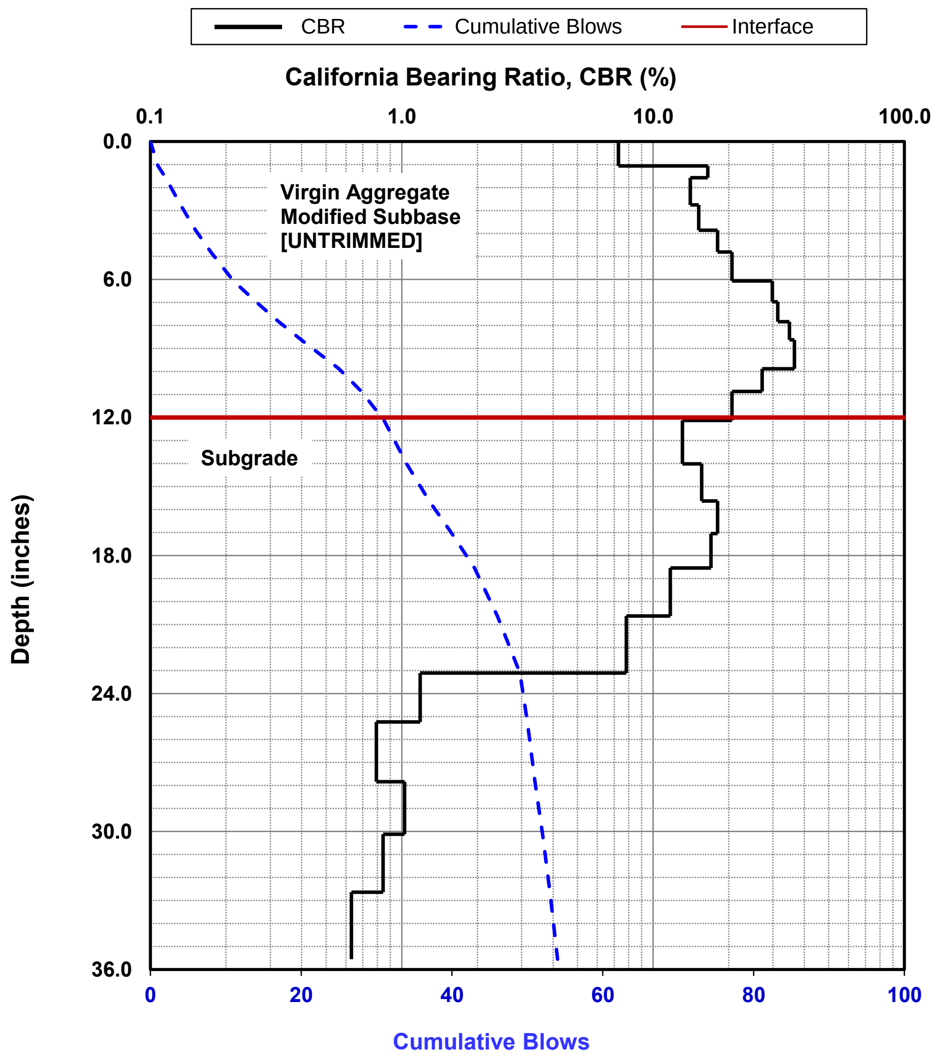
[2]E (ksi) = (17.6 CBR$^{0.64}$) x 0.1450377

[3]S_u (psf) =(3.794 x CBR$^{0.664}$) x 144

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name: Iowa DOT STIC

Project ID: SIA-00001

Location: Polk County I-80/35 and 100th St. Ramps (Project #7)

Date of Test	4/25/2018	Test ID	STIC_7_12_pt3	Operator	DW/HG	ASTM	D6951
Latitude, N	41.6513100	Longitude, W	93.7526550	Elevation (ft)	912		
Location	I-80/35 100th St.	Station	4506 + 20				
Comments	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	11.2	19.5	17.1	3,932
Avg. Subgrade Layer (top 12 in.)	19.2	9.4	10.7	2,411
Ratio of Avg. Top/Bottom Layer	0.6	2.1	1.6	1.6
Std.Dev.Subbase Layer	8.2	13.7	13.6	3,100
Std. Dev. Subgrade Layer (top 12 in.)	25.1	12.5	12.9	2,925

NOTES:

Subgrade is assumed as sandy clay.

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

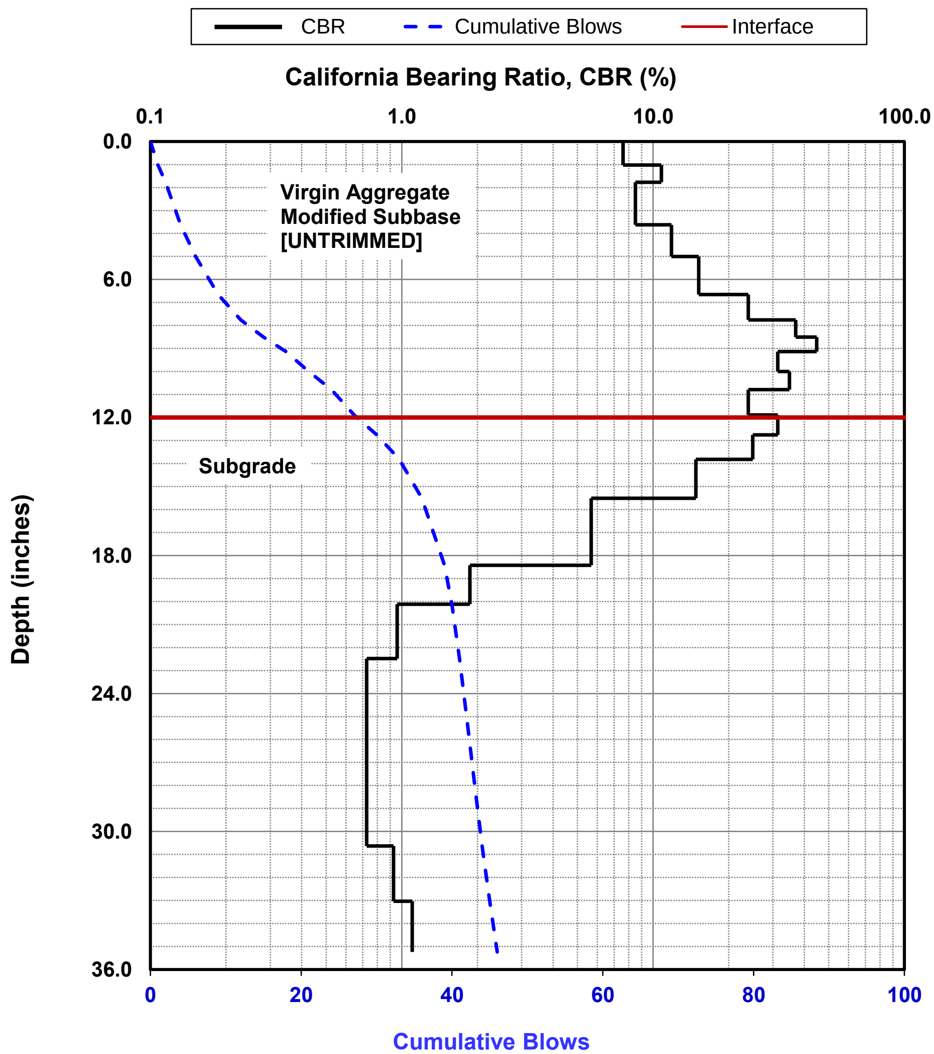
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Polk County I-80/35 and 100th St. Ramps (Project #7)

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Date of Test	4/25/2018	Test ID	STIC_7_12_pt4	Operator	DW/HG	ASTM	D6951
Latitude, N	41.6512340	Longitude, W	93.7530820			Elevation (ft)	915
Location	I-80/35 100th St.	Station	4505 + 00				
Comments	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	7.1	32.5	23.7	5,517
Avg. Subgrade Layer (top 12 in.)	11.4	19.2	16.9	3,884
Ratio of Avg. Top/Bottom Layer	0.6	1.7	1.4	1.4
Std.Dev.Subbase Layer	4.2	14.7	14.3	3,258
Std. Dev. Subgrade Layer (top 12 in.)	12.3	12.5	12.8	2,915

NOTES:

Subgrade is assumed as sandy clay.

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

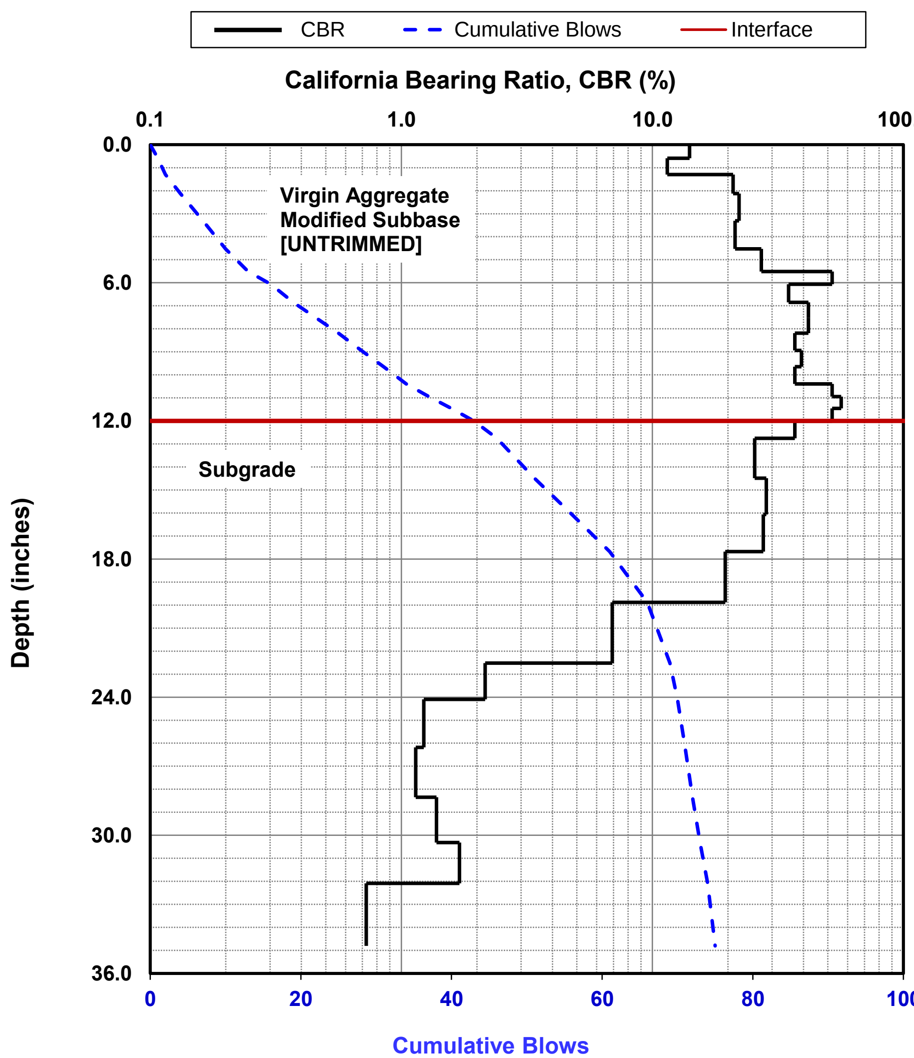
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Polk County I-80/35 and 100th St. Ramps (Project #7)

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Date of Test	4/25/2018	Test ID	STIC_7_12_pt5	Operator	DW/HG	ASTM	D6951
Latitude, N	41.6511420	Longitude, W	93.7535020	Elevation (ft)	909		
Location	I-80/35 100th St.	Station	4503 + 80				
Comments	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	6.7	34.5	24.6	5,731
Avg. Subgrade Layer (top 12 in.)	14.0	15.1	14.5	3,320
Ratio of Avg. Top/Bottom Layer	0.5	2.3	1.7	1.7
Std.Dev.Subbase Layer	3.2	10.6	11.6	2,622
Std. Dev. Subgrade Layer (top 12 in.)	4.8	6.2	8.2	1,843

NOTES:

Subgrade is assumed as sandy clay.

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

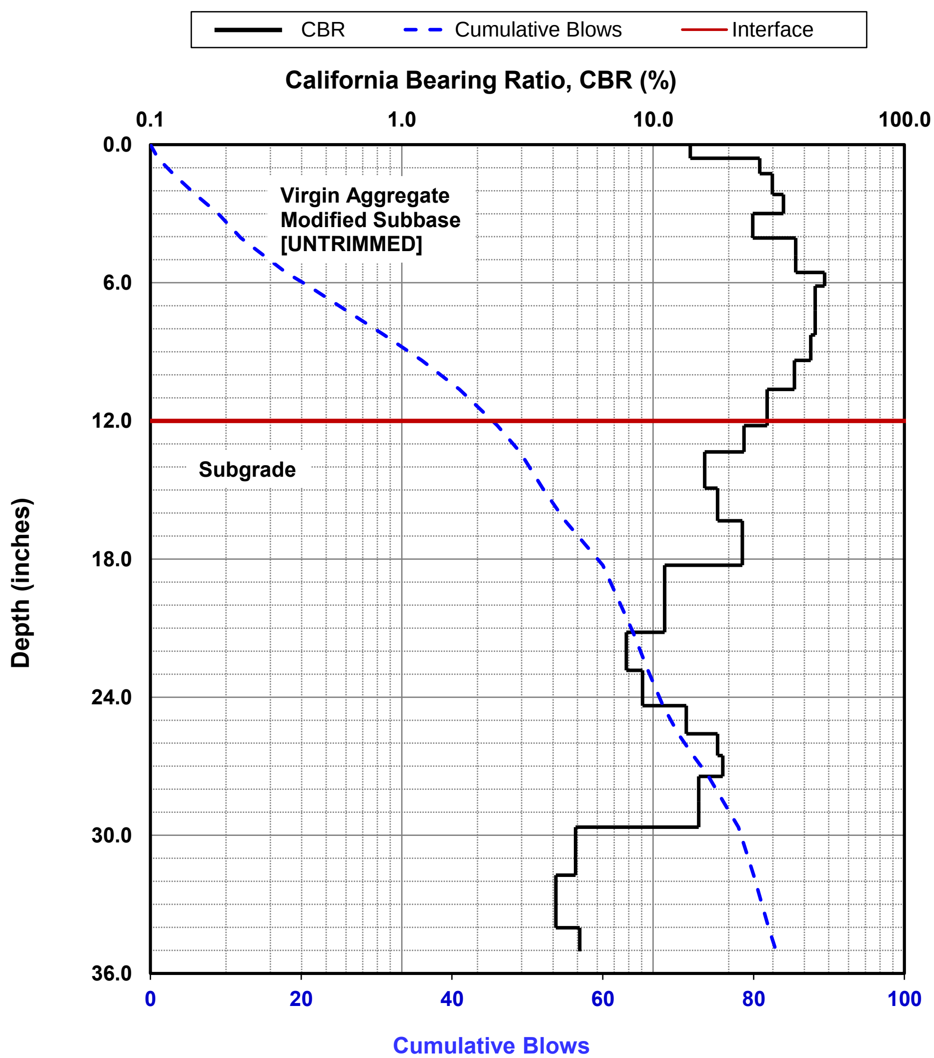
[2]$E\text{ (ksi)} = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\text{ (psf)} = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name: Iowa DOT STIC

Project ID: SIA-00001

Location: Polk County I-80/35 and 100th St. Ramps (Project #7)

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Date of Test	4/25/2018	Test ID	STIC_7_12_pt6	Operator	DW/HG	ASTM	D6951
Latitude, N	41.6510930		Longitude, W	93.7537920		Elevation (ft)	917
Location	I-80/35 100th St.		Station	4503 + 00			
Comments	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	S_{u-CBR}, Bearing Capacity (psf)
Avg. Subbase layer	7.9	29.0	22.0	5,117
Avg. Subgrade Layer (top 12 in.)	20.7	8.1	9.7	2,185
Ratio of Avg. Top/Bottom Layer	0.4	3.6	2.3	2.3
Std.Dev.Subbase Layer	4.5	11.4	12.1	2,742
Std. Dev. Subgrade Layer (top 12 in.)	11.9	7.9	9.6	2,150

NOTES:

Subgrade is assumed as sandy clay.

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

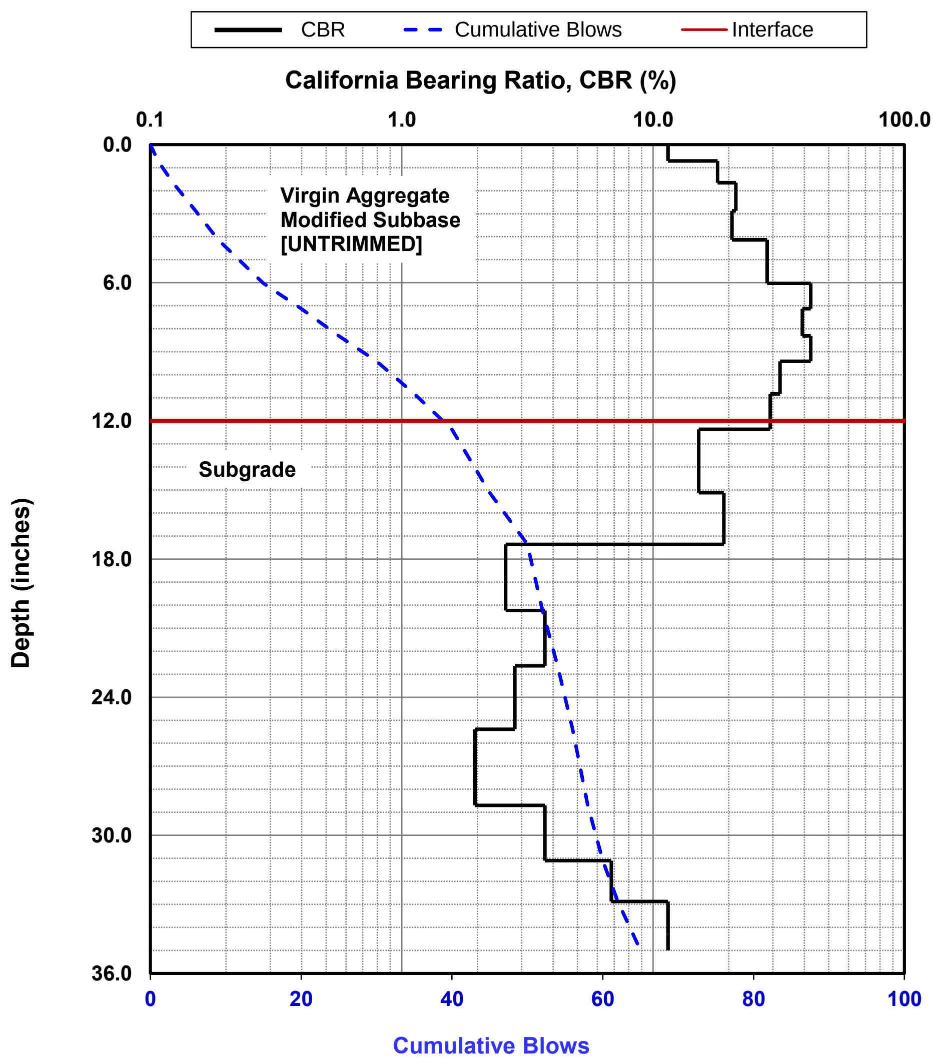
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Polk County I-80/35 and 100th St. Ramps (Project #7)

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Date of Test	4/25/2018	Test ID	STIC_7_12_pt7	Operator	DW/HG	ASTM	D6951
Latitude, N	41.6510280	Longitude, W		93.7541280		Elevation (ft)	930
Location	I-80/35 100th St.	Station		4502 + 00			
Comments	East bound on-ramp. 12 inches modified subbase (virgin material) untrimmed over select subgrade.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	6.4	36.5	25.5	5,956
Avg. Subgrade Layer (top 12 in.)	14.3	14.9	14.4	3,282
Ratio of Avg. Top/Bottom Layer	0.4	2.5	1.8	1.8
Std.Dev.Subbase Layer	7.0	16.5	15.4	3,514
Std. Dev. Subgrade Layer (top 12 in.)	4.4	6.9	8.8	1,977

NOTES:

Subgrade is assumed as sandy clay.

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

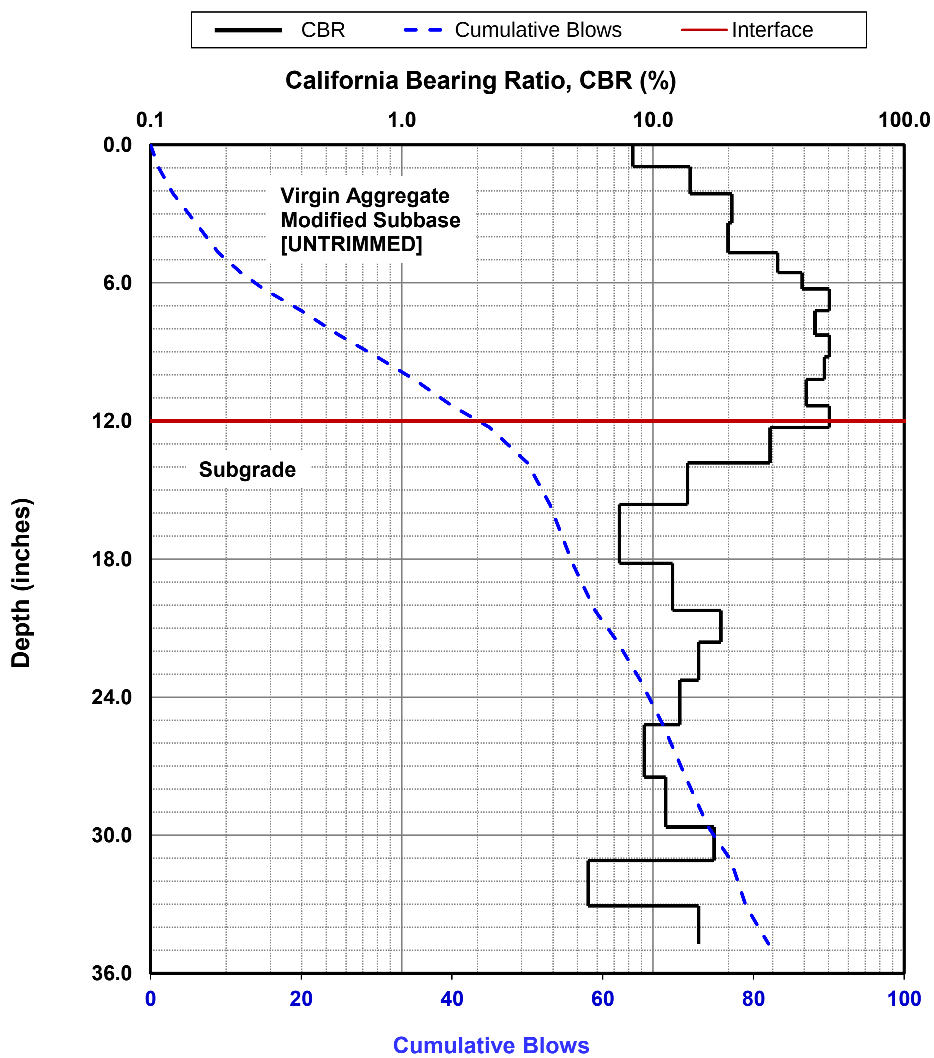
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2] Powell et al. (1986)

[3] Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Polk County I-80/35 and 100th St. Ramps (Project #7)

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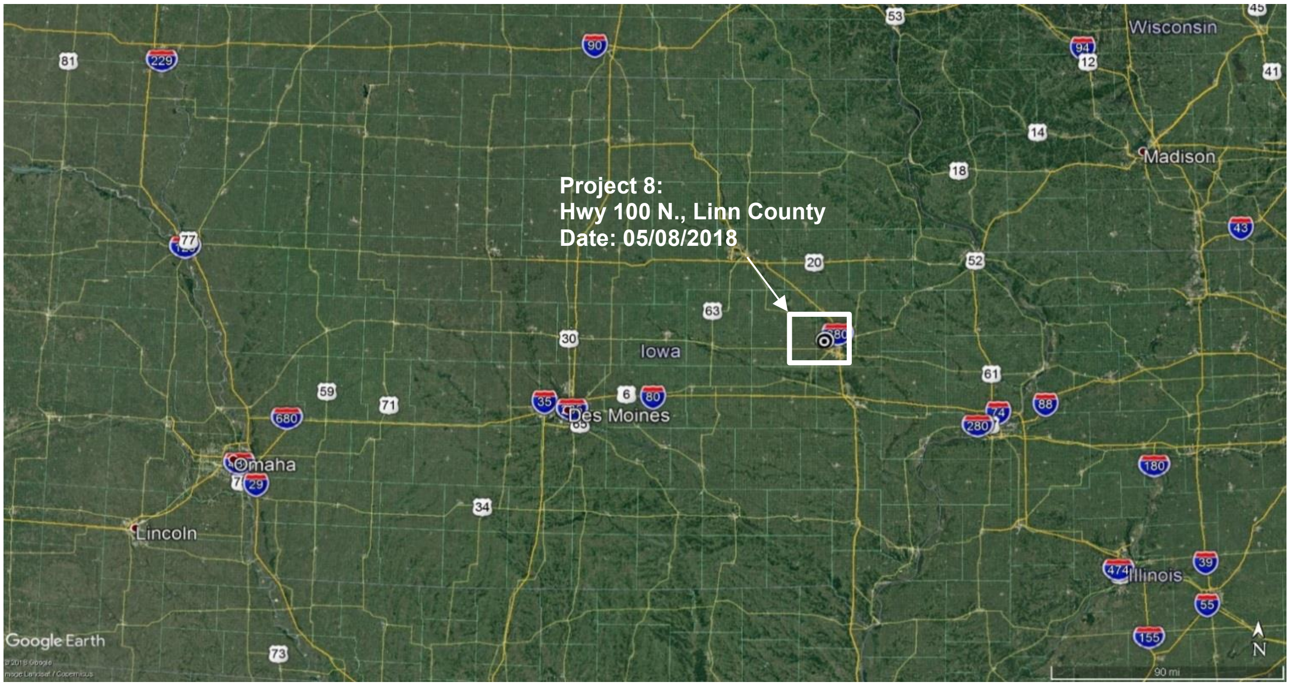
Field Project # 8

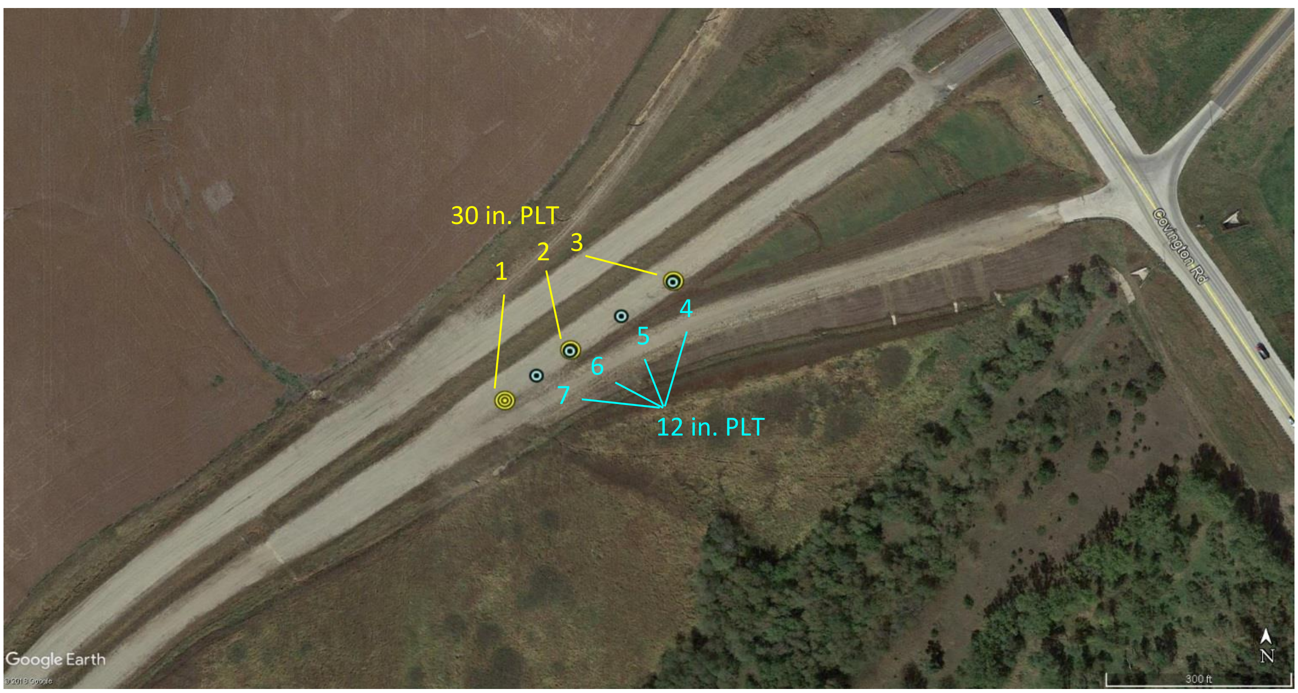
Hwy100 N., Linn County, IA

05/08/2018

Modified subbase (crushed limestone and recycled concrete) over select subgrade

Project Location and Test Locations





Test Locations

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 100 N. of E Ave., Linn County (Project #8)

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Site Conditions and Pictures

APLT Test Setup
for 12 in. Cyclic PLT

30 in. Static Plate
Load Testing

Pictures

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 100 N. of E Ave., Linn County (Project #8)

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Summary of Test Results

Summary of Cyclic APLT Test Results

	4 psi cyclic stress @ surface				8 psi plate cyclic stress @ surface			
Point #	$M_{r\text{-Comp}}$ (psi)	$M_{r\text{-Base}}$ (psi)	$M_{r\text{-SG}}$ (psi)	$\Delta\delta_p$ ([in.)	$M_{r\text{-Comp}}$ (psi)	$M_{r\text{-Base}}$ (psi)	$M_{r\text{-SG}}$ (psi)	$\Delta\delta_p$ ([in.)
PT4 / 3	13,624	23,515	8,627	-0.0003	11,732	18,515	7,937	-0.0001
PT5	21,197	35,951	12,378	0.0000	18,746	31,526	11,100	0.0002
PT6 / 2	14,679	30,298	7,748	-0.0001	13,147	25,221	7,332	0.0004
PT7	21,467	35,623	12,374	-0.0003	20,029	31,708	12,101	-0.0001
AVG	**17,742**	**31,347**	**10,282**	**(0.0002)**	**15,913**	**26,743**	**9,618**	**0.0001**
COV	23%	19%	24%	-81%	26%	23%	24%	219%

	13 psi cyclic stress @ surface				18 psi plate cyclic stress @ surface			
Point #	$M_{r\text{-Comp}}$ (psi)	$M_{r\text{-Base}}$ (psi)	$M_{r\text{-SG}}$ (psi)	$\Delta\delta_p$ ([in.)	$M_{r\text{-Comp}}$ (psi)	$M_{r\text{-Base}}$ (psi)	$M_{r\text{-SG}}$ (psi)	$\Delta\delta_p$ ([in.)
PT4 / 3	11,411	19,535	7,283	0.0005	9,651	16,447	6,181	0.0097
PT5	18,141	31,768	10,385	0.0014	16,157	27,734	9,411	0.0138
PT6 / 2	12,687	26,054	6,744	0.0022	11,277	21,967	6,219	0.0140
PT7	19,789	32,710	11,496	0.0010	17,982	27,971	11,071	0.0082
AVG	**15,507**	**27,517**	**8,977**	**0.0013**	**13,767**	**23,530**	**8,221**	**0.0115**
COV	26%	22%	26%	56%	29%	23%	30%	26%

	28 psi cyclic stress @ surface				38 psi plate cyclic stress @ surface			
Point #	$M_{r\text{-Comp}}$ (psi)	$M_{r\text{-Base}}$ (psi)	$M_{r\text{-SG}}$ (psi)	$\Delta\delta_p$ ([in.)	$M_{r\text{-Comp}}$ (psi)	$M_{r\text{-Base}}$ (psi)	$M_{r\text{-SG}}$ (psi)	$\Delta\delta_p$ ([in.)
PT4 / 3	7,642	12,752	4,987	0.0512	6,752	11,565	4,312	0.1028
PT5	12,785	19,552	8,208	0.0594	11,113	16,407	7,367	0.1083
PT6 / 2	9,096	15,585	5,525	0.0578	8,239	13,961	5,042	0.1076
PT7	15,181	21,261	10,324	0.0329	13,808	18,641	9,717	0.0615
AVG	**11,176**	**17,288**	**7,261**	**0.0503**	**9,978**	**15,144**	**6,610**	**0.0951**
COV	31%	22%	34%	24%	31%	20%	37%	24%

Summary of Test Results

Summary of AASHTO (2015) universal model parameters

$M_{r\text{-}Comp}$

Point #	$k^*_{1(Comp)}$	$k^*_{2(Comp)}$	$k^*_{3(Comp)}$	R^2(Adj.)	Std. Error (psi)	$M_{r\text{-}Comp(pred)\text{-}BP}$ (psi)	$\sigma_{cyclic\text{-}BP}$ (psi)
PT4 / 3	1,002.3	-0.024	-2.211	0.975	412	14,453	2.0
PT5	1,612.3	0.035	-2.435	0.983	499	21,617	2.0
PT6 / 2	1,085.4	0.001	-1.997	0.981	338	15,269	2.0
PT7	1,616.1	0.055	-1.905	0.979	426	21,477	3.0
AVG	**1,329.0**	**0.017**	**-2.137**	**0.979**	**418**	**18,204**	**2.3**
COV	25%	207%	-0.111	0%	16%	21%	22%

$M_{r\text{-}Base}$

Point #	$k^*_{1(Base)}$	$k^*_{2(Base(}$	$k^*_{3(Base)}$	R^2(Adj.)	Std. Error (psi)
PT4 / 3	1,640.3	-0.066	-1.849	0.916	1,243
PT5	3,047.8	0.169	-3.894	0.959	1,522
PT6 / 2	2,363.9	0.055	-3.059	0.935	1,571
PT7	2,875.6	0.121	-3.089	0.949	1,487
AVG	**2,481.9**	**0.070**	**-2.973**	**0.940**	**1,456**
COV	25%	146%	-0.284	2%	10%

$M_{r\text{-}SG}$

Point #	$k^*_{1(SG)}$	$k^*_{2(SG)}$	$k^*_{3(SG)}$	R^2(Adj.)	Std. Error (psi)
PT4 / 3	667.6	-0.010	-3.996	0.990	166
PT5	723.2	-0.157	-1.358	0.998	86
PT6 / 2	490.0	-0.097	-1.543	0.994	83
PT7	834.0	-0.037	-1.091	0.993	84
AVG	**678.7**	**(0.075)**	**-1.997**	**0.994**	**105**
COV	21%	-87%	-0.674	0%	39%

Summary of Test Results

Summary of Static PLT results

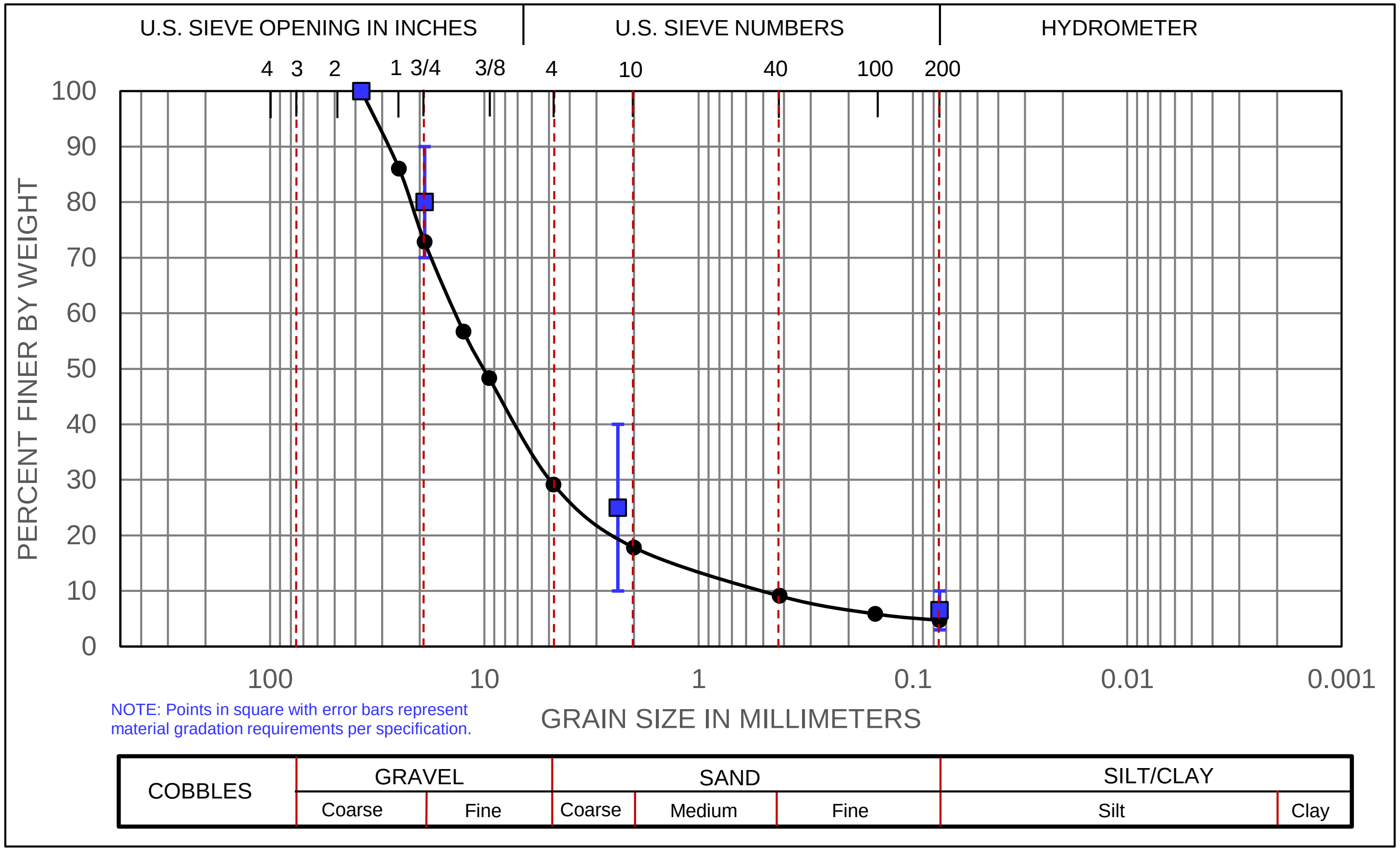
Point #	30 in. static PLT k_u (pci) at δ = 0.05 in.[a]	k_{u1} (pci) at 10 psi[b]	k_{u2} (pci) at 10 psi	Ratio of k_{u2}/k_{u1}
PT1	104	106	351	3.3
PT2 / 6	58	62	275	4.5
PT3 / 4	52	52	224	4.3

[a]per PCA design critera
[b]per AASHTO T222

Summary of DCP test results

	Subbase Layer			Subgrade Layer			Ratio
Point #	Thickness, H_1 (in.)	Avg. CBR (%)	St. Dev CBR (%)	Thickness, H_2 (in.)	Avg. CBR (%)	St. Dev CBR (%)	CBR_1/ CBR_2
PT1	9.6	26.0	10.1	12.0	8.4	6.0	3.1
PT2 / 6	8.1	29.8	9.1	12.0	3.9	2.2	7.6
PT3 / 4	7.5	20.6	3.0	12.0	3.6	2.9	5.7
PT5	8.6	22.2	3.9	12.0	4.9	3.3	4.5
PT7	9.0	28.7	9.3	12.0	5.5	3.1	5.2
AVG	**8.6**	**25.5**	**7.1**	**12.0**	**5.3**	**3.5**	**5.2**
COV	**9%**	**16%**	**47%**	**0%**	**36%**	**42%**	**31%**

GRAIN SIZE DISTRIBUTION
ASTM D422/C136



Gradation Summary

% Gravel	70.9
% Sand	24.4
% Fines	4.7
D_{10} (mm)	0.583
D_{30} (mm)	4.968
D_{50} (mm)	10.108
D_{60} (mm)	13.837
D_{85} (mm)	24.536
C_u	23.739
C_c	3.060

Atterberg Limits

LL	NP
PL	NP
PI	NP

Classification

AASHTO:	A-1-a
USCS:	GP

MATERIAL: Crushed Recycled Material - Top 3 in. (Iowa DOT Gradation 4123 - Modified Subbase)

LOCATION: Hwy 100 N. of E Ave., Linn County (Project #8) **TESTED BY:** DW

SAMPLE DATE: 5/8/2018 **TEST DATE:** 9/7/2018

Gradation and Soil Classification Test Results

Project Name: Iowa DOT STIC

Project ID: SIA-00001

Location: Hwy 100 N. of E Ave., Linn County (Project #8)

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Automated Plate Load Test [APLT]

Test:	In-Situ Static Plate Load Test: Two Loading Cycles.				
Date:	5/8/2018	Time:	12:11:03 PM	Test ID	100th_30in._pt1
Tested By	DW, JV	Location:	EB, Center	Sta.	NA
Latitude:	42.01031	Longitude:	91.76941	Elev. (ft):	776
Comments:	Design: 6 in. modified subbase over polymer geogrid. Subbase = 3 in. virgn (bottom) + 3 in. recyled (top)				

Cycle	Stage	Load Step	Target Applied Load (lbs)	Target Applied Stress (psi)	Actual Applied Stress (psi)	Deformation (in.) Sensor 1	Sensor 2	Sensor 3	Average Def. (in.)
0	Seating	0	707	1	1.30	0.0290	0.0176	0.0050	0.0172
Zero load and deformation sensors after applying the seating stress.									
1	Seating	0	0	0	0.00	0.0000	0.0000	0.0000	0.0000
1	Load	1	1767	2.5	2.48	0.0299	0.0314	0.0179	0.0264
1	Load	2	3534	5	4.96	0.0521	0.0570	0.0343	0.0478
1	Load	3	5301	7.5	7.42	0.0745	0.0808	0.0525	0.0693
1	Load	4	7069	10	9.90	0.0996	0.1067	0.0747	0.0937
1	Load	5	8836	12.5	12.38	0.1226	0.1328	0.0959	0.1171
1	Load	6	10603	15	14.88	0.1424	0.1547	0.1143	0.1371
1	Unload	7	7069	10	9.90	0.1357	0.1481	0.1074	0.1304
1	Unload	8	3534	5	4.98	0.1239	0.1332	0.0935	0.1169
1	Unload	9	1767	2.5	2.47	0.1144	0.1208	0.0834	0.1062
2	Load	10	3534	5	4.95	0.1187	0.1268	0.0884	0.1113
2	Load	11	7069	10	9.88	0.1309	0.1414	0.1011	0.1244
2	Load	12	10603	15	14.86	0.1464	0.1581	0.1173	0.1406
2	Unload	13	1767	2.5	2.50	0.1175	0.1238	0.0859	0.1091
2	Unload	14	0	0	0.00	0.1032	0.1066	0.0721	0.0940

Plate Diameter:	30.0	in.
Shape factor:	2.67	
Material Type:	B	A = Cohesive, B = Granular, C = Intermediate
Poisson's ratio:	0.4	
Design Stress:	10.0	psi
Target Deformation:	0.05	in.

AASHTO T222 Method
PCA Design Criteria

k_{u1} (pci) @ design stress:	106
k_u (pci) @ δ = 0.05 in.:	104

Modulus at target deformation

Stress @ δ = 0.05 in. (psi)	5.2
E_1 (psi)	3,511
k'_u (pci)	105
k_u (pci)	104

Modulus at target/design applied stress

First Loading Cycle

δ_1 (in.)	0.0937
E_1 (psi)	3,569
k'_{u1} (pci)	107
k_{u1} (pci)	106

Second Loading Cycle

δ_2 (in.)	0.0230
E_2 (psi)	11,804
k'_{u2} (pci)	434
k_{u2} (pci)	351
E_2 / E_1 or k_2 / k_1 Ratio	3.3

Plate Bending Correction for

$k'_u \geq 100$ *and* $1{,}000$ *pci*

$k_u = -39.9178 + 5.5076\,[k'_u]^{0.7019}$

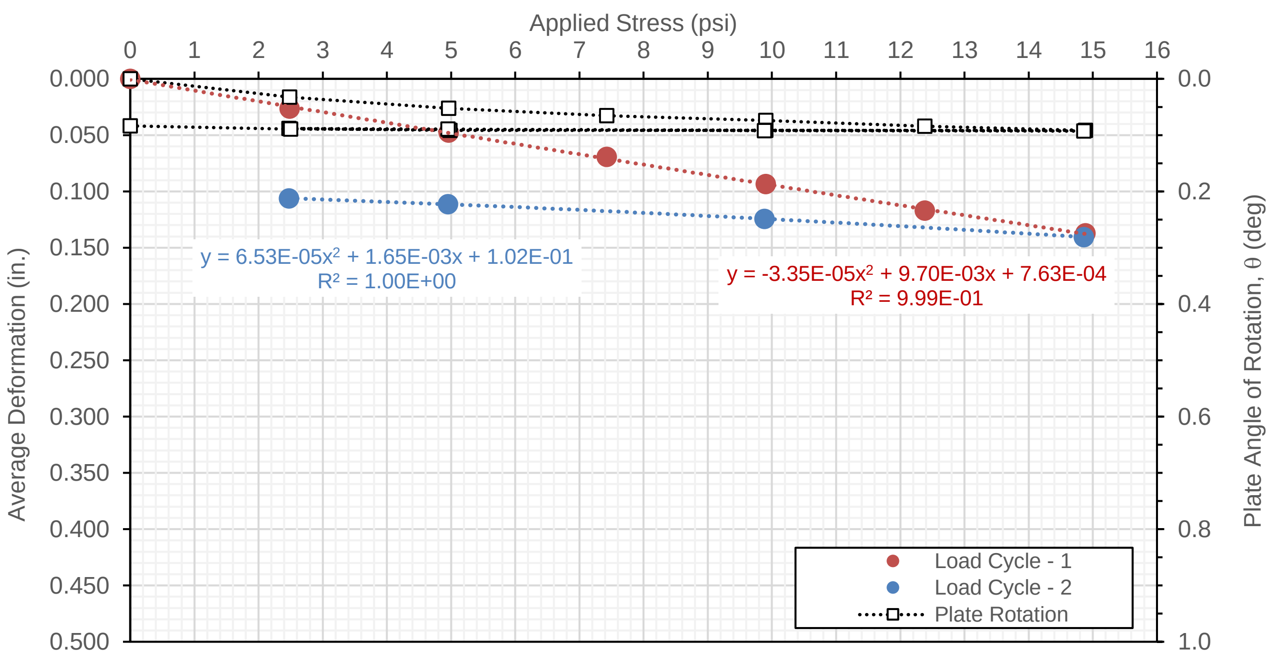
In-situ Modulus of Subgrade Reaction (k) and Elastic Modulus

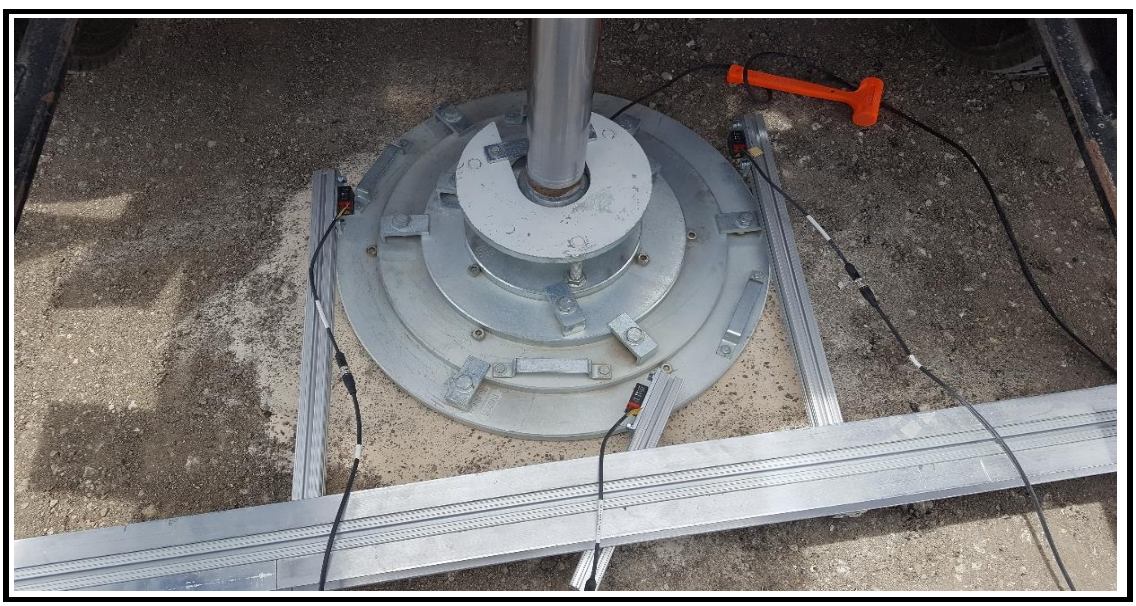
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 100 N. of E Ave., Linn County (Project #8)

Polynomial Fit Parameters

First Cycle		*Second Cycle*			
a_1	-3.35E-05	a_1	6.53E-05	θ_{max} (deg)	0.0927
a_2	9.70E-03	a_2	1.65E-03		
R^2	1.00	R^2	1.00		

NOTES:
1. Test performed per AASHTO T222/ASTM D1196.
2. k-value determined using:
   (a) calculated stress at 0.05 in. plate deformation (δ) for first loading cycle, per PCA design guidelines, and
   (b) for a defined target stress and calculating corresponding plate deformations using polynomial fit parameters.





Automated Plate Load Test [APLT]

Test:	In-Situ Static Plate Load Test: Two Loading Cycles.				
Date:	5/8/2018	Time:	12:55:51 PM	Test ID	100th_30in._pt2
Tested By	DW, JV	Location:	EB, Center	Sta.	NA
Latitude:	42.01055	Longitude:	91.76899	Elev. (ft):	776
Comments:	Design: 6 in. modified subbase over polymer geogrid. Subbase = 3 in. virgn (bottom) + 3 in. recyled (top)				

Cycle	Stage	Load Step	Target Applied Load (lbs)	Target Applied Stress (psi)	Actual Applied Stress (psi)	Deformation (in.) Sensor 1	Sensor 2	Sensor 3	Average Def. (in.)
0	Seating	0	707	1	1.31	0.0312	0.0385	0.0290	0.0329
Zero load and deformation sensors after applying the seating stress.									
1	Seating	0	0	0	0.00	0.0000	0.0000	0.0000	0.0000
1	Load	1	1767	2.5	2.47	0.0411	0.0616	0.0337	0.0454
1	Load	2	3534	5	4.96	0.0845	0.1129	0.0661	0.0879
1	Load	3	5301	7.5	7.41	0.1209	0.1504	0.0972	0.1228
1	Load	4	7069	10	9.89	0.1630	0.1891	0.1329	0.1616
1	Load	5	8836	12.5	12.39	0.2024	0.2224	0.1628	0.1959
1	Load	6	10603	15	14.74	0.2437	0.2606	0.1911	0.2318
1	Unload	7	7069	10	9.90	0.2323	0.2519	0.1832	0.2225
1	Unload	8	3534	5	4.97	0.2102	0.2331	0.1682	0.2038
1	Unload	9	1767	2.5	2.47	0.1901	0.2155	0.1540	0.1866
2	Load	10	3534	5	4.97	0.1978	0.2221	0.1595	0.1932
2	Load	11	7069	10	9.88	0.2203	0.2430	0.1749	0.2127
2	Load	12	10603	15	14.86	0.2547	0.2696	0.1974	0.2406
2	Unload	13	1767	2.5	2.51	0.1994	0.2245	0.1603	0.1947
2	Unload	14	0	0	0.00	0.1725	0.1983	0.1349	0.1686

Plate Diameter:	30.0	in.
Shape factor:	2.67	
Material Type:	B	A = Cohesive, B = Granular, C = Intermediate
Poisson's ratio:	0.4	
Design Stress:	10.0	psi
Target Deformation:	0.05	in.

AASHTO T222 Method
PCA Design Criteria

k_{u1} (pci) @ design stress:	62
k_u (pci) @ δ = 0.05 in.:	58

Modulus at target deformation

Stress @ δ = 0.05 in. (psi)	2.9
E_1 (psi)	1,949
k'_u (pci)	58
k_u (pci)	58

Modulus at target/design applied stress

First Loading Cycle

δ_1 (in.)	0.1621
E_1 (psi)	2,073
k'_{u1} (pci)	62
k_{u1} (pci)	62

Second Loading Cycle

δ_2 (in.)	0.0314
E_2 (psi)	9,230
k'_{u2} (pci)	318
k_{u2} (pci)	275
E_2 / E_1 or k_2 / k_1 Ratio	4.5

Plate Bending Correction for

$k'_u \geq 100$ *and* $1{,}000$ *pci*

$k_u = -39.9178 + 5.5076\,[k'_u]^{0.7019}$

In-situ Modulus of Subgrade Reaction (k) and Elastic Modulus

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 100 N. of E Ave., Linn County (Project #8)

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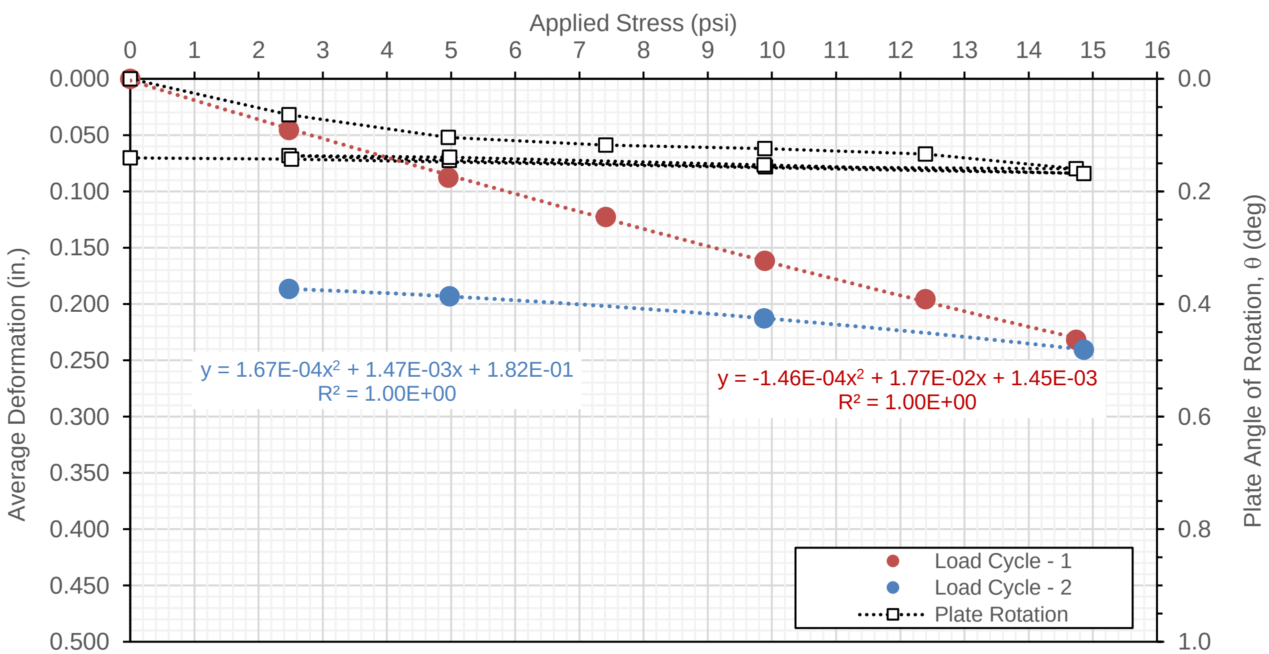
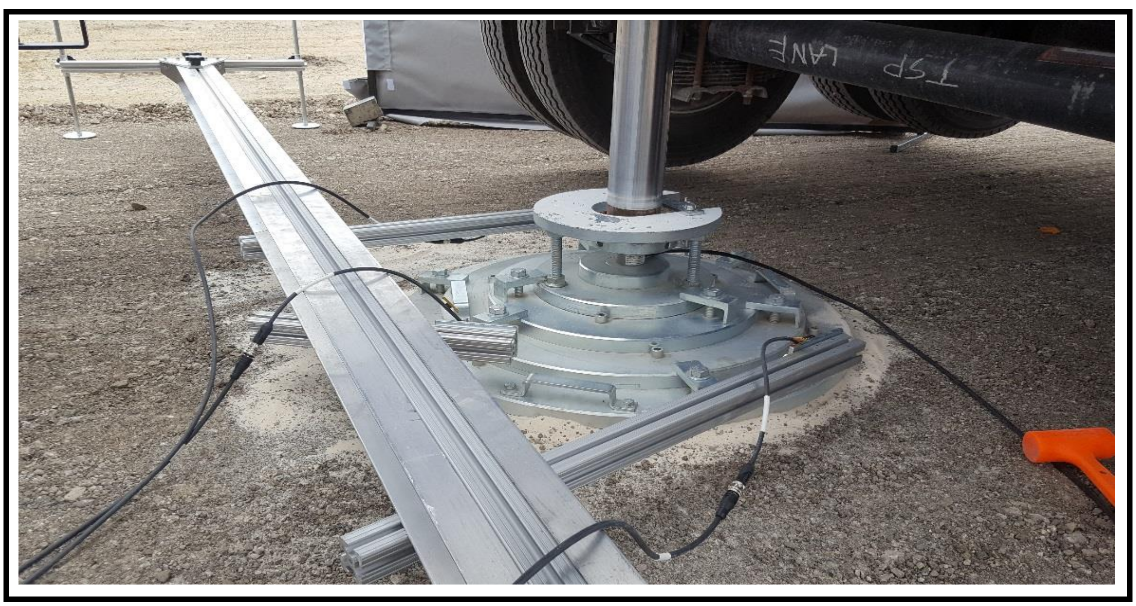
Polynomial Fit Parameters

First Cycle		*Second Cycle*			
a_1	-1.46E-04	a_1	1.67E-04	θ_{max} (deg)	0.1681
a_2	1.77E-02	a_2	1.47E-03		
R^2	1.00	R^2	1.00		

NOTES:
1. Test performed per AASHTO T222/ASTM D1196.
2. k-value determined using:
   (a) calculated stress at 0.05 in. plate deformation (δ) for first loading cycle, per PCA design guidelines, and
   (b) for a defined target stress and calculating corresponding plate deformations using polynomial fit parameters.





Automated Plate Load Test [APLT]

Test:	In-Situ Static Plate Load Test: Two Loading Cycles.				
Date:	5/8/2018	Time:	1:43:14 PM	Test ID	100th_30in._pt3
Tested By	DW, JV	Location:	EB, Center	Sta.	NA
Latitude:	42.01088	Longitude:	91.76841	Elev. (ft):	764
Comments:	Design: 6 in. modified subbase over polymer geogrid. Subbase = 3 in. virgn (bottom) + 3 in. recyled (top)				

Cycle	Stage	Load Step	Target Applied Load (lbs)	Target Applied Stress (psi)	Actual Applied Stress (psi)	Deformation (in.) Sensor 1	Sensor 2	Sensor 3	Average Def. (in.)
0	Seating	0	707	1	1.31	0.0319	0.0458	0.0410	0.0396
Zero load and deformation sensors after applying the seating stress.									
1	Seating	0	0	0	0.00	0.0000	0.0000	0.0000	0.0000
1	Load	1	1767	2.5	2.49	0.0533	0.0583	0.0500	0.0539
1	Load	2	3534	5	4.97	0.0976	0.1088	0.0945	0.1003
1	Load	3	5301	7.5	7.44	0.1463	0.1569	0.1324	0.1452
1	Load	4	7069	10	9.93	0.1944	0.2032	0.1765	0.1914
1	Load	5	8836	12.5	12.38	0.2480	0.2518	0.2248	0.2415
1	Load	6	10603	15	14.85	0.2999	0.2980	0.2711	0.2897
1	Unload	7	7069	10	9.91	0.2873	0.2861	0.2597	0.2777
1	Unload	8	3534	5	4.97	0.2578	0.2626	0.2342	0.2515
1	Unload	9	1767	2.5	2.48	0.2339	0.2409	0.2143	0.2297
2	Load	10	3534	5	4.95	0.2431	0.2511	0.2226	0.2389
2	Load	11	7069	10	9.87	0.2703	0.2729	0.2469	0.2634
2	Load	12	10603	15	14.88	0.3096	0.3082	0.2828	0.3002
2	Unload	13	1767	2.5	2.47	0.2445	0.2521	0.2249	0.2405
2	Unload	14	0	0	0.00	0.2078	0.2117	0.1955	0.2050

Plate Diameter:	30.0	in.
Shape factor:	2.67	
Material Type:	B	A = Cohesive, B = Granular, C = Intermediate
Poisson's ratio:	0.4	
Design Stress:	10.0	psi
Target Deformation:	0.05	in.

AASHTO T222 Method
PCA Design Criteria

k_{u1} (pci) @ design stress:	52
k_u (pci) @ δ = 0.05 in.:	52

Modulus at target deformation

Stress @ δ = 0.05 in. (psi)	2.6
E_1 (psi)	1,735
k'_u (pci)	52
k_u (pci)	52

Plate Bending Correction for

$$k'_u \geq 100 \text{ and } 1{,}000 \text{ pci}$$

$$k_u = -39.9178 + 5.5076\,[k'_u]^{0.7019}$$

Modulus at target/design applied stress

First Loading Cycle

δ_1 (in.)	0.1931
E_1 (psi)	1,740
k'_{u1} (pci)	52
k_{u1} (pci)	52

Second Loading Cycle

δ_2 (in.)	0.0404
E_2 (psi)	7,513
k'_{u2} (pci)	247
k_{u2} (pci)	224
E_2 / E_1 or k_2 / k_1 Ratio	4.3

In-situ Modulus of Subgrade Reaction (k) and Elastic Modulus

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 100 N. of E Ave., Linn County (Project #8)

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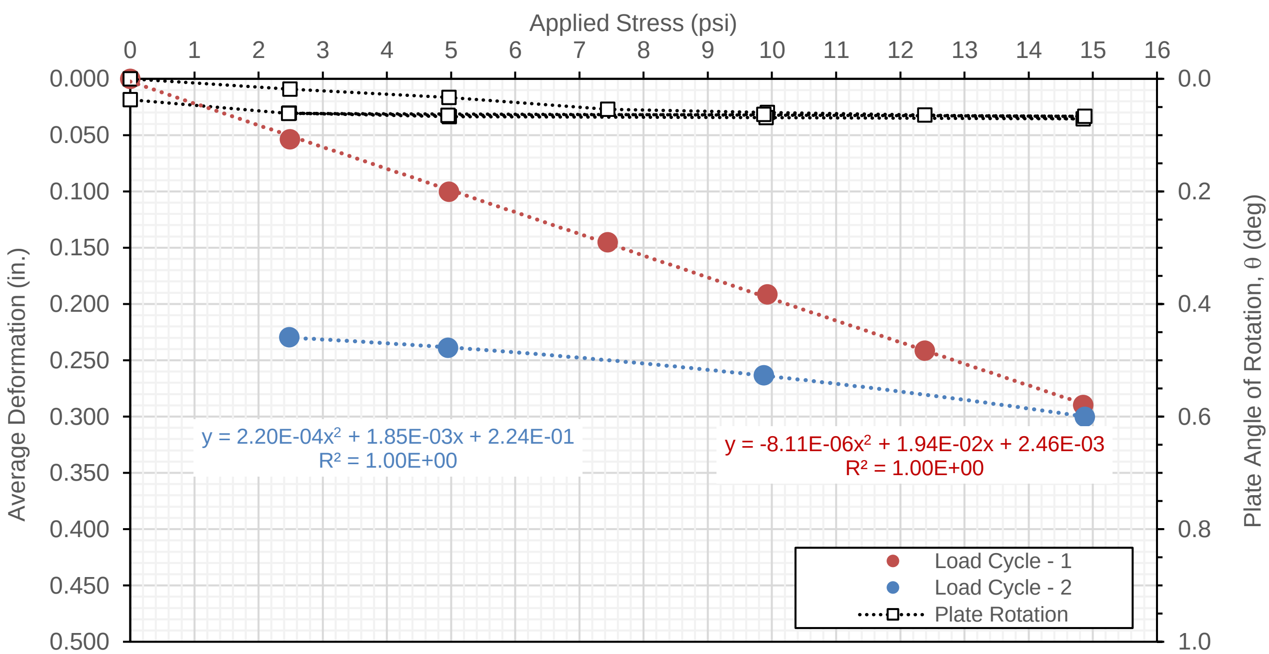
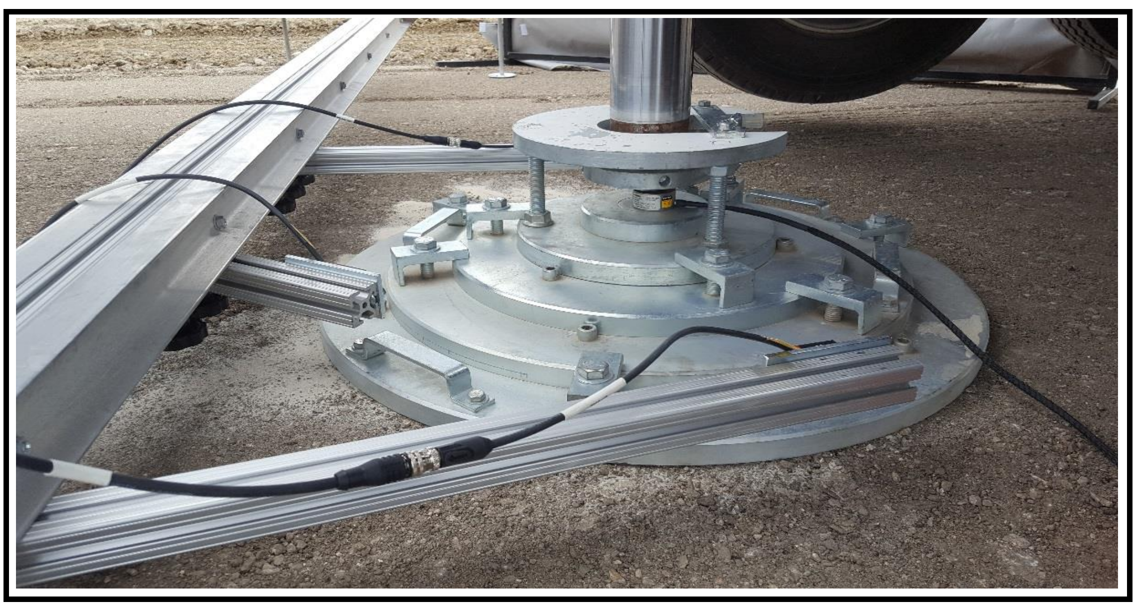
Polynomial Fit Parameters

First Cycle		*Second Cycle*			
a_1	-8.11E-06	a_1	2.20E-04	θ_{max} (deg)	0.0712
a_2	1.94E-02	a_2	1.85E-03		
R^2	1.00	R^2	1.00		

NOTES:
1. Test performed per AASHTO T222/ASTM D1196.
2. k-value determined using:
   (a) calculated stress at 0.05 in. plate deformation (δ) for first loading cycle, per PCA design guidelines, and
   (b) for a defined target stress and calculating corresponding plate deformations using polynomial fit parameters.

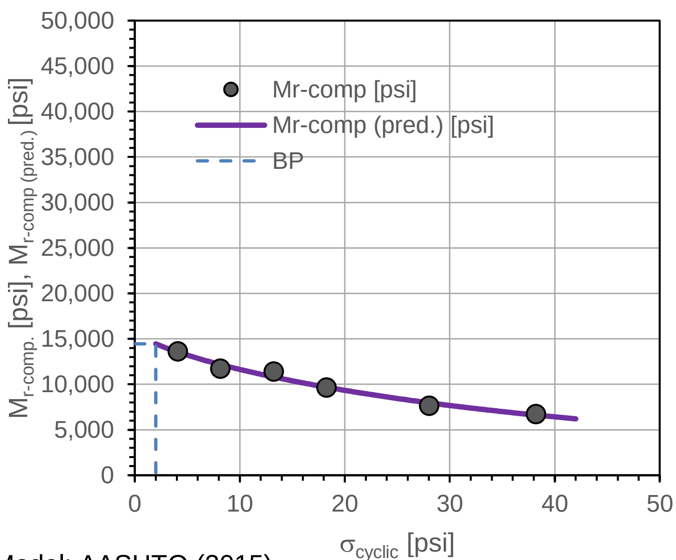


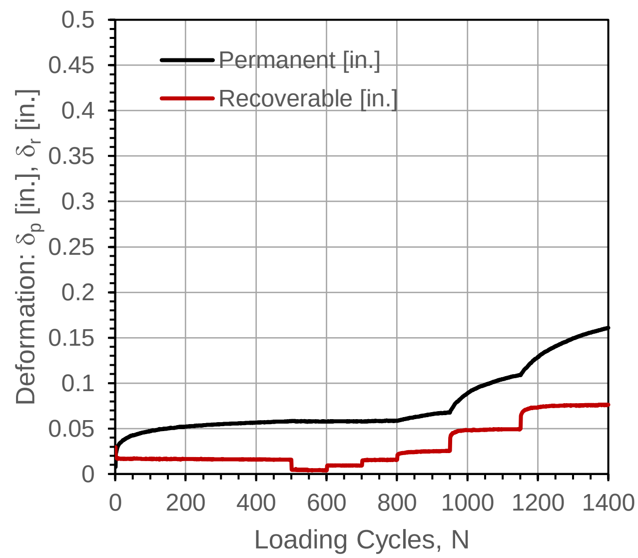


Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	5/8/2018	Time:	2:45:26 PM	Test ID	**100th_12_pt4**
Tested By	DW, JV	Location:	Hwy 100	Sta.	NA
Latitude,N:	42.010868	Longitude,W:	91.768410	Elev. (ft):	763
Comments:	Design: 6 in. modified subbase over polymer geogrid. Subbase = 3 in. virgn (bottom) + 3 in. recyled (top)				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.23	---	---	0.0581	---	0.162	---
1	100	4.11	13,624	13,537	0.0578	-0.0003	-0.140	Y
2	100	8.15	11,732	12,175	0.0580	-0.0001	0.119	Y
3	100	13.23	11,411	10,803	0.0586	0.0005	0.452	Y
4	150	18.26	9,651	9,683	0.0679	0.0097	0.793	N
5	200	28.04	7,642	7,962	0.1093	0.0512	0.688	N
6	250	38.21	6,752	6,617	0.1609	0.1028	0.785	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	1,002.3	9.71E-07
k^*_2	-0.024	8.15E-01
k^*_3	-2.211	4.77E-02
Adj. R^2	0.975	
Std. Error [psi]	412	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	14,453
$\sigma_{cyclic\text{-}BP}$ [psi]	2.0

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 100 N. of E Ave., Linn County (Project #8)

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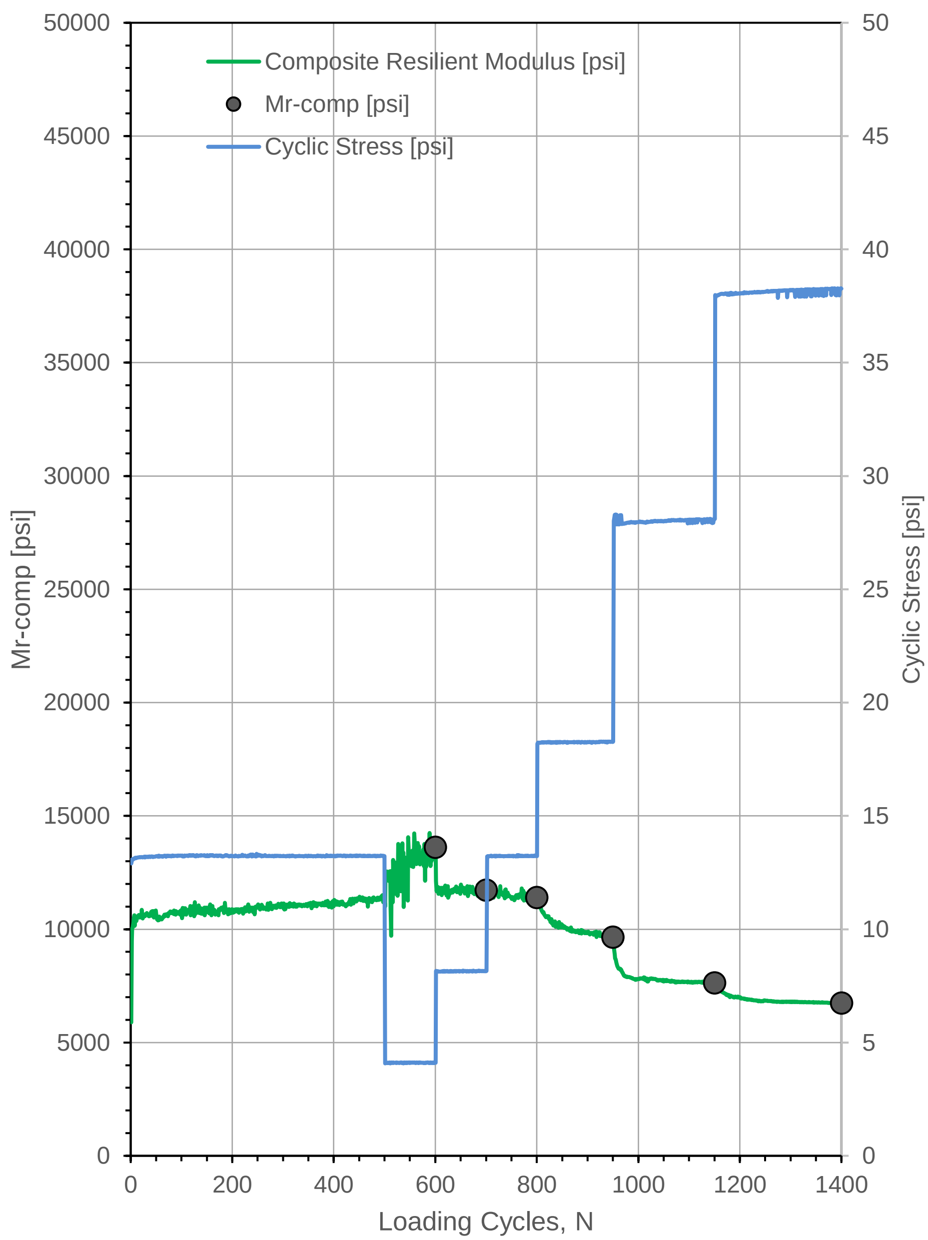
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	5/8/2018	Time:	2:45:26 PM	Test ID	**100th_12_pt4**
Tested By	DW, JV	Location:	Hwy 100	Sta.	NA
Latitude,N:	42.010868	Longitude,W:	91.768410	Elev. (ft):	763
Comments:	Design: 6 in. modified subbase over polymer geogrid. Subbase = 3 in. virgn (bottom) + 3 in. recyled (top)				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	14,453
3	13,988
4	13,579
5	13,205
6	12,857
7	12,530
8	12,219
9	11,924
10	11,641
11	11,370
12	11,110
13	10,860
14	10,619
15	10,387
16	10,163
17	9,946
18	9,737
21	9,148
22	8,964
23	8,785
24	8,612
25	8,444
26	8,281
27	8,122
28	7,968
29	7,819
30	7,673
31	7,532
32	7,394
33	7,260
34	7,130
35	7,003
36	6,879
37	6,759
38	6,642
39	6,527
40	6,416



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

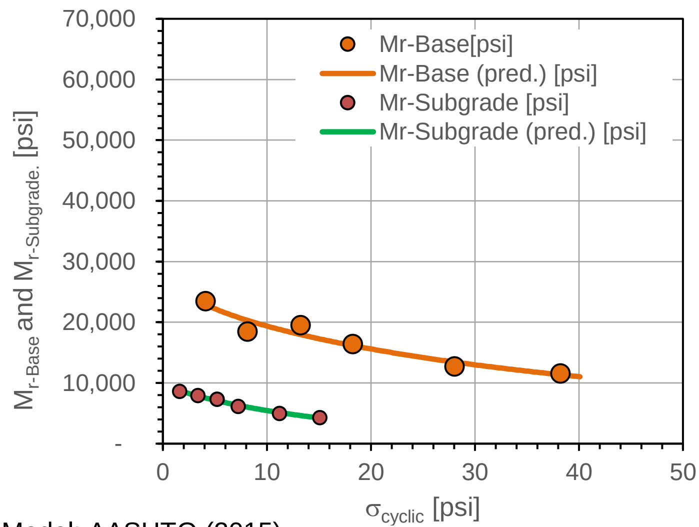
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 100 N. of E Ave., Linn County (Project #8)

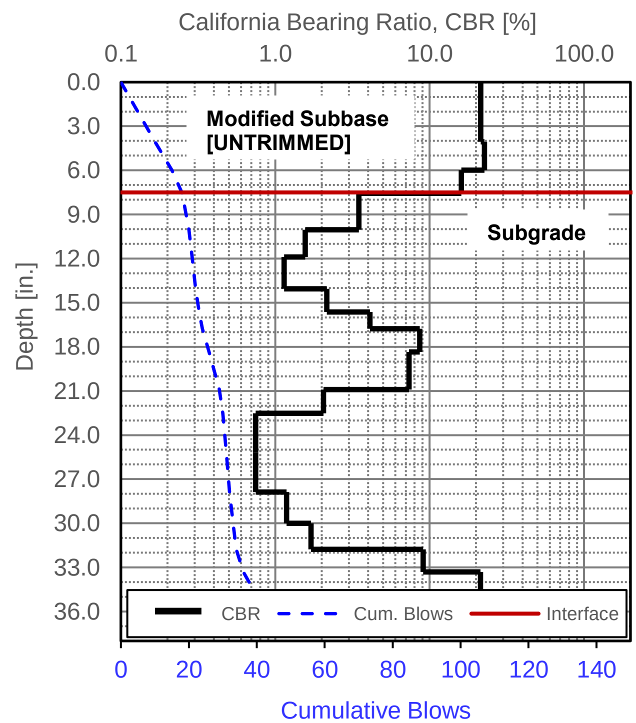
ingios GEOTECHNICS

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	5/8/2018	Time:	2:45:26 PM	Test ID	**100th_12_pt4**
Tested By	DW, JV	Location:	Hwy 100	Sta.	NA
Latitude,N:	42.010868	Longitude,W:	91.768410	Elev. (ft):	763
Comments:	Design: 6 in. modified subbase over polymer geogrid. Subbase = 3 in. virgn (bottom) + 3 in. recyled (top)				

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	13.23	---	---	---	---	---	---
1	100	4.11	23,515	22,913	1.61	8,627	8,724	2.73
2	100	8.15	18,515	20,312	3.37	7,937	7,850	2.33
3	100	13.23	19,535	17,971	5.22	7,283	7,064	2.68
4	100	18.26	16,447	16,155	7.23	6,181	6,323	2.66
5	100	28.04	12,752	13,446	11.22	4,987	5,126	2.56
6	100	38.21	11,565	11,355	15.08	4,312	4,228	2.68

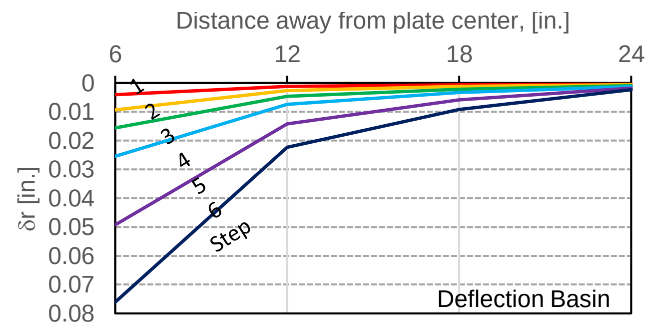




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\ (Base)}$	1640.3	4.16E-06
$k^*_{2\ (Base)}$	-0.066	7.10E-01
$k^*_{3\ (Base)}$	-1.849	2.17E-01
Adj. R^2	0.916	
Std. Error [psi]	1243	
$k^*_{1\ (Subgrade)}$	667.6	7.14E-06
$k^*_{2\ (Subgrade)}$	-0.010	9.05E-01
$k^*_{3\ (Subgrade)}$	-3.996	1.65E-02
Adj. R^2	0.990	
Std. Error [psi]	166	



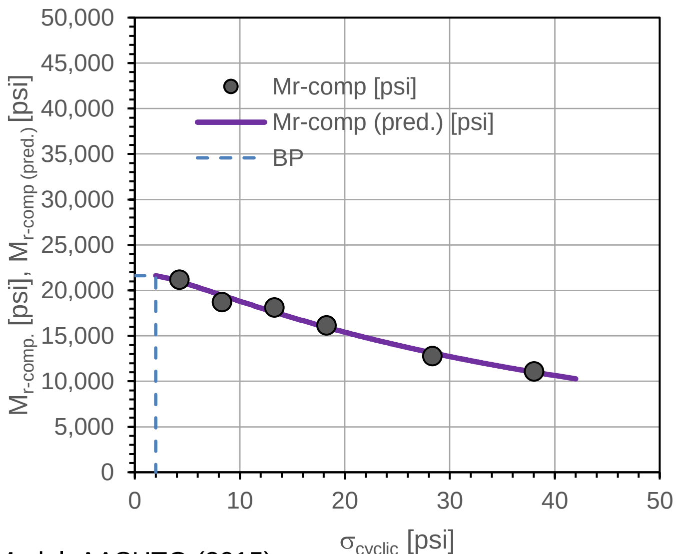
In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

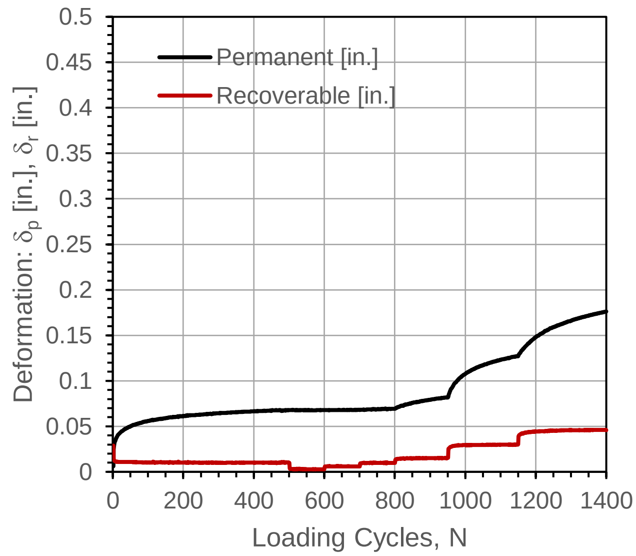
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 100 N. of E Ave., Linn County (Project #8)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	5/8/2018	Time:	3:24:03 PM	Test ID	**100th_12_pt5**
Tested By	DW, JV	Location:	Hwy 100	Sta.	NA
Latitude,N:	42.010708	Longitude,W:	91.768715	Elev. (ft):	766
Comments:	Design: 6 in. modified subbase over polymer geogrid. Subbase = 3 in. virgn (bottom) + 3 in. recyled (top)				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.29	---	---	0.0679	---	0.166	---
1	100	4.26	21,197	20,973	0.0678	0.0000	-0.133	Y
2	100	8.31	18,746	19,457	0.0681	0.0002	0.166	Y
3	100	13.29	18,141	17,611	0.0692	0.0014	0.562	Y
4	150	18.27	16,157	15,940	0.0817	0.0138	0.694	N
5	200	28.35	12,785	13,121	0.1272	0.0594	0.652	N
6	250	38.02	11,113	11,009	0.1762	0.1083	0.700	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	1,612.3	2.92E-07
k^*_2	0.035	6.46E-01
k^*_3	-2.435	1.66E-02
Adj. R^2	0.983	
Std. Error [psi]	499	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	21,617
$\sigma_{cyclic\text{-}BP}$ [psi]	2.0

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 100 N. of E Ave., Linn County (Project #8)

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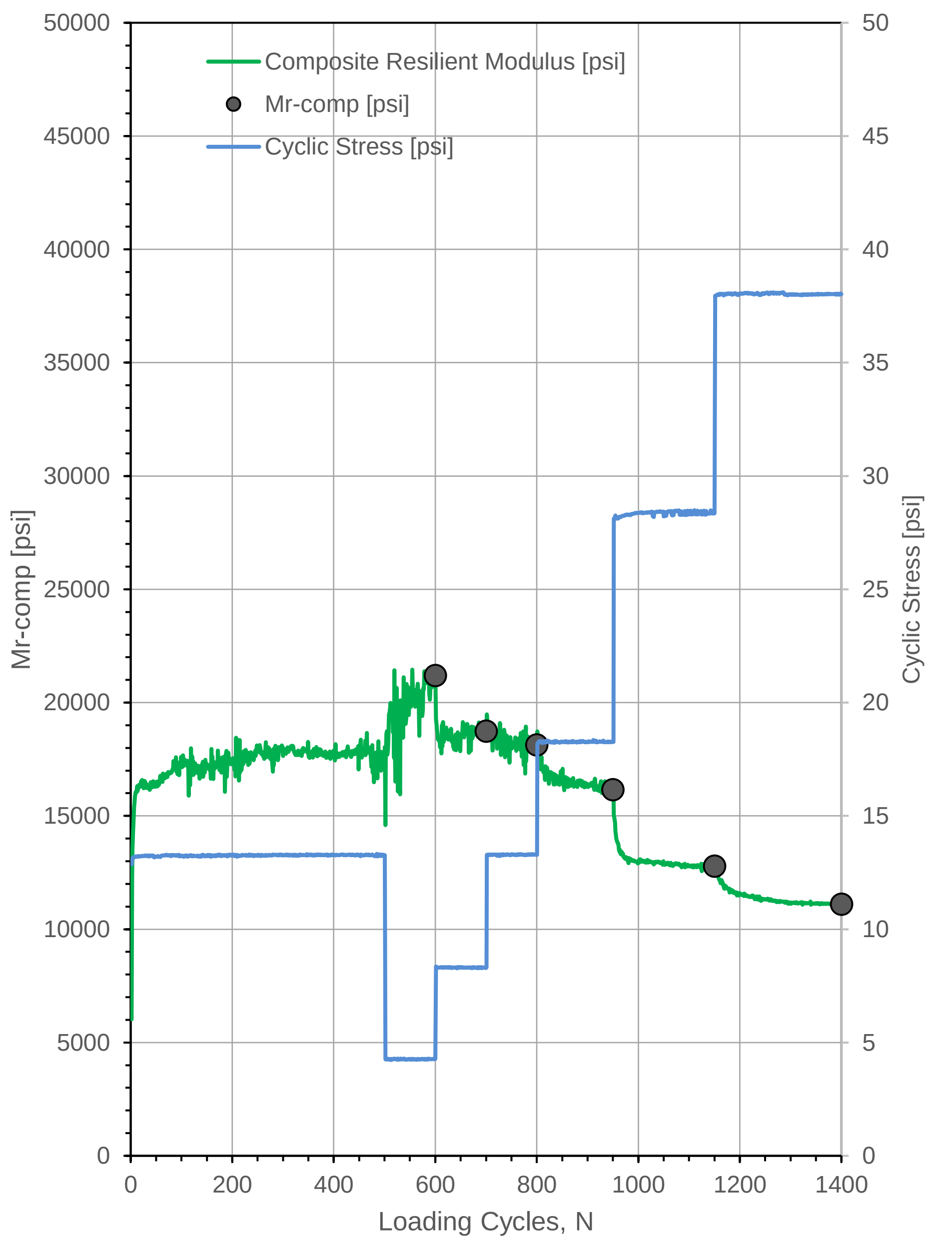
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	5/8/2018	Time:	3:24:03 PM	Test ID	**100th_12_pt5**
Tested By	DW, JV	Location:	Hwy 100	Sta.	NA
Latitude,N:	42.010708	Longitude,W:	91.768715	Elev. (ft):	766
Comments:	Design: 6 in. modified subbase over polymer geogrid. Subbase = 3 in. virgn (bottom) + 3 in. recyled (top)				

σ_{cyclic} [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]
2	21,617
3	21,380
4	21,064
5	20,710
6	20,338
7	19,957
8	19,574
9	19,193
10	18,814
11	18,441
12	18,074
13	17,714
14	17,361
15	17,016
16	16,678
17	16,348
18	16,026
21	15,106
22	14,814
23	14,529
24	14,251
25	13,981
26	13,717
27	13,459
28	13,208
29	12,963
30	12,725
31	12,492
32	12,265
33	12,043
34	11,827
35	11,616
36	11,411
37	11,210
38	11,014
39	10,823
40	10,636



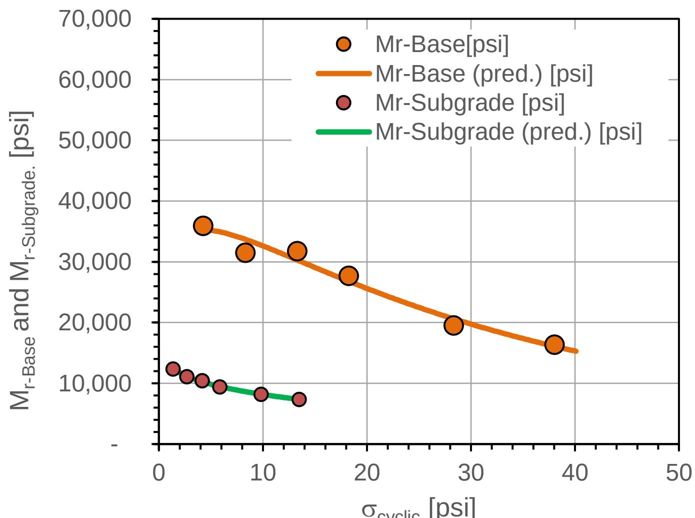
In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

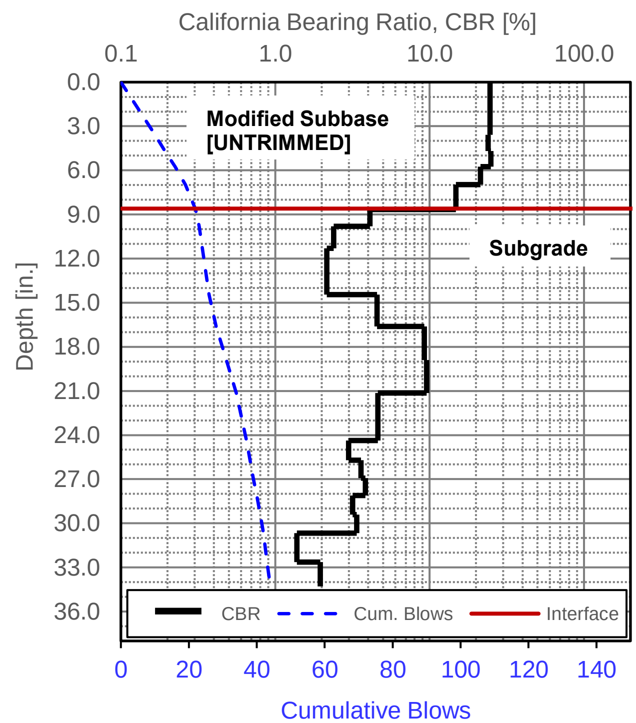
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 100 N. of E Ave., Linn County (Project #8)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	5/8/2018	Time:	3:24:03 PM	Test ID	**100th_12_pt5**
Tested By	DW, JV	Location:	Hwy 100	Sta.	NA
Latitude,N:	42.010708	Longitude,W:	91.768715	Elev. (ft):	766
Comments:	Design: 6 in. modified subbase over polymer geogrid. Subbase = 3 in. virgn (bottom) + 3 in. recyled (top)				

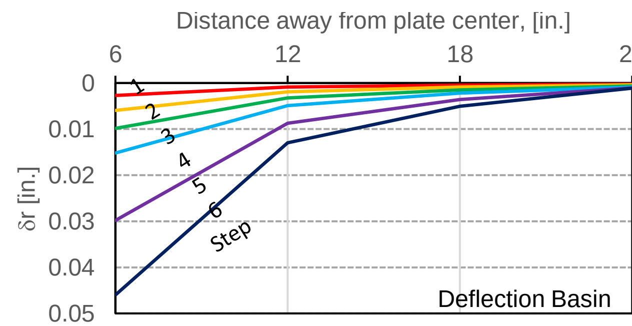
Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	13.29	---	---	---	---	---	---
1	100	4.26	35,951	35,255	1.37	12,378	12,374	2.90
2	100	8.31	31,526	33,712	2.69	11,100	11,162	2.84
3	100	13.29	31,768	30,310	4.19	10,385	10,248	3.06
4	100	18.27	27,734	26,788	5.84	9,411	9,494	2.95
5	100	28.35	19,552	20,620	9.82	8,208	8,209	2.38
6	100	38.02	16,407	16,098	13.48	7,367	7,361	2.23





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
$k^*_{1\ (Base)}$	3047.8	1.47E-06
$k^*_{2\ (Base)}$	0.169	2.81E-01
$k^*_{3\ (Base)}$	-3.894	2.49E-02
Adj. R^2	0.959	
Std. Error [psi]	1522	
$k^*_{1\ (Subgrade)}$	723.2	2.96E-07
$k^*_{2\ (Subgrade)}$	-0.157	8.18E-03
$k^*_{3\ (Subgrade)}$	-1.358	1.88E-02
Adj. R^2	0.998	
Std. Error [psi]	86	

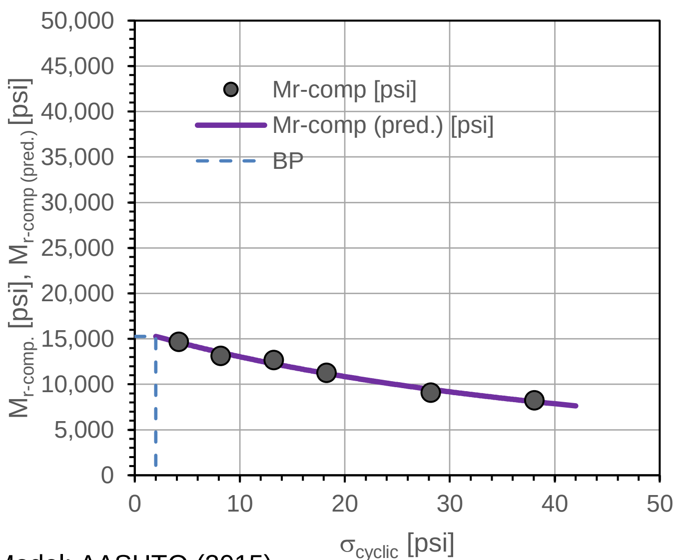
In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

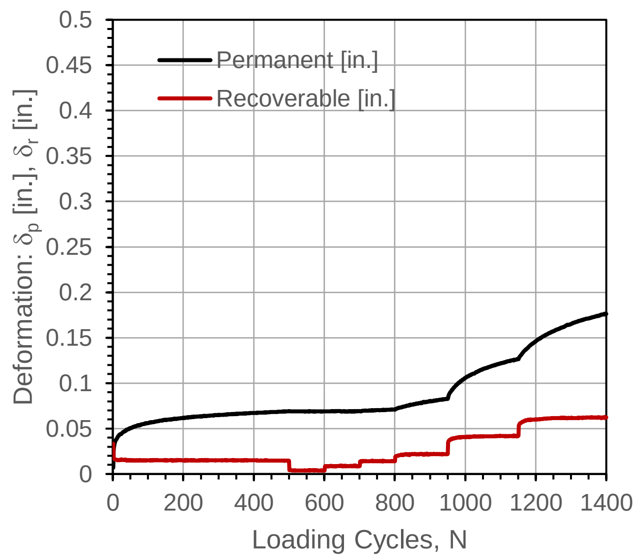
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 100 N. of E Ave., Linn County (Project #8)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	5/8/2018	Time:	4:00:20 PM	Test ID	**100th_12_pt6**
Tested By	DW, JV	Location:	Hwy 100	Sta.	NA
Latitude,N:	42.010544	Longitude,W:	91.769020	Elev. (ft):	761
Comments:	Design: 6 in. modified subbase over polymer geogrid. Subbase = 3 in. virgn (bottom) + 3 in. recyled (top)				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.24	---	---	0.0688	---	0.164	---
1	100	4.20	14,679	14,608	0.0688	-0.0001	-0.116	Y
2	100	8.18	13,147	13,501	0.0692	0.0004	0.026	Y
3	100	13.24	12,687	12,262	0.0710	0.0022	0.537	Y
4	150	18.27	11,277	11,191	0.0829	0.0140	0.746	N
5	200	28.20	9,096	9,449	0.1266	0.0578	0.631	N
6	250	38.06	8,239	8,091	0.1765	0.1076	0.730	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	1,085.4	4.12E-07
k^*_2	0.001	9.85E-01
k^*_3	-1.997	3.20E-02
Adj. R^2	0.981	
Std. Error [psi]	338	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	15,269
$\sigma_{cyclic\text{-}BP}$ [psi]	2.0

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 100 N. of E Ave., Linn County (Project #8)

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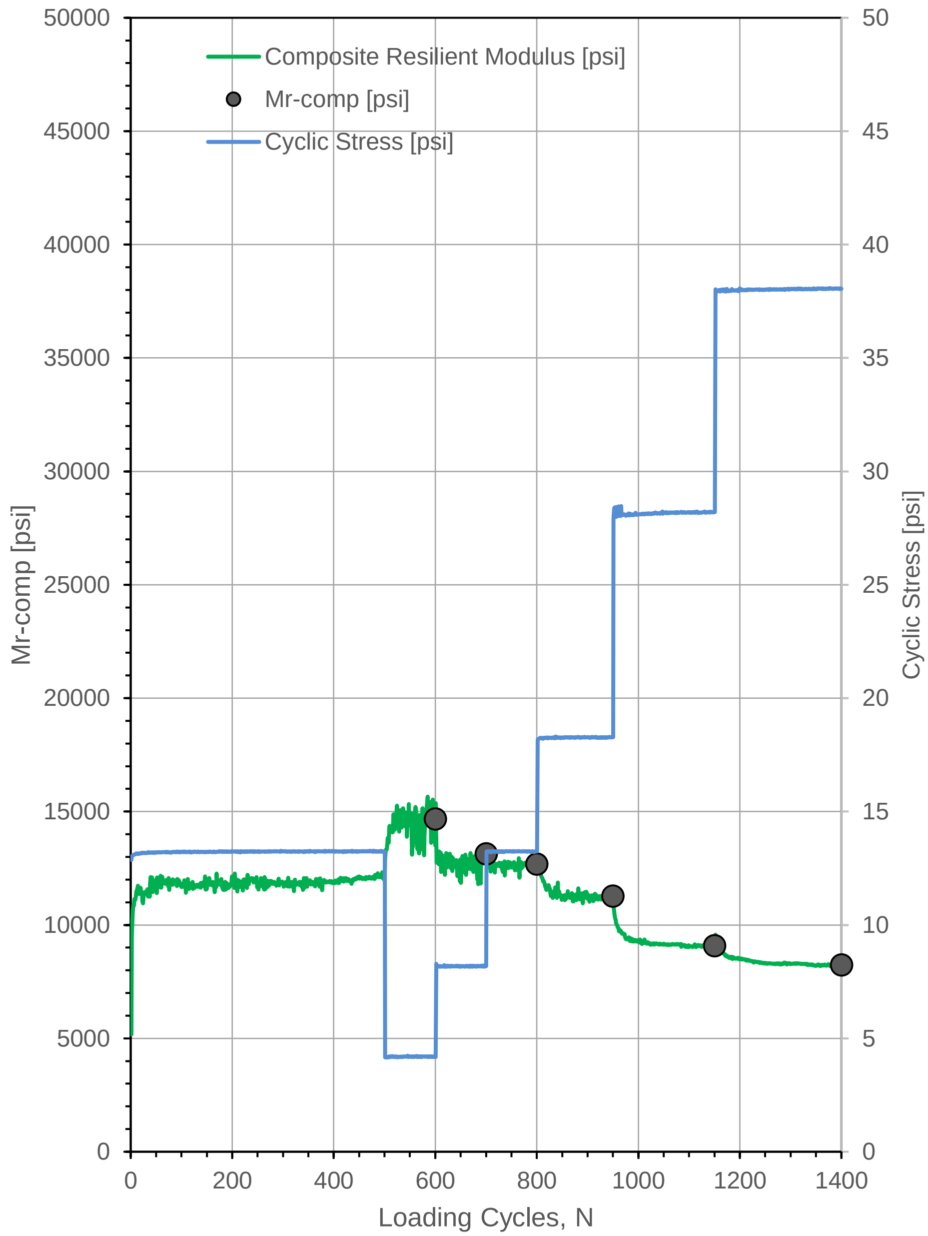
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	5/8/2018	Time:	4:00:20 PM	Test ID	**100th_12_pt6**
Tested By	DW, JV	Location:	Hwy 100	Sta.	NA
Latitude,N:	42.010544	Longitude,W:	91.769020	Elev. (ft):	761
Comments:	Design: 6 in. modified subbase over polymer geogrid. Subbase = 3 in. virgn (bottom) + 3 in. recyled (top)				

σ_{cyclic} [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]
2	15,269
3	14,964
4	14,665
5	14,374
6	14,091
7	13,816
8	13,548
9	13,288
10	13,035
11	12,789
12	12,550
13	12,317
14	12,091
15	11,870
16	11,656
17	11,448
18	11,245
21	10,667
22	10,484
23	10,306
24	10,132
25	9,962
26	9,797
27	9,636
28	9,479
29	9,326
30	9,176
31	9,030
32	8,887
33	8,748
34	8,612
35	8,479
36	8,349
37	8,222
38	8,098
39	7,977
40	7,859



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 100 N. of E Ave., Linn County (Project #8)

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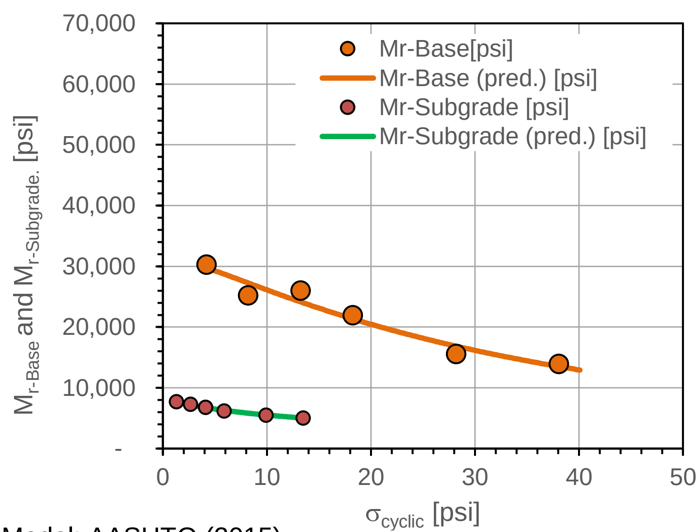
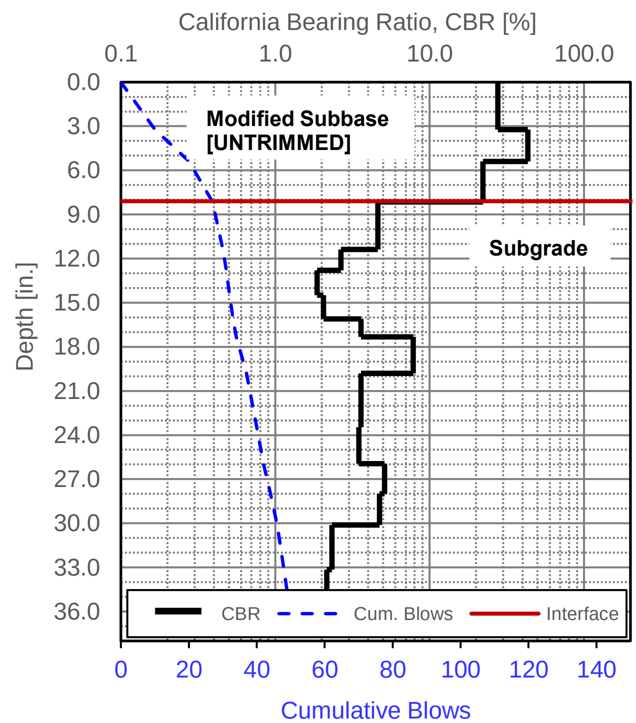
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	5/8/2018	Time:	4:00:20 PM	Test ID	**100th_12_pt6**
Tested By	DW, JV	Location:	Hwy 100	Sta.	NA
Latitude,N:	42.010544	Longitude,W:	91.769020	Elev. (ft):	761
Comments:	Design: 6 in. modified subbase over polymer geogrid. Subbase = 3 in. virgn (bottom) + 3 in. recyled (top)				

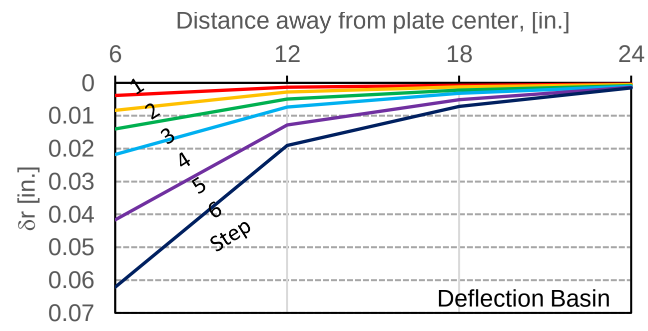
Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-Base}}$[psi]	$M_{r\text{-Base (pred.)}}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-Subgrade}}$ [psi]	$M_{r\text{-Subgrade}}$ (pred.) [psi]	Modulus Ratio
Conditioning	500	13.24	---	---	---	---	---	---
1	100	4.20	30,298	29,712	1.30	7,748	7,815	3.91
2	100	8.18	25,221	27,279	2.66	7,332	7,201	3.44
3	100	13.24	26,054	24,148	4.11	6,744	6,739	3.86
4	100	18.27	21,967	21,352	5.89	6,219	6,294	3.53
5	100	28.20	15,585	16,859	9.92	5,525	5,535	2.82
6	100	38.06	13,961	13,506	13.48	5,042	5,023	2.77





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
$k^*_{1\ (Base)}$	2363.9	3.84E-06
$k^*_{2\ (Base)}$	0.055	7.67E-01
$k^*_{3\ (Base)}$	-3.059	8.87E-02
Adj. R^2	0.935	
Std. Error [psi]	1571	
$k^*_{1\ (Subgrade)}$	490.0	8.85E-07
$k^*_{2\ (Subgrade)}$	-0.097	6.04E-02
$k^*_{3\ (Subgrade)}$	-1.543	2.98E-02
Adj. R^2	0.994	
Std. Error [psi]	83	

In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 100 N. of E Ave., Linn County (Project #8)

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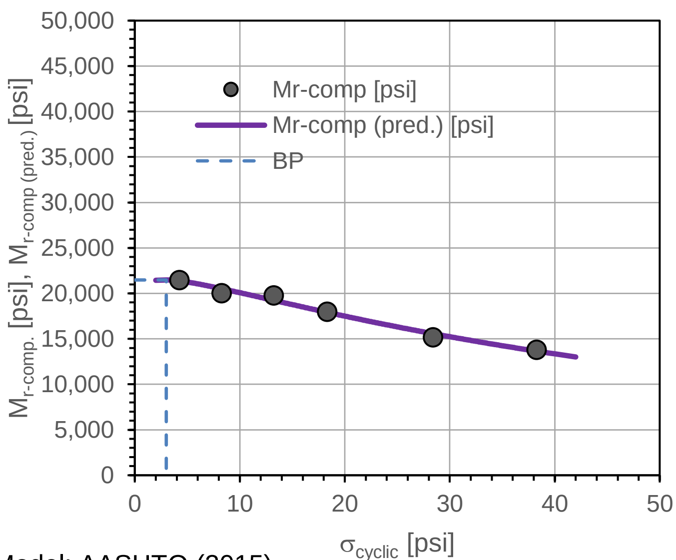
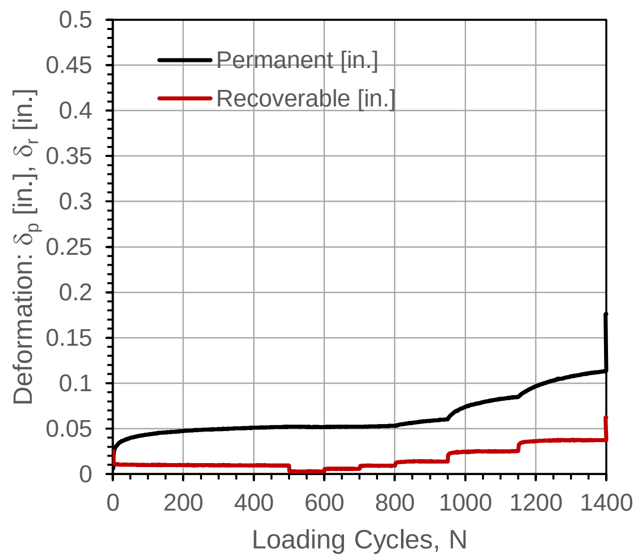
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	5/8/2018	Time:	4:36:54 PM	Test ID	**100th_12_pt7**
Tested By	DW, JV	Location:	Hwy 100	Sta.	NA
Latitude,N:	42.010429	Longitude,W:	91.769218	Elev. (ft):	770
Comments:	Design: 6 in. modified subbase over polymer geogrid. Subbase = 3 in. virgn (bottom) + 3 in. recyled (top)				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.23	---	---	0.0520	---	0.146	---
1	100	4.27	21,467	21,359	0.0517	-0.0003	-0.210	Y
2	100	8.29	20,029	20,515	0.0520	-0.0001	0.194	Y
3	100	13.23	19,789	19,233	0.0530	0.0010	0.570	Y
4	150	18.34	17,982	17,912	0.0602	0.0082	0.709	N
5	200	28.42	15,181	15,568	0.0849	0.0329	0.574	N
6	250	38.28	13,808	13,647	0.1135	0.0615	0.700	N





Model: AASHTO (2015)

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

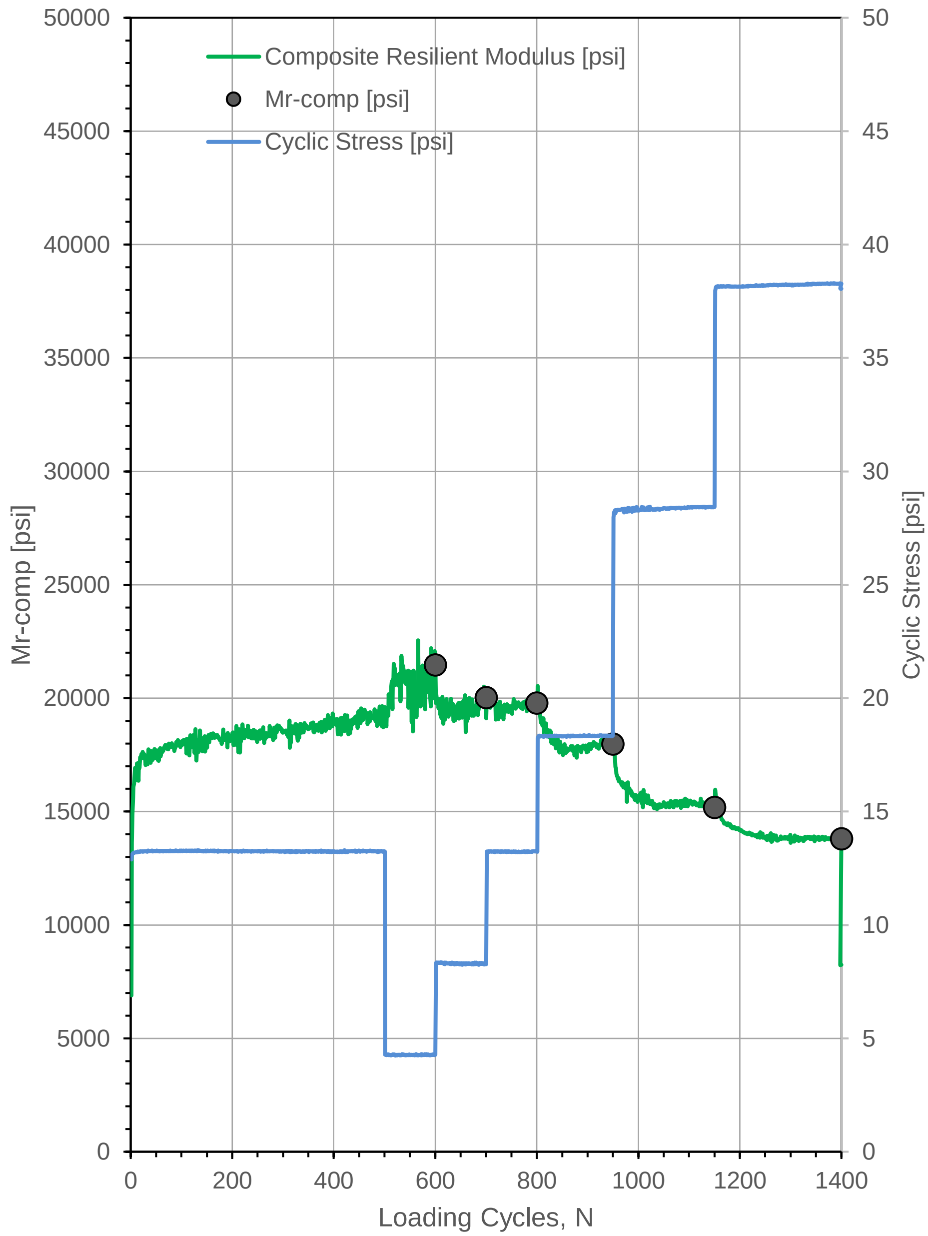
Parameter	Value	P-Value
k^*_1	1,616.1	1.54E-07
k^*_2	0.055	4.02E-01
k^*_3	-1.905	1.82E-02
Adj. R^2	0.979	
Std. Error [psi]	426	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	21,477
$\sigma_{cyclic\text{-}BP}$ [psi]	3.0

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	5/8/2018	Time:	4:36:54 PM	Test ID	**100th_12_pt7**
Tested By	DW, JV	Location:	Hwy 100	Sta.	NA
Latitude,N:	42.010429	Longitude,W:	91.769218	Elev. (ft):	770
Comments:	Design: 6 in. modified subbase over polymer geogrid. Subbase = 3 in. virgn (bottom) + 3 in. recyled (top)				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	21,424
3	21,477
4	21,395
5	21,242
6	21,047
7	20,825
8	20,587
9	20,337
10	20,081
11	19,820
12	19,557
13	19,293
14	19,030
15	18,769
16	18,509
17	18,252
18	17,998
21	17,256
22	17,016
23	16,780
24	16,548
25	16,320
26	16,095
27	15,875
28	15,658
29	15,445
30	15,236
31	15,031
32	14,830
33	14,632
34	14,438
35	14,247
36	14,060
37	13,877
38	13,696
39	13,519
40	13,346



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 100 N. of E Ave., Linn County (Project #8)

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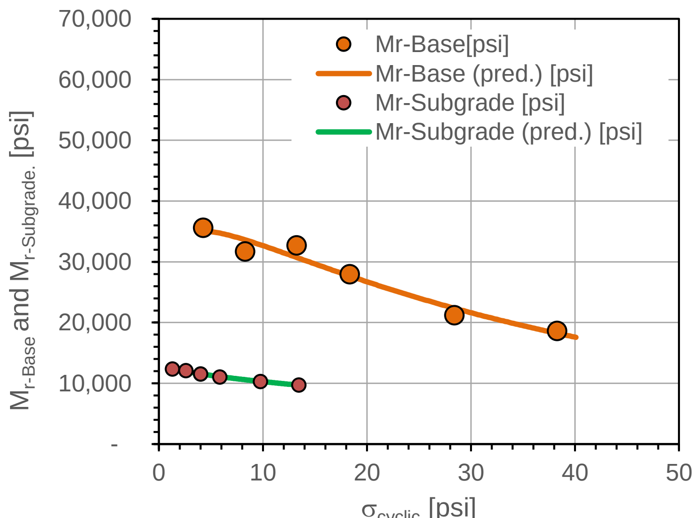
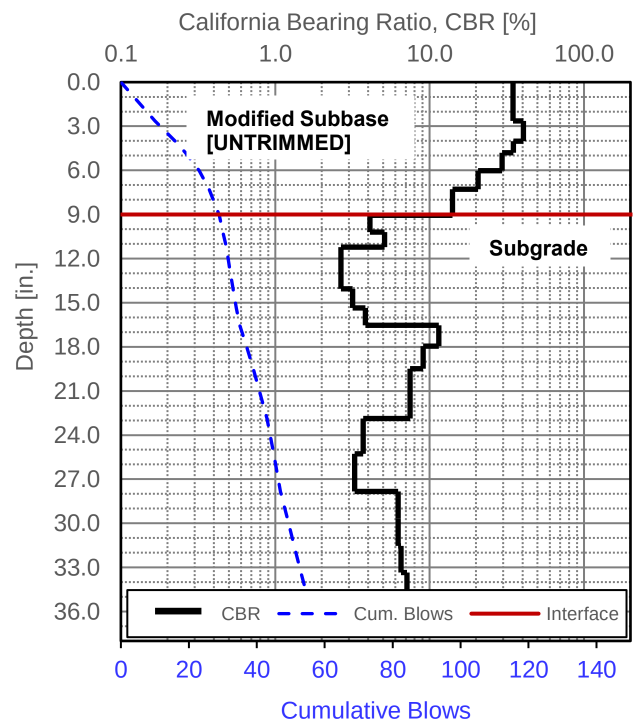
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	5/8/2018	Time:	4:36:54 PM	Test ID	**100th_12_pt7**
Tested By	DW, JV	Location:	Hwy 100	Sta.	NA
Latitude,N:	42.010429	Longitude,W:	91.769218	Elev. (ft):	770
Comments:	Design: 6 in. modified subbase over polymer geogrid. Subbase = 3 in. virgn (bottom) + 3 in. recyled (top)				

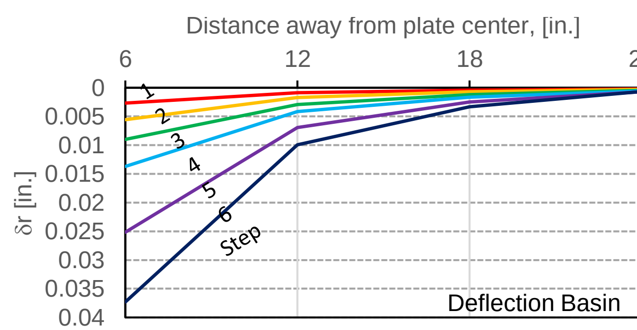
Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	13.23	---	---	---	---	---	---
1	100	4.27	35,623	35,130	1.29	12,374	12,434	2.88
2	100	8.29	31,708	33,619	2.61	12,101	11,959	2.62
3	100	13.23	32,710	30,736	4.03	11,496	11,551	2.85
4	100	18.34	27,971	27,676	5.85	11,071	11,108	2.53
5	100	28.42	21,261	22,359	9.75	10,324	10,324	2.06
6	100	38.28	18,641	18,234	13.45	9,717	9,706	1.92





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
$k^*_{1\ (Base)}$	2875.6	1.31E-06
$k^*_{2\ (Base)}$	0.121	4.00E-01
$k^*_{3\ (Base)}$	-3.089	4.04E-02
Adj. R^2	0.949	
Std. Error [psi]	1487	
$k^*_{1\ (Subgrade)}$	834.0	1.55E-07
$k^*_{2\ (Subgrade)}$	-0.037	1.67E-01
$k^*_{3\ (Subgrade)}$	-1.091	2.00E-02
Adj. R^2	0.993	
Std. Error [psi]	84	

In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 100 N. of E Ave., Linn County (Project #8)

Date of Test	5/8/2018	Test ID	100th_30in._pt1	Operator	DW,JV	ASTM	D6951
Latitude, N	42.0103067	Longitude, W		91.7694100		Elevation (ft)	776
Location	Hwy 100	Station		NA			
Comments	Design: 6 in. modified subbase over polymer geogrid. Subbase = 3 in. virgn (bottom) + 3 in. recyled (top)						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	8.7	26.0	20.5	4,749
Avg. Subgrade Layer (top 12 in.)	20.3	8.4	9.9	2,239
Ratio of Avg. Top/Bottom Layer	0.4	3.1	2.1	2.1
Std.Dev.Subbase Layer	5.7	10.1	11.2	2,539
Std. Dev. Subgrade Layer (top 12 in.)	7.6	6.0	8.1	1,804

NOTES:

Subgrade is assumed as sandy clay.

[1] $CBR = 292/DPI^{1.12}$

[1] $CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

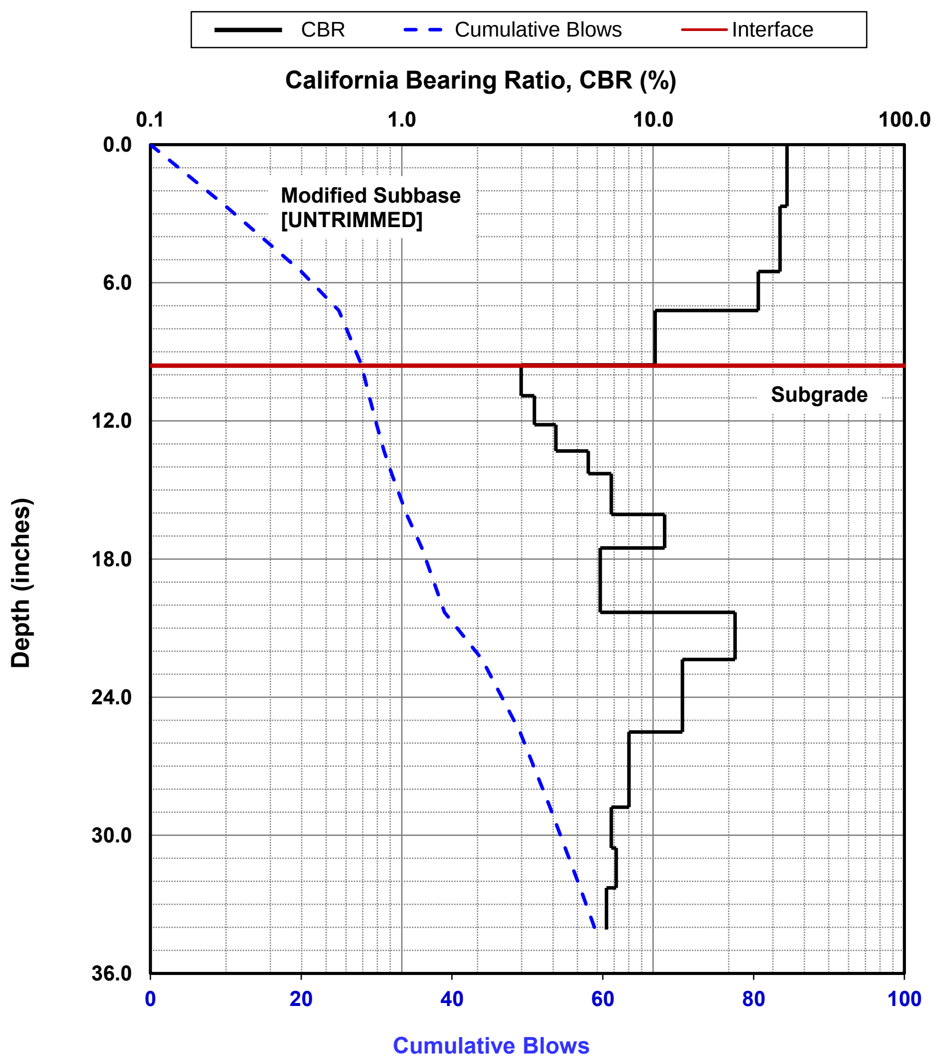
[2] $E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3] $S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2] Powell et al. (1986)

[3] Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 100 N. of E Ave., Linn County (Project #8)

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Date of Test	5/8/2018	Test ID	100th_12_pt4	Operator	DW,JV	ASTM	D6951
Latitude, N	42.0108680	Longitude, W	91.7684100			Elevation (ft)	763
Location	Hwy 100	Station	NA				
Comments	Design: 6 in. modified subbase over polymer geogrid. Subbase = 3 in. virgn (bottom) + 3 in. recyled (top)						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	10.7	20.6	17.7	4,073
Avg. Subgrade Layer (top 12 in.)	30.8	3.6	5.8	1,287
Ratio of Avg. Top/Bottom Layer	0.3	5.7	3.0	3.2
Std.Dev.Subbase Layer	1.6	3.0	5.1	1,121
Std. Dev. Subgrade Layer (top 12 in.)	13.0	2.9	5.0	1,108

NOTES:

Subgrade is assumed as sandy clay.

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

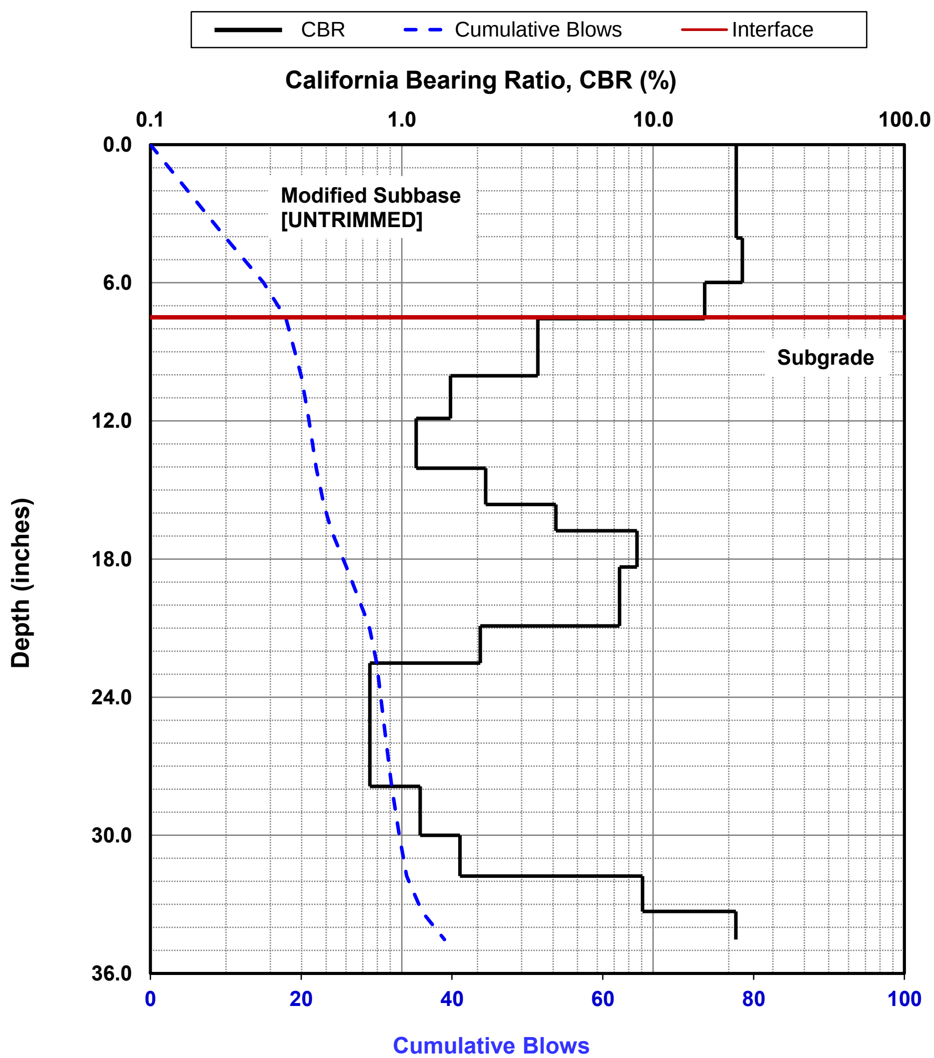
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 100 N. of E Ave., Linn County (Project #8)

Date of Test	5/8/2018	Test ID	100th_12_pt5	Operator	DW,JV	ASTM	D6951
Latitude, N	42.0107080		Longitude, W	91.7687150		Elevation (ft)	766
Location	Hwy 100		Station	NA			
Comments	Design: 6 in. modified subbase over polymer geogrid. Subbase = 3 in. virgn (bottom) + 3 in. recyled (top)						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	10.0	22.2	18.5	4,274
Avg. Subgrade Layer (top 12 in.)	26.4	4.9	7.1	1,580
Ratio of Avg. Top/Bottom Layer	0.4	4.5	2.6	2.7
Std.Dev.Subbase Layer	2.1	3.9	6.1	1,357
Std. Dev. Subgrade Layer (top 12 in.)	8.9	3.3	5.5	1,204

NOTES:

Subgrade is assumed as sandy clay.

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

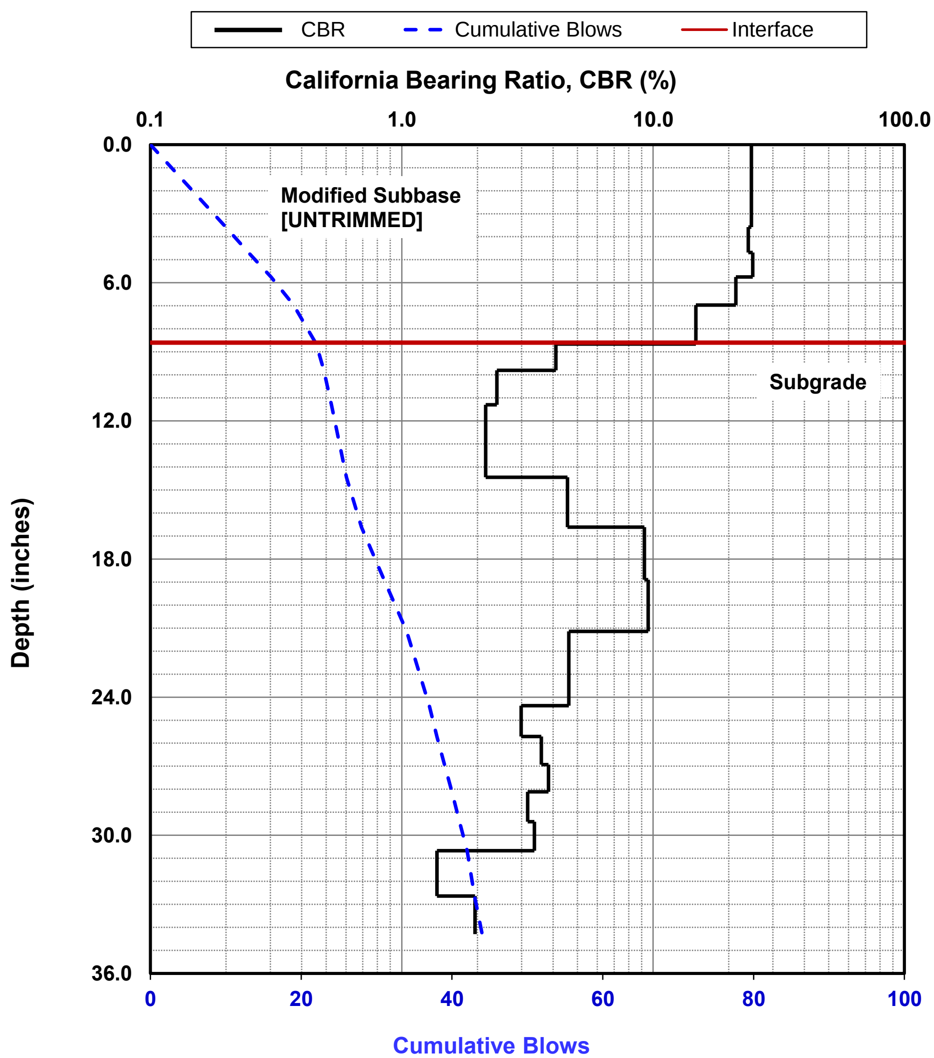
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 100 N. of E Ave., Linn County (Project #8)

Date of Test	5/8/2018	Test ID	100th_12_pt6	Operator	DW,JV	ASTM	D6951
Latitude, N	42.0105440	Longitude, W		91.7690200		Elevation (ft)	761
Location	Hwy 100	Station		NA			
Comments	Design: 6 in. modified subbase over polymer geogrid. Subbase = 3 in. virgn (bottom) + 3 in. recyled (top)						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	7.7	29.8	22.4	5,207
Avg. Subgrade Layer (top 12 in.)	29.6	3.9	6.1	1,358
Ratio of Avg. Top/Bottom Layer	0.3	7.6	3.7	3.8
Std.Dev.Subbase Layer	1.9	9.1	10.5	2,367
Std. Dev. Subgrade Layer (top 12 in.)	8.4	2.2	4.3	932

NOTES:

Subgrade is assumed as sandy clay.

[1]CBR = $292/DPI^{1.12}$

[1]CBR = $1/(0.017019DPI)^2$

for CL soils with CBR < 10

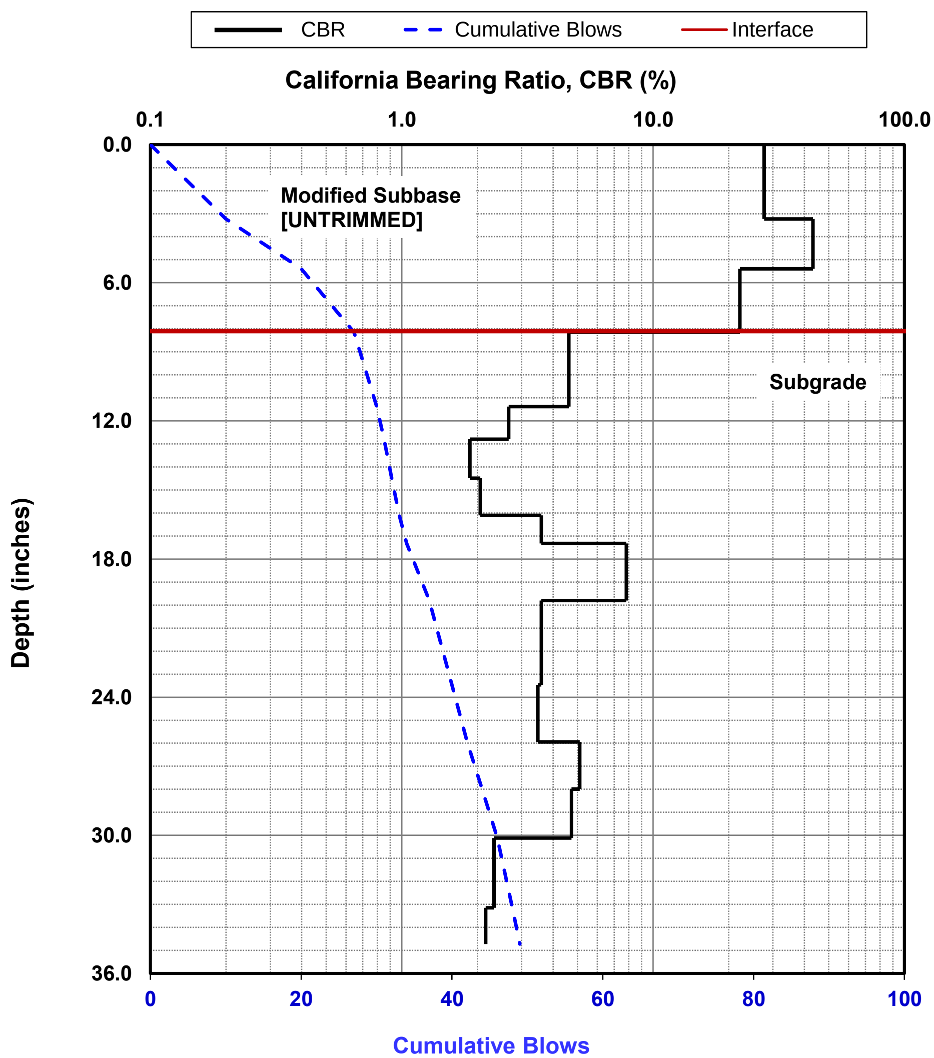
[2]E (ksi) = $(17.6\ CBR^{0.64}) \times 0.1450377$

[3]S_u (psf) = $(3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 100 N. of E Ave., Linn County (Project #8)

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Date of Test	5/8/2018	Test ID	100th_12_pt7	Operator	DW,JV	ASTM	D6951
Latitude, N	42.0104290	Longitude, W		91.7692180		Elevation (ft)	770
Location	Hwy 100	Station		NA			
Comments	Design: 6 in. modified subbase over polymer geogrid. Subbase = 3 in. virgn (bottom) + 3 in. recyled (top)						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	7.9	28.7	21.9	5,078
Avg. Subgrade Layer (top 12 in.)	25.1	5.5	7.6	1,693
Ratio of Avg. Top/Bottom Layer	0.3	5.2	2.9	3.0
Std.Dev.Subbase Layer	3.3	9.3	10.6	2,404
Std. Dev. Subgrade Layer (top 12 in.)	6.9	3.1	5.3	1,167

NOTES:

Subgrade is assumed as sandy clay.

[1] $CBR = 292/DPI^{1.12}$

[1] $CBR = 1/(0.017019 DPI)^2$

for CL soils with CBR < 10

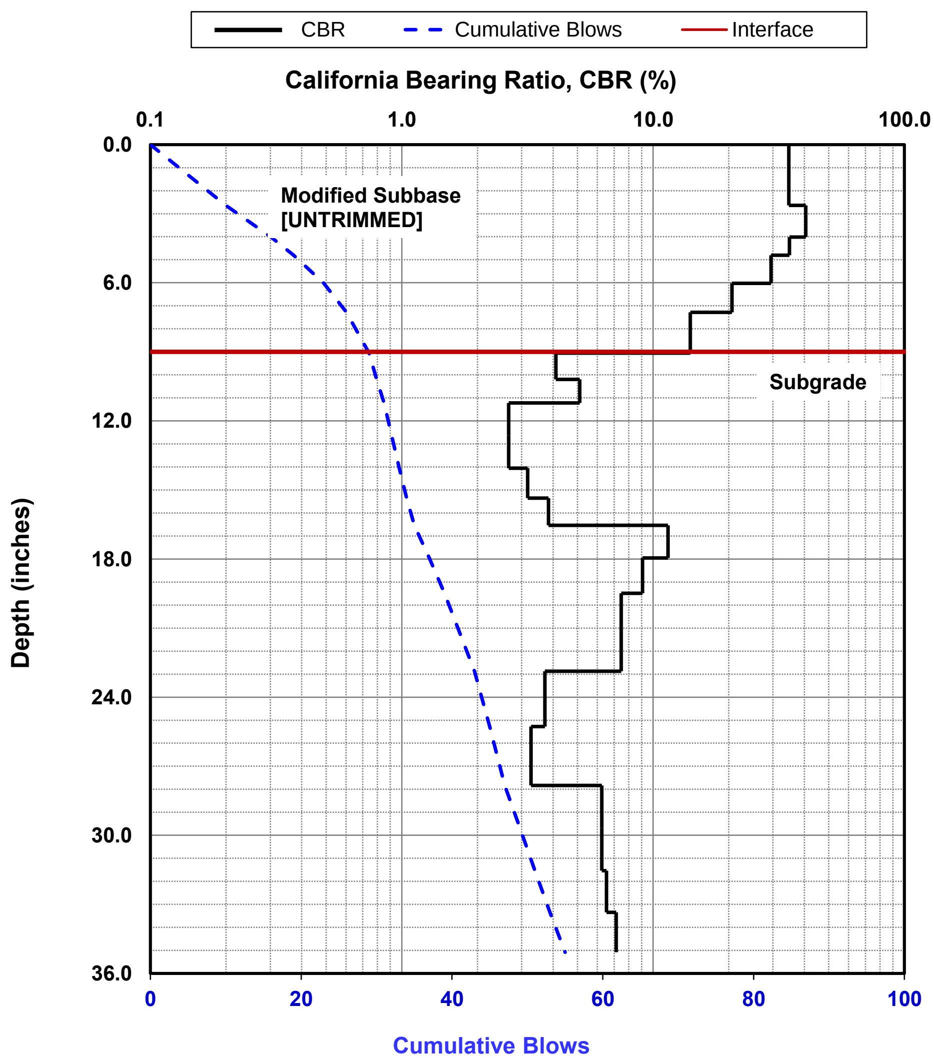
[2] $E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3] $S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2] Powell et al. (1986)

[3] Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 100 N. of E Ave., Linn County (Project #8)

Field Project # 9

Hwy20, Woodbury County, IA

05/16/2018

Granular subbase (recycled concrete) over select subgrade

Project Location and Test Locations

Test Locations	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Woodbury County, IA (Project #9)

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Site Conditions and Pictures

Pictures	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Woodbury County, IA (Project #9)

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Summary of Test Results

Summary of DCP test results

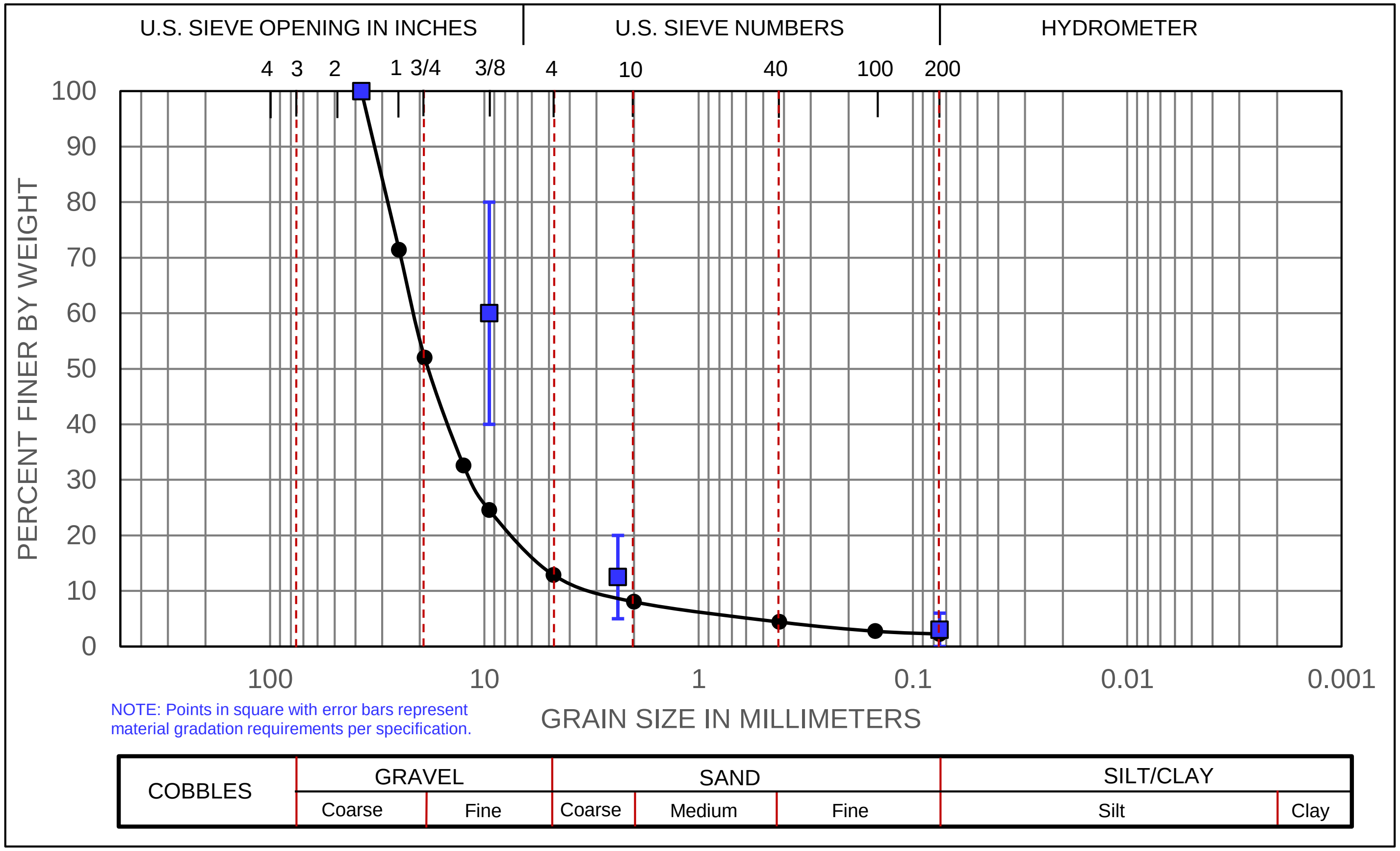
	Subbase Layer			Subgrade Layer			
Point #	**Thickness, H_1 (in.)**	**Avg. CBR (%)**	**St. Dev CBR (%)**	**Thickness, H_2 (in.)**	**Avg. CBR (%)**	**St. Dev CBR (%)**	**Ratio CBR_1/ CBR_2**
PT1	6.7	45.3	59.1	12.0	2.2	0.5	20.3
PT2	6.7	5.7	2.2	12.0	2.5	1.0	2.3
PT3	9.3	5.7	3.4	12.0	3.1	0.8	1.9
PT4	6.5	8.3	3.1	12.0	2.3	0.6	3.6
PT5	9.0	4.1	2.8	12.0	1.3	0.5	3.1
PT6	6.5	3.3	2.1	12.0	2.2	0.2	1.5
PT7	10.0	3.6	2.4	12.0	1.0	0.7	3.5
PT8	6.0	3.4	0.3	12.0	1.8	0.6	1.9
PT9	8.2	2.5	0.2	12.0	2.5	1.2	1.0
PT10	8.5	6.2	4.5	12.0	2.4	1.8	2.5
PT11	7.5	5.0	2.1	12.0	2.2	1.3	2.2
PT12	10.3	5.2	2.6	12.0	2.0	0.9	2.6
AVG	**7.9**	**8.2**	**7.1**	**12.0**	**2.1**	**0.8**	**3.9**
COV	**19%**	**144%**	**232%**	**0%**	**25%**	**51%**	**135%**

Notes:

At test PT1, DCP hit a large rock in the subbase layer.

According to the project plans, the granular layer design thickness is 6 in. near left shoulder and thicker near the center due to sloping grade at the top of subgrade.

GRAIN SIZE DISTRIBUTION
ASTM D422/C136



Gradation Summary

% Gravel	87.1
% Sand	10.6
% Fines	2.2
D_{10} (mm)	3.122
D_{30} (mm)	11.529
D_{50} (mm)	18.323
D_{60} (mm)	21.467
D_{85} (mm)	30.940
C_u	6.9
C_c	2.0

Atterberg Limits

LL	NP
PL	NP
PI	NP

Classification

AASHTO:	A-1-a
USCS:	GW

MATERIAL: Gray Crushed Recycled Granular Subbase (Iowa DOT Gradation 4121 - Recycled Material)

LOCATION: Hwy 20, Woodbury County, IA (Project #9) **TESTED BY:** DW

SAMPLE DATE: 5/16/2018 **TEST DATE:** 9/6/2018

Gradation and Soil Classification Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Woodbury County, IA (Project #9)

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Date of Test	5/16/2018	Test ID	Hwy20_Pt1	Operator	CV, HG	ASTM	D6951
Latitude, N	NA		Longitude, W	NA		Elevation (ft)	NA
Location	Hwy20		Station	NA			
Comments	Design: 6 in. granular subbase over select subgrade.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	5.3	45.3	29.3	6,871
Avg. Subgrade Layer (top 12 in.)	39.4	2.2	4.3	930
Ratio of Avg. Top/Bottom Layer	0.1	20.3	6.9	7.4
Std.Dev.Subbase Layer	26.1	59.1	34.7	8,202
Std. Dev. Subgrade Layer (top 12 in.)	3.9	0.5	1.7	349

NOTES:

Subgrade is assumed as sandy clay.

[1] $CBR = 292/DPI^{1.12}$

[1] $CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

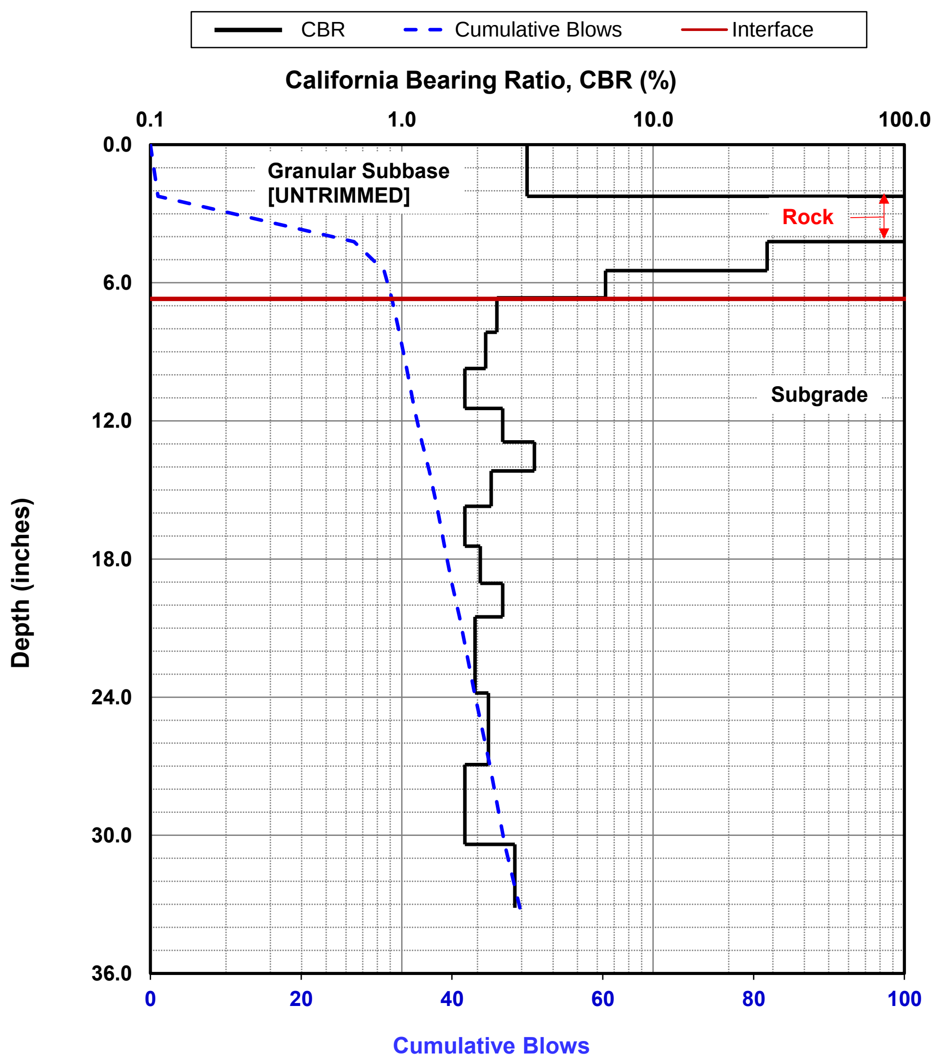
[2] $E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3] $S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2] Powell et al. (1986)

[3] Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name: Iowa DOT STIC

Project ID: SIA-00001

Location: Hwy 20, Woodbury County, IA (Project #9)

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Date of Test	5/16/2018	Test ID	Hwy20_Pt2	Operator	CV, HG	ASTM	D6951
Latitude, N	NA	Longitude, W		NA		Elevation (ft)	NA
Location	Hwy20	Station		NA			
Comments	Design: 6 in. granular subbase over select subgrade.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	33.8	5.7	7.7	1,728
Avg. Subgrade Layer (top 12 in.)	37.5	2.5	4.5	992
Ratio of Avg. Top/Bottom Layer	0.9	2.3	1.7	1.7
Std.Dev.Subbase Layer	16.1	2.2	4.3	930
Std. Dev. Subgrade Layer (top 12 in.)	6.2	1.0	2.5	529

NOTES:

Subgrade is assumed as sandy clay.

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

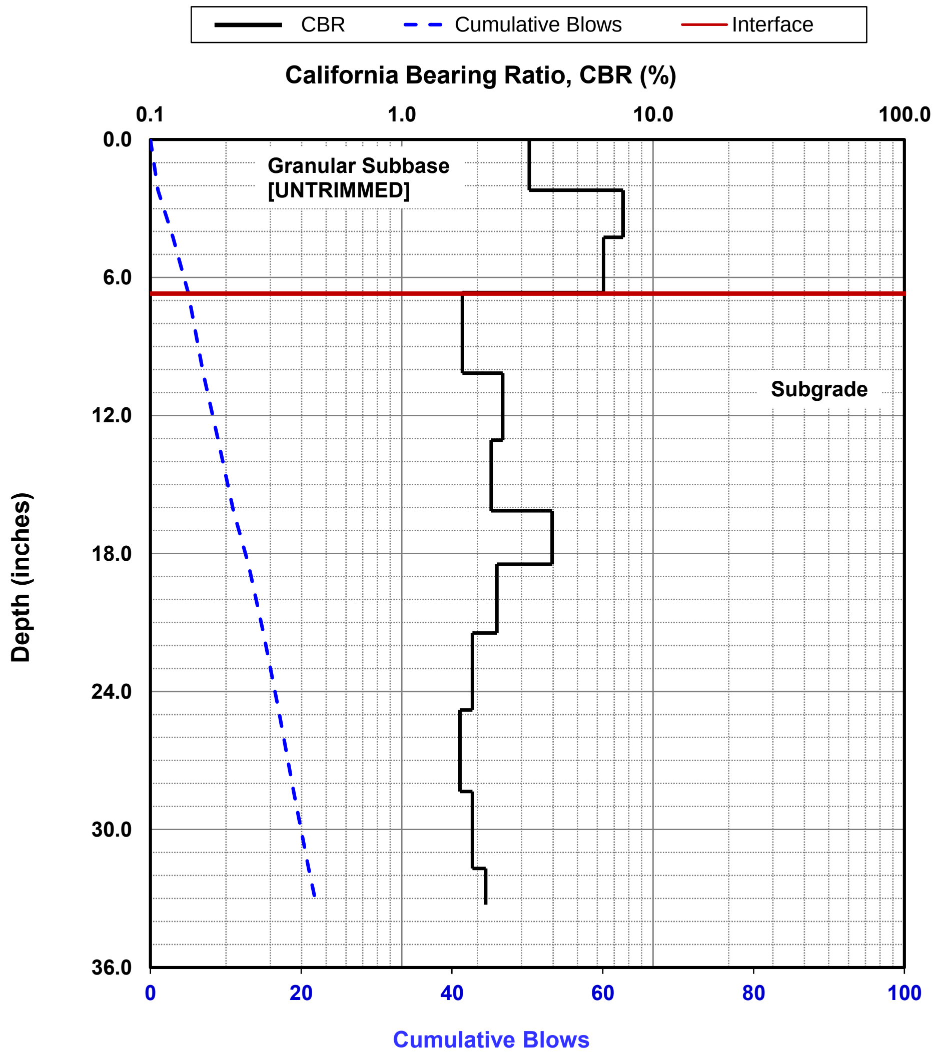
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Woodbury County, IA (Project #9)

Date of Test	5/16/2018	Test ID	Hwy20_Pt3	Operator	CV, HG	ASTM	D6951
Latitude, N	NA		Longitude, W	NA		Elevation (ft)	NA
Location	Hwy20		Station	NA			
Comments	Design: 6 in. granular subbase over select subgrade.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	33.9	5.7	7.7	1,725
Avg. Subgrade Layer (top 12 in.)	33.6	3.1	5.2	1,146
Ratio of Avg. Top/Bottom Layer	1.0	1.9	1.5	1.5
Std.Dev.Subbase Layer	27.9	3.4	5.6	1,238
Std. Dev. Subgrade Layer (top 12 in.)	5.0	0.8	2.2	463

NOTES:

Subgrade is assumed as sandy clay.

[1]CBR = 292/DPI$^{1.12}$

[1]CBR = 1/(0.017019DPI)^2

for CL soils with CBR < 10

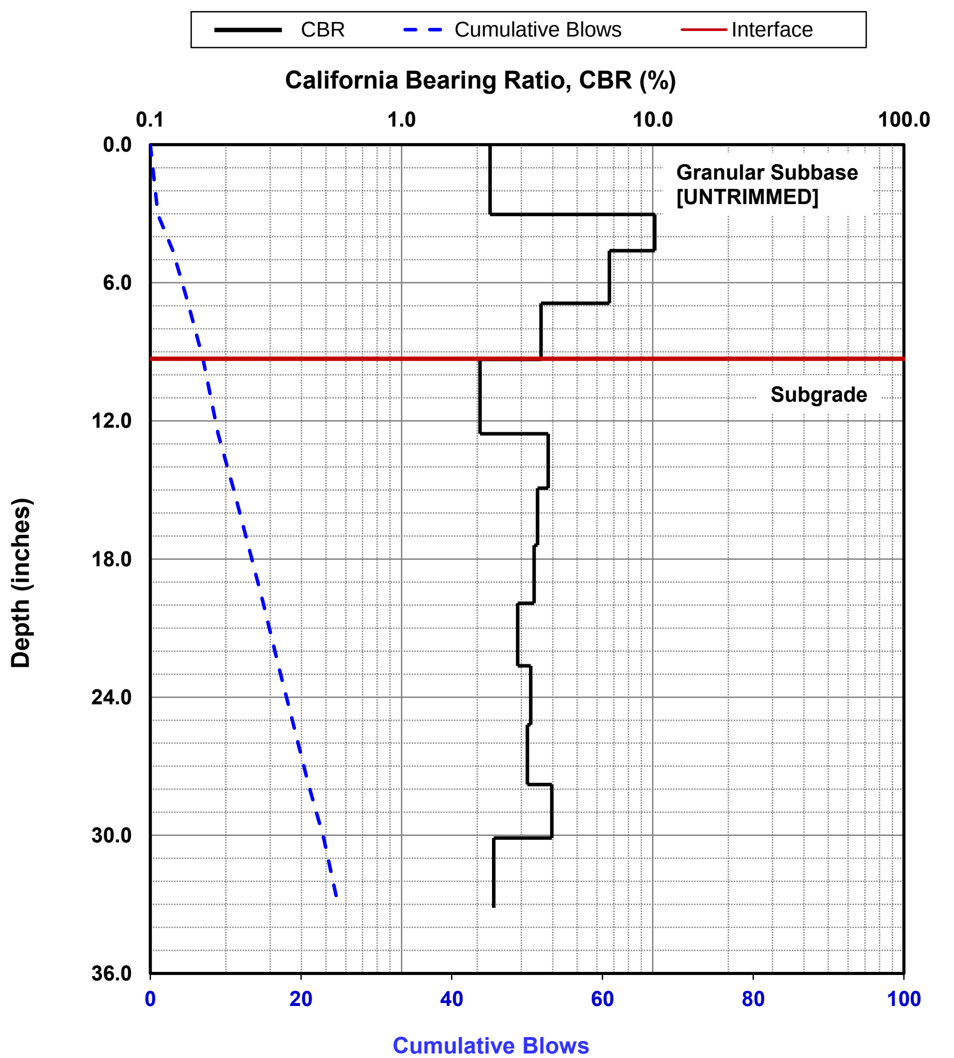
[2]E (ksi) = (17.6 CBR$^{0.64}$) x 0.1450377

[3]S_u (psf) =(3.794 x CBR$^{0.664}$) x 144

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Woodbury County, IA (Project #9)

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Date of Test	5/16/2018	Test ID	Hwy20_Pt4	Operator	CV, HG	ASTM	D6951
Latitude, N	NA		Longitude, W	NA		Elevation (ft)	NA
Location	Hwy20		Station	NA			
Comments	Design: 6 in. granular subbase over select subgrade.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	24.0	8.3	9.9	2,229
Avg. Subgrade Layer (top 12 in.)	38.6	2.3	4.4	954
Ratio of Avg. Top/Bottom Layer	0.6	3.6	2.3	2.3
Std.Dev.Subbase Layer	12.3	3.1	5.3	1,167
Std. Dev. Subgrade Layer (top 12 in.)	4.4	0.6	1.8	371

NOTES:

Subgrade is assumed as sandy clay.

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

[2]$E\text{ (ksi)} = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\text{ (psf)} = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

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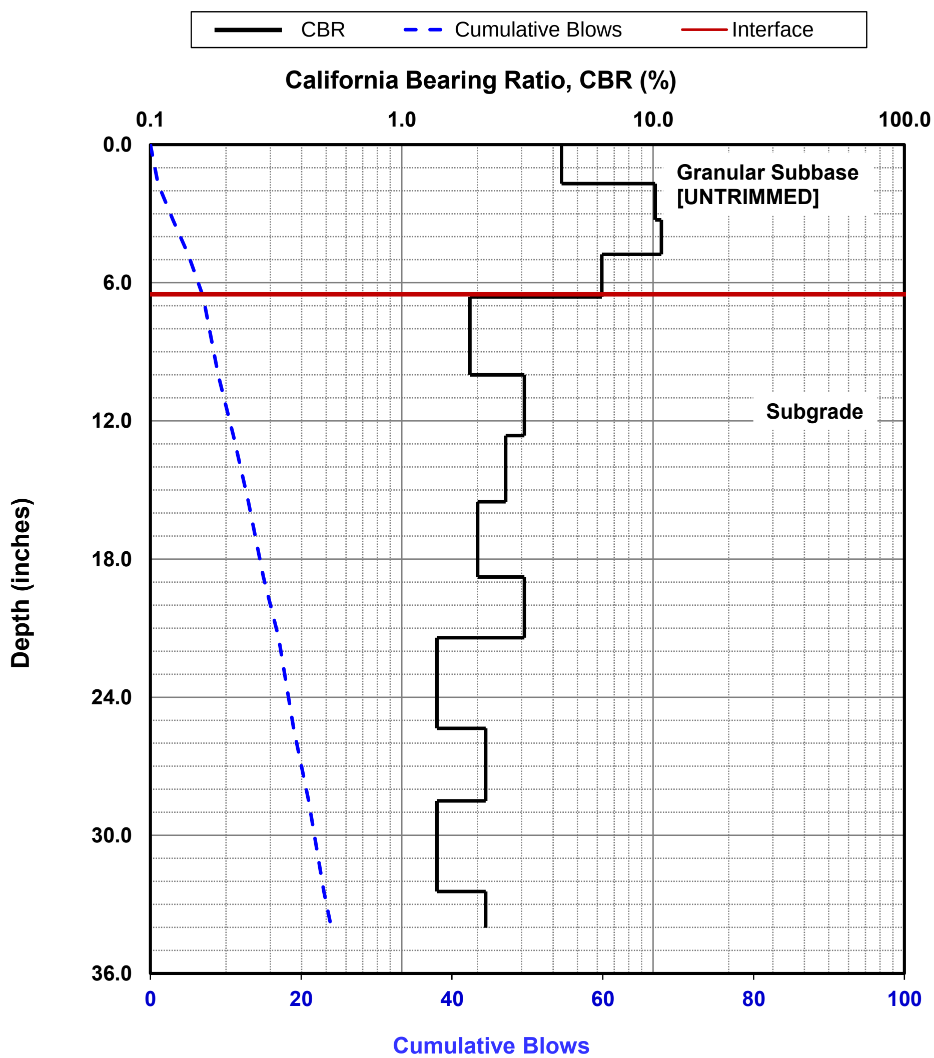

Dynamic Cone Penetrometer (DCP) Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Woodbury County, IA (Project #9)

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Date of Test	5/16/2018	Test ID	Hwy20_Pt5	Operator	CV, HG	ASTM	D6951
Latitude, N	NA		Longitude, W	NA		Elevation (ft)	NA
Location	Hwy20		Station	NA			
Comments	Design: 6 in. granular subbase over select subgrade.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	45.0	4.1	6.3	1,396
Avg. Subgrade Layer (top 12 in.)	51.2	1.3	3.0	657
Ratio of Avg. Top/Bottom Layer	0.9	3.1	2.1	2.1
Std.Dev.Subbase Layer	43.3	2.8	5.0	1,088
Std. Dev. Subgrade Layer (top 12 in.)	9.8	0.5	1.7	365

NOTES:

Subgrade is assumed as sandy clay.

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

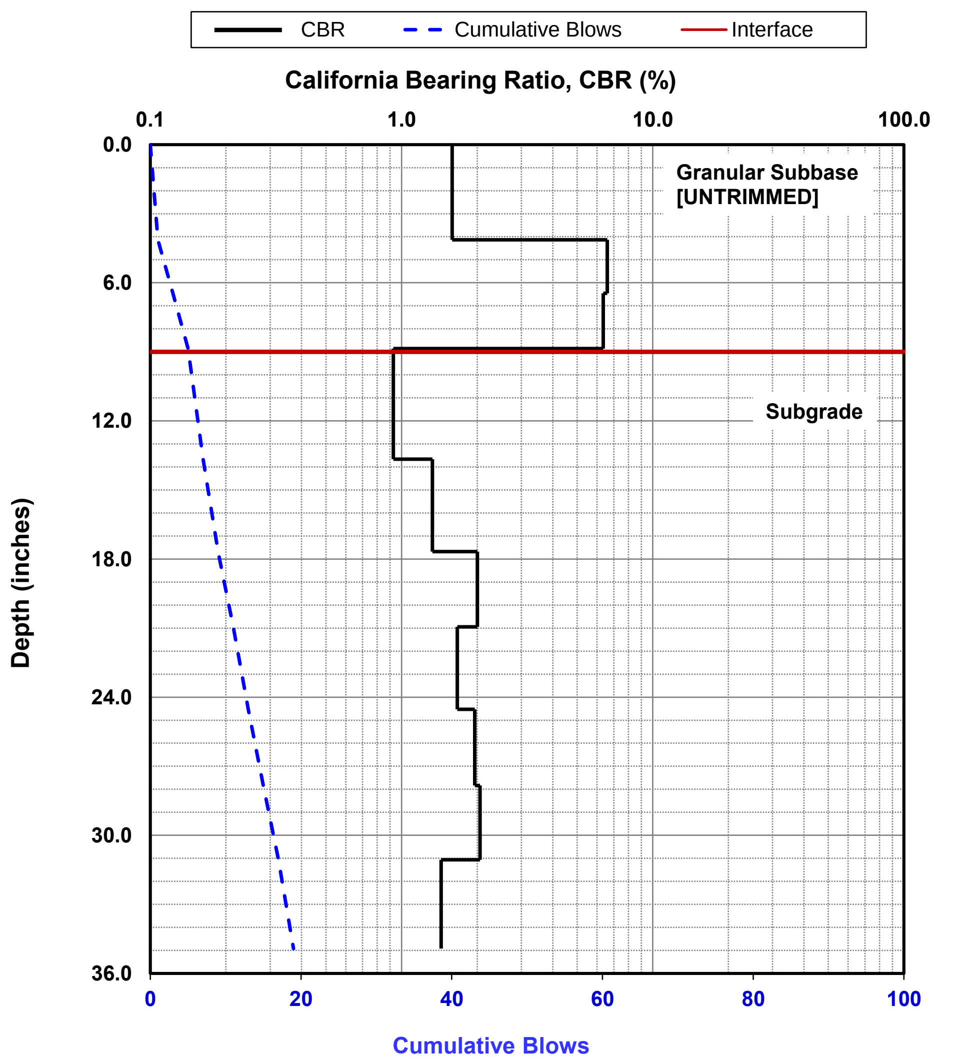
[2]$E\text{ (ksi)} = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\text{ (psf)} = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Woodbury County, IA (Project #9)

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Date of Test	5/16/2018	Test ID	Hwy20_Pt6	Operator	CV, HG	ASTM	D6951
Latitude, N	NA		Longitude, W	NA		Elevation (ft)	NA
Location	Hwy20		Station	NA			
Comments	Design: 6 in. granular subbase over select subgrade.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	54.3	3.3	5.5	1,214
Avg. Subgrade Layer (top 12 in.)	39.5	2.2	4.2	926
Ratio of Avg. Top/Bottom Layer	1.4	1.5	1.3	1.3
Std.Dev.Subbase Layer	33.5	2.1	4.1	892
Std. Dev. Subgrade Layer (top 12 in.)	2.2	0.2	1.0	207

NOTES:

Subgrade is assumed as sandy clay.

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

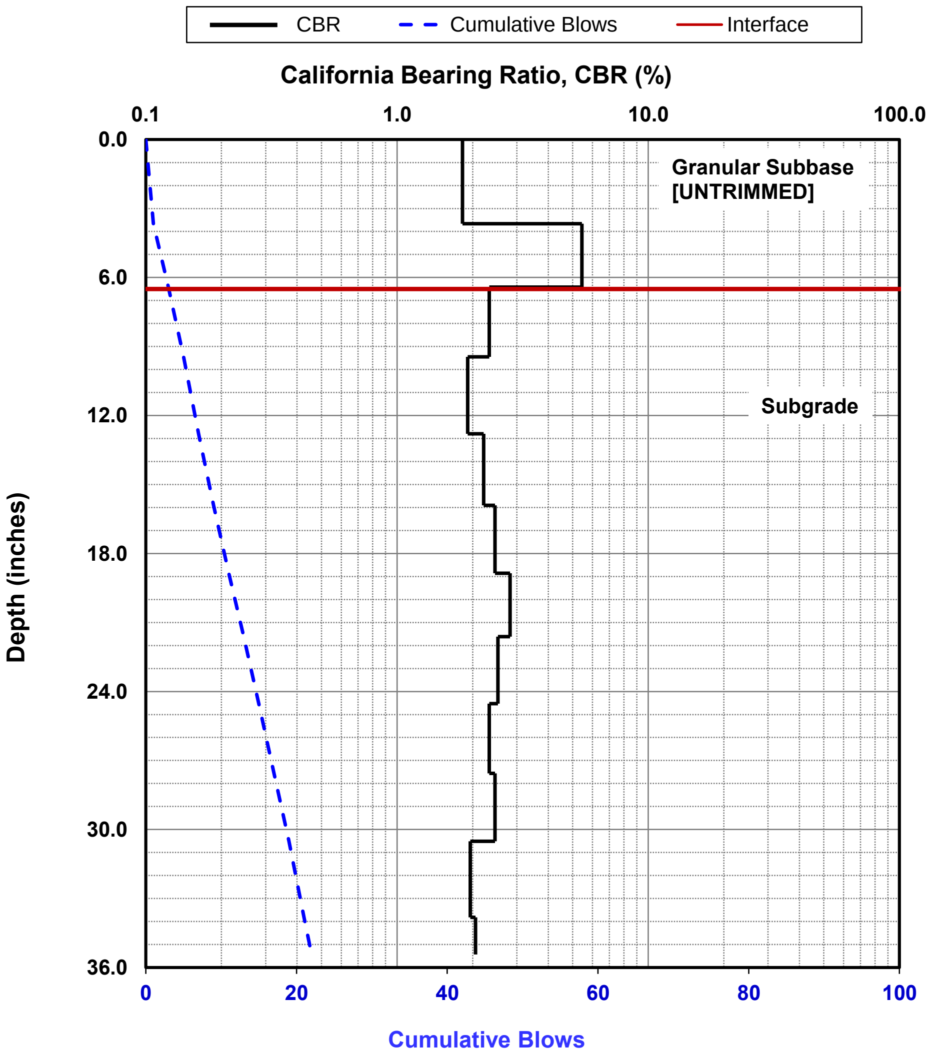
[2]$E\text{ (ksi)} = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\text{ (psf)} = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Woodbury County, IA (Project #9)

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Date of Test	5/16/2018	Test ID	Hwy20_Pt7	Operator	CV, HG	ASTM	D6951
Latitude, N	NA		Longitude, W	NA		Elevation (ft)	NA
Location	Hwy20		Station	NA			
Comments	Design: 6 in. granular subbase over select subgrade.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	51.0	3.6	5.8	1,272
Avg. Subgrade Layer (top 12 in.)	58.0	1.0	2.6	556
Ratio of Avg. Top/Bottom Layer	0.9	3.5	2.2	2.3
Std.Dev.Subbase Layer	40.1	2.4	4.4	965
Std. Dev. Subgrade Layer (top 12 in.)	19.3	0.7	1.9	411

NOTES:

Subgrade is assumed as sandy clay.

[1] $CBR = 292/DPI^{1.12}$

[1] $CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

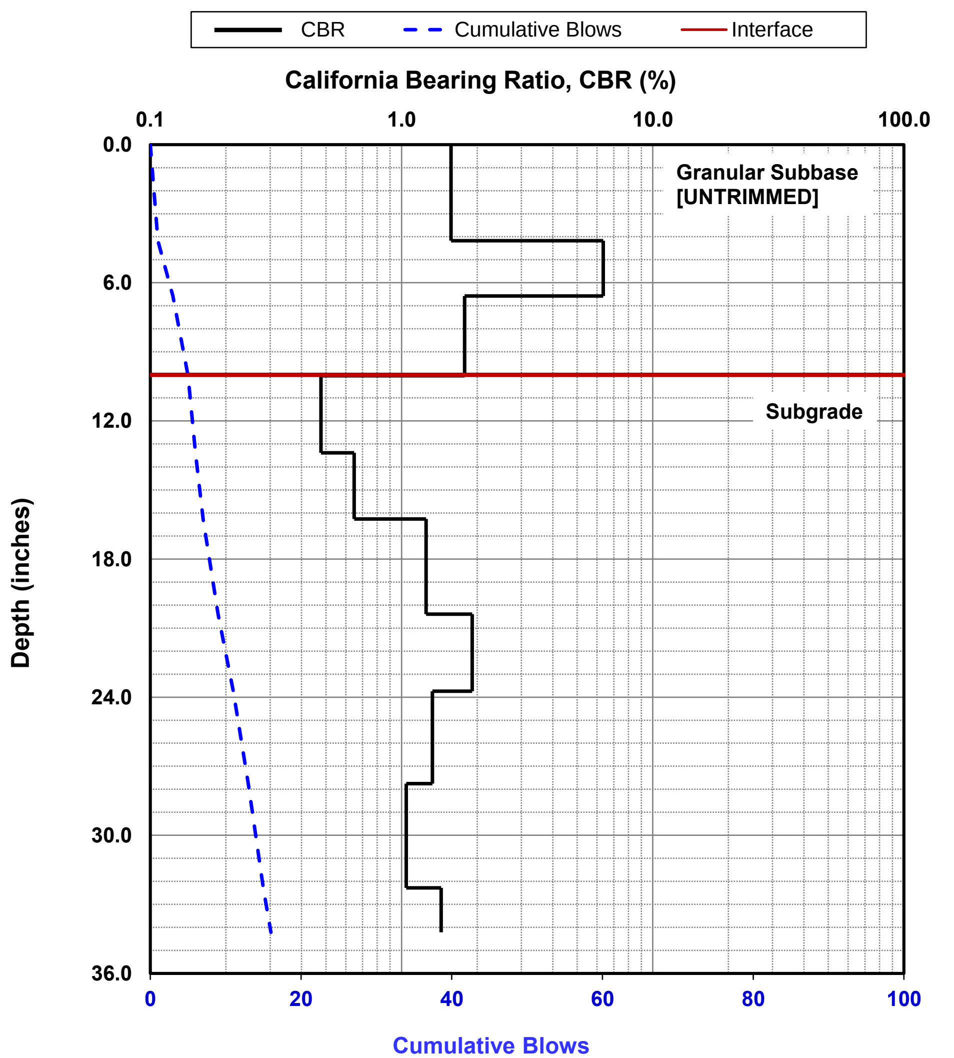
[2] $E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3] $S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2] Powell et al. (1986)

[3] Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Woodbury County, IA (Project #9)

Date of Test	5/16/2018	Test ID	Hwy20_Pt8	Operator	CV, HG	ASTM	D6951
Latitude, N	NA		Longitude, W	NA		Elevation (ft)	NA
Location	Hwy20		Station	NA			
Comments	Design: 6 in. granular subbase over select subgrade.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	52.7	3.4	5.6	1,242
Avg. Subgrade Layer (top 12 in.)	43.6	1.8	3.7	811
Ratio of Avg. Top/Bottom Layer	1.2	1.9	1.5	1.5
Std.Dev.Subbase Layer	17.6	0.3	1.1	233
Std. Dev. Subgrade Layer (top 12 in.)	8.7	0.6	1.8	390

NOTES:

Subgrade is assumed as sandy clay.

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

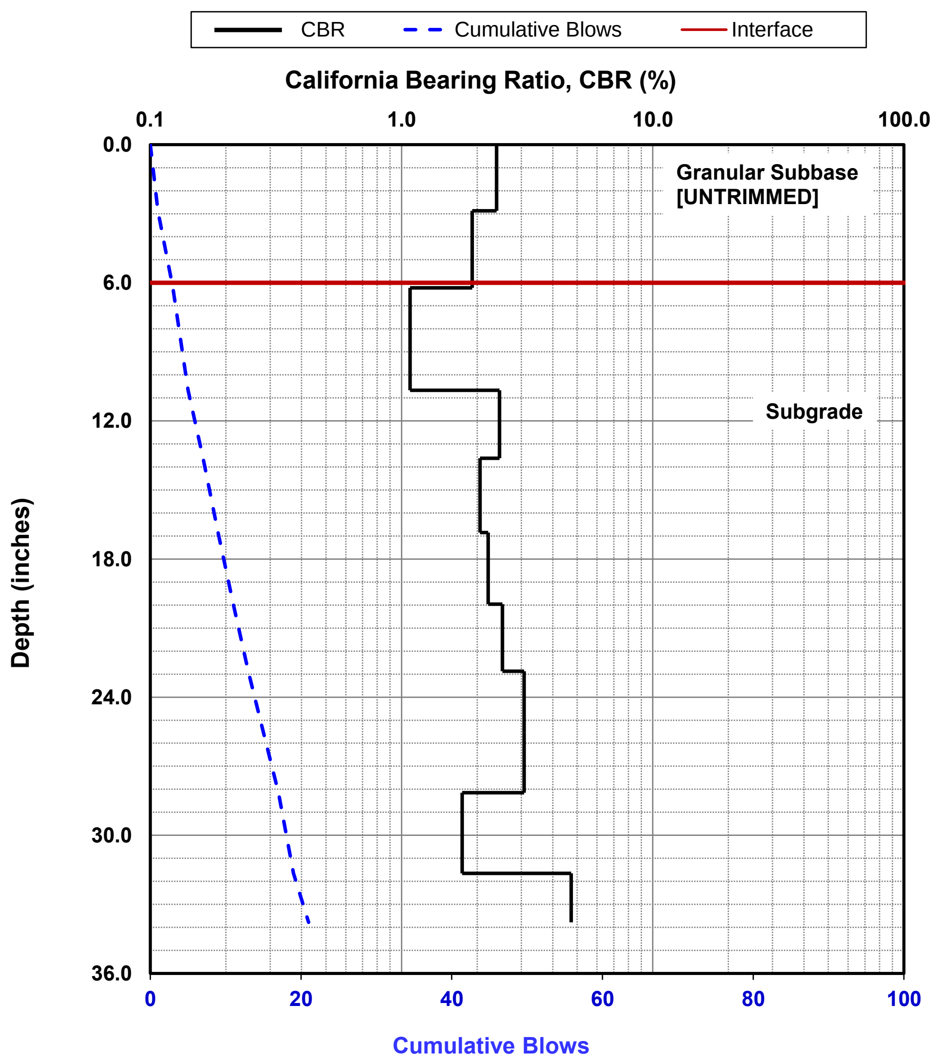
[2]E (ksi) = $(17.6\ CBR^{0.64}) \times 0.1450377$

[3]S_u (psf) $= (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Woodbury County, IA (Project #9)

Date of Test	5/16/2018	Test ID	Hwy20_Pt9	Operator	CV, HG	ASTM	D6951
Latitude, N	NA		Longitude, W	NA		Elevation (ft)	NA
Location	Hwy20		Station	NA			
Comments	Design: 6 in. granular subbase over select subgrade.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	69.7	2.5	4.6	1,009
Avg. Subgrade Layer (top 12 in.)	37.5	2.5	4.5	992
Ratio of Avg. Top/Bottom Layer	1.9	1.0	1.0	1.0
Std.Dev.Subbase Layer	42.7	0.2	0.9	179
Std. Dev. Subgrade Layer (top 12 in.)	11.8	1.2	2.9	623

NOTES:

Subgrade is assumed as sandy clay.

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

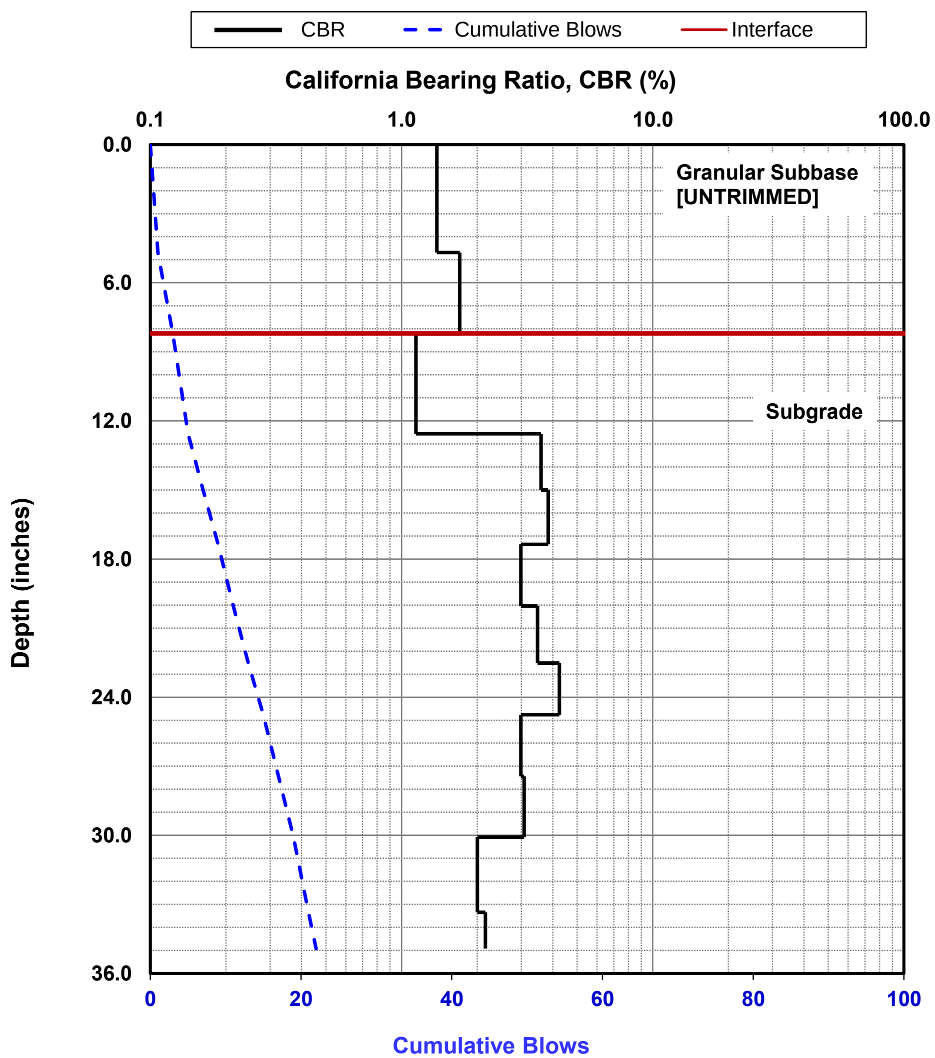
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Woodbury County, IA (Project #9)

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Date of Test	5/16/2018	Test ID	Hwy20_Pt10	Operator	CV, HG	ASTM	D6951
Latitude, N	NA		Longitude, W	NA		Elevation (ft)	NA
Location	Hwy20		Station	NA			
Comments	Design: 6 in. granular subbase over select subgrade.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	31.3	6.2	8.2	1,830
Avg. Subgrade Layer (top 12 in.)	37.6	2.4	4.5	988
Ratio of Avg. Top/Bottom Layer	0.8	2.5	1.8	1.9
Std.Dev.Subbase Layer	31.6	4.5	6.7	1,482
Std. Dev. Subgrade Layer (top 12 in.)	8.9	1.8	3.7	802

NOTES:

Subgrade is assumed as sandy clay.

[1] $CBR = 292/DPI^{1.12}$

[1] $CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

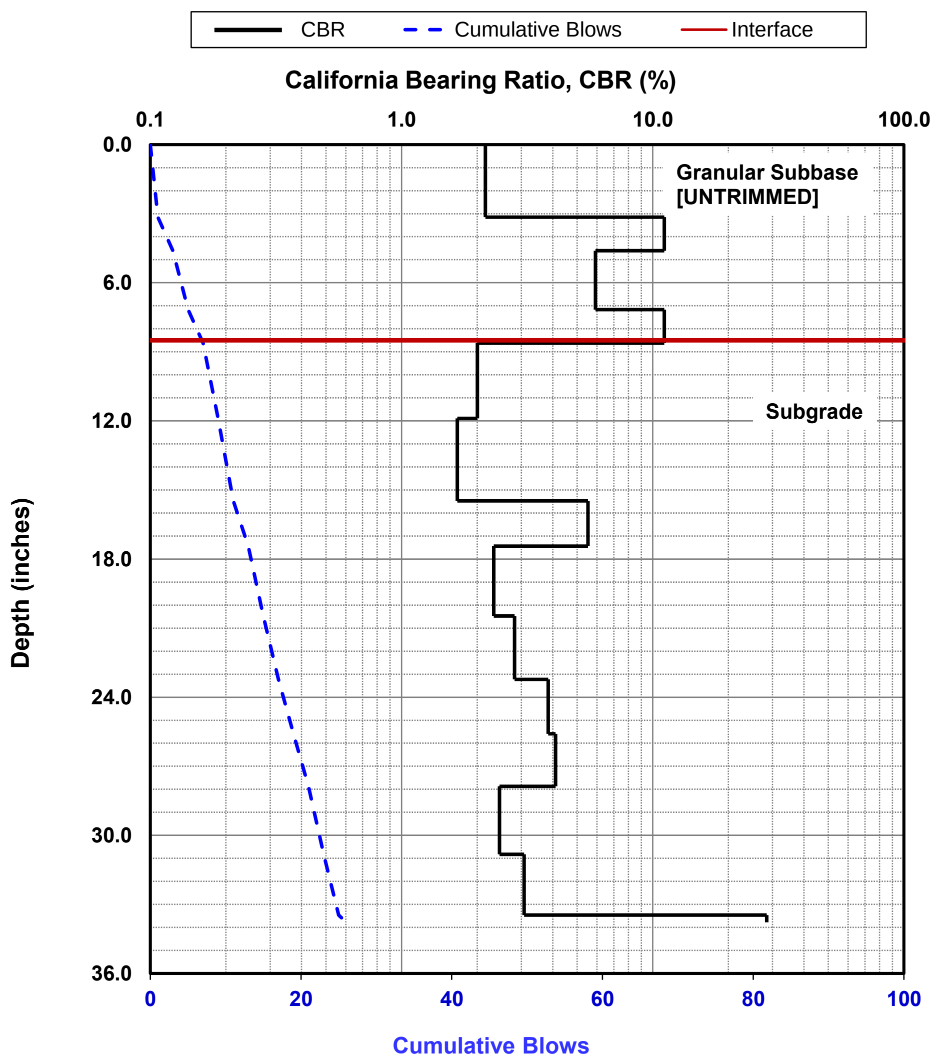
[2] $E \text{ (ksi)} = (17.6\ CBR^{0.64}) \times 0.1450377$

[3] $S_u \text{ (psf)} = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2] Powell et al. (1986)

[3] Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Woodbury County, IA (Project #9)

Date of Test	5/16/2018	Test ID	Hwy20_Pt11	Operator	CV, HG	ASTM	D6951
Latitude, N	NA		Longitude, W	NA		Elevation (ft)	NA
Location	Hwy20		Station	NA			
Comments	Design: 6 in. granular subbase over select subgrade.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	38.0	5.0	7.1	1,584
Avg. Subgrade Layer (top 12 in.)	39.3	2.2	4.3	934
Ratio of Avg. Top/Bottom Layer	1.0	2.2	1.7	1.7
Std.Dev.Subbase Layer	19.7	2.1	4.1	902
Std. Dev. Subgrade Layer (top 12 in.)	12.7	1.3	3.0	636

NOTES:

Subgrade is assumed as sandy clay.

[1] $CBR = 292/DPI^{1.12}$

[1] $CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

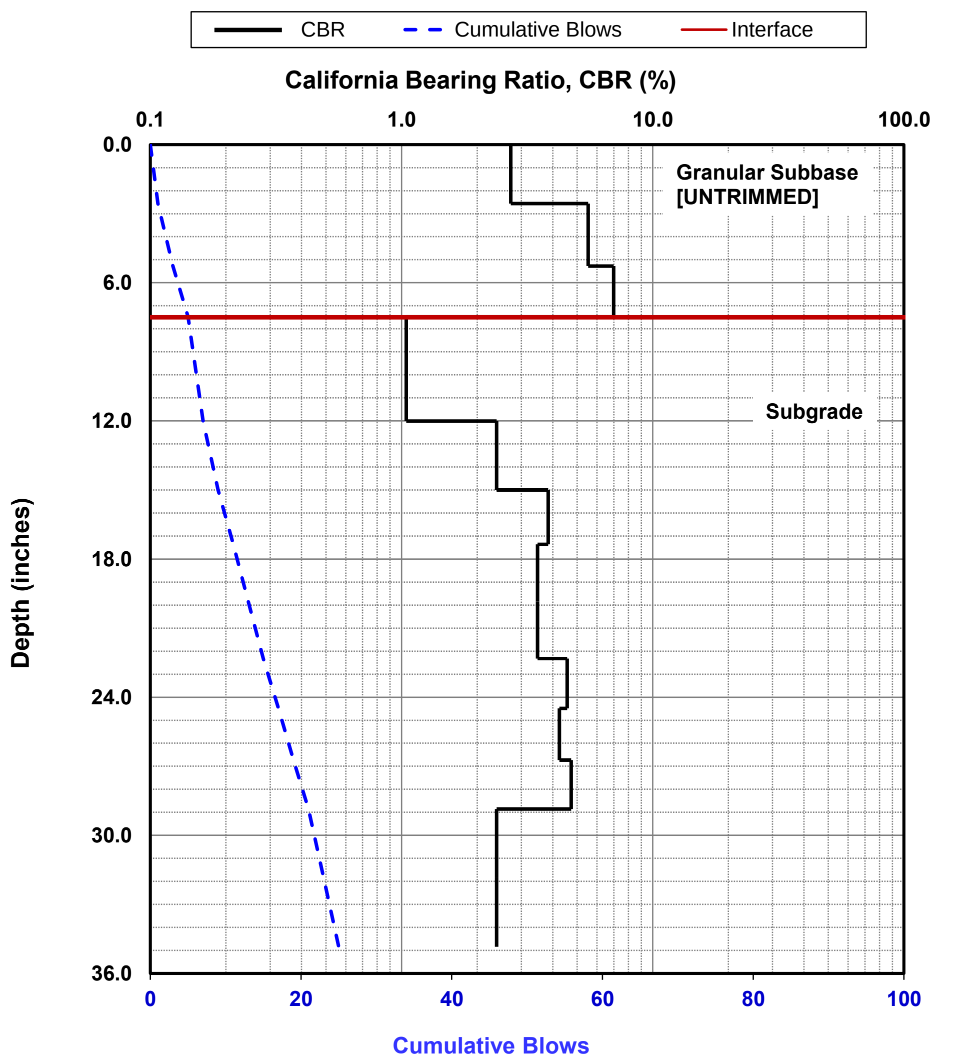
[2] $E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3] $S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2] Powell et al. (1986)

[3] Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Woodbury County, IA (Project #9)

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Date of Test	5/16/2018	Test ID	Hwy20_Pt12	Operator	CV, HG	ASTM	D6951
Latitude, N	NA		Longitude, W	NA		Elevation (ft)	NA
Location	Hwy20		Station	NA			
Comments	Design: 6 in. granular subbase over select subgrade.						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase layer	36.7	5.2	7.3	1,625
Avg. Subgrade Layer (top 12 in.)	41.9	2.0	3.9	857
Ratio of Avg. Top/Bottom Layer	0.9	2.6	1.9	1.9
Std.Dev.Subbase Layer	26.1	2.6	4.7	1,040
Std. Dev. Subgrade Layer (top 12 in.)	19.4	0.9	2.5	526

NOTES:

Subgrade is assumed as sandy clay.

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

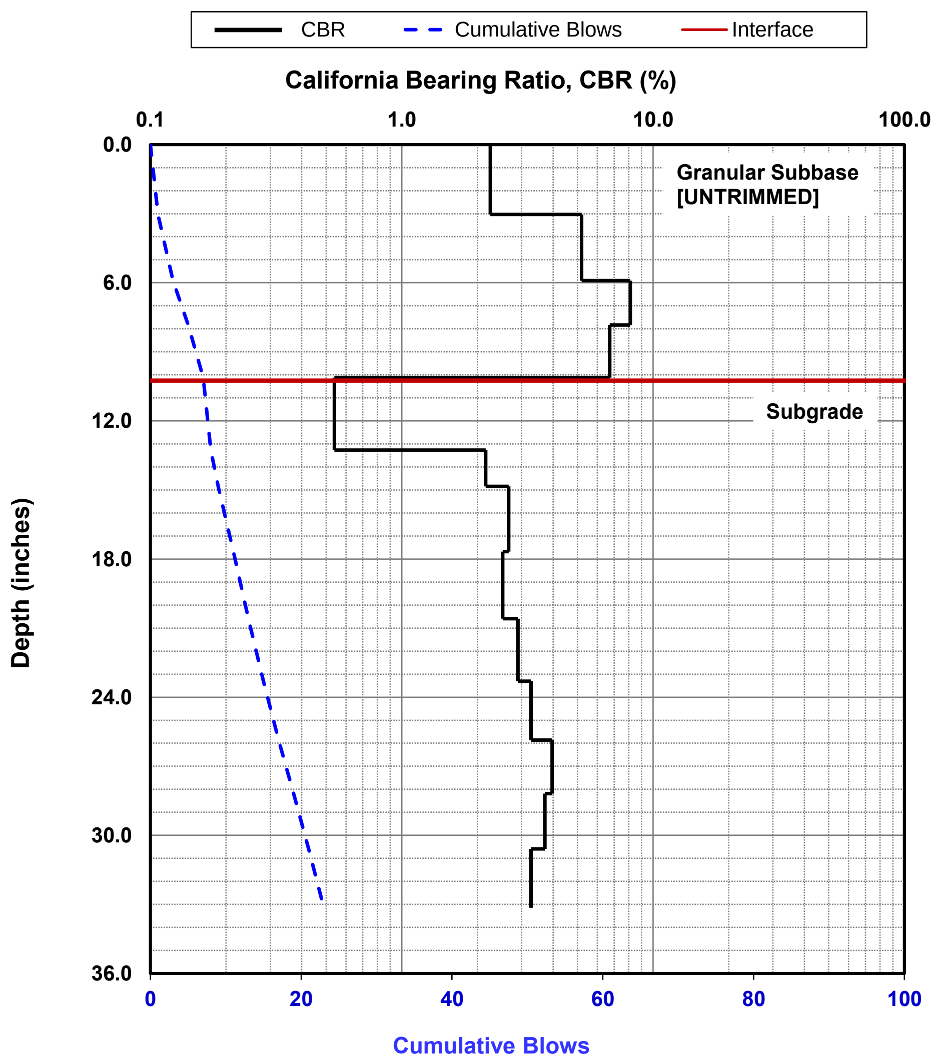
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 20, Woodbury County, IA (Project #9)

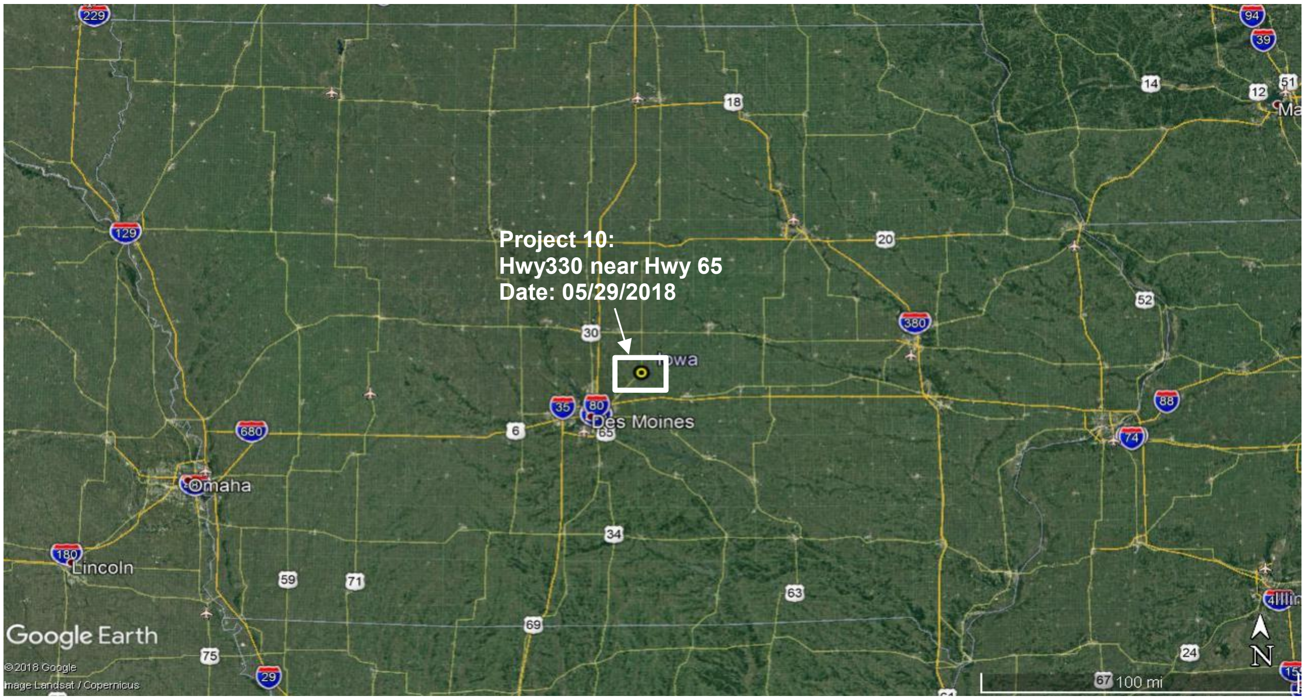
Field Project # 10 (same location as #4)

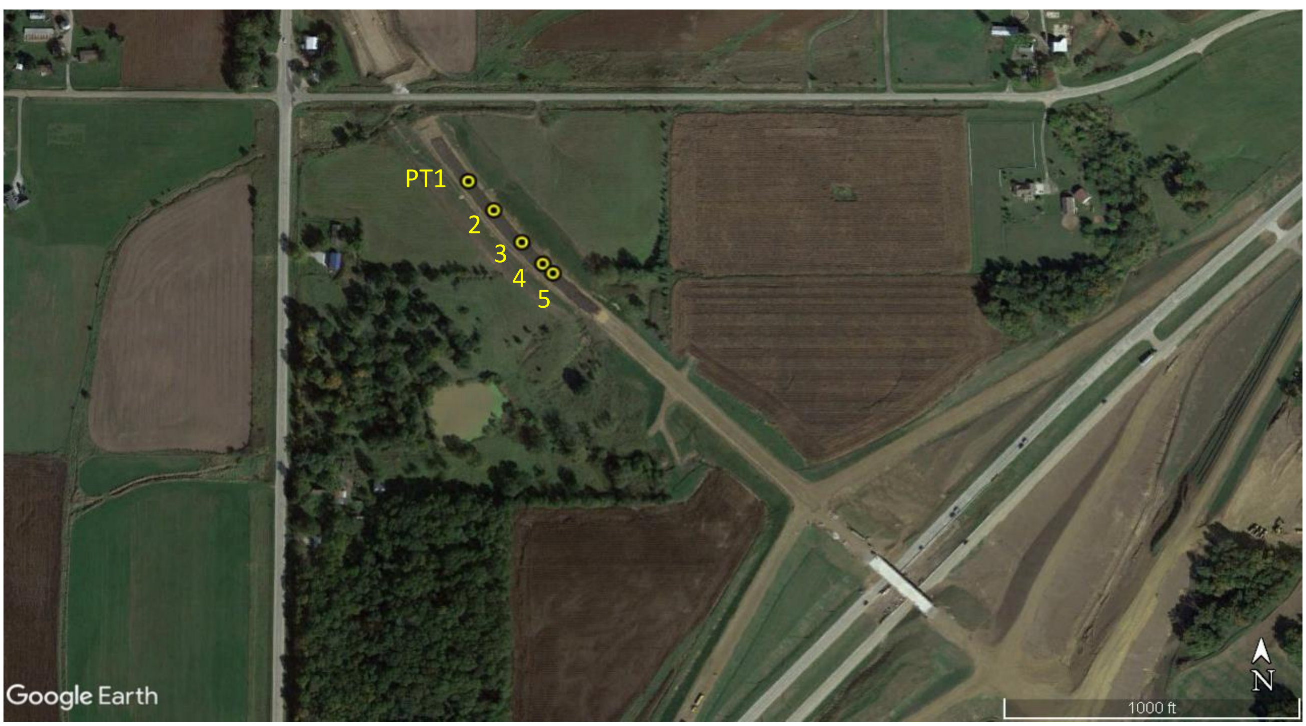
Hwy330 near Hwy65, Jasper County, IA

05/29/2018

Granular subbase (crushed limestone) over special backfill and embankment cut/fill

Project Location and Test Locations





Test Locations	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 330 near Hwy 65 (Project #10)

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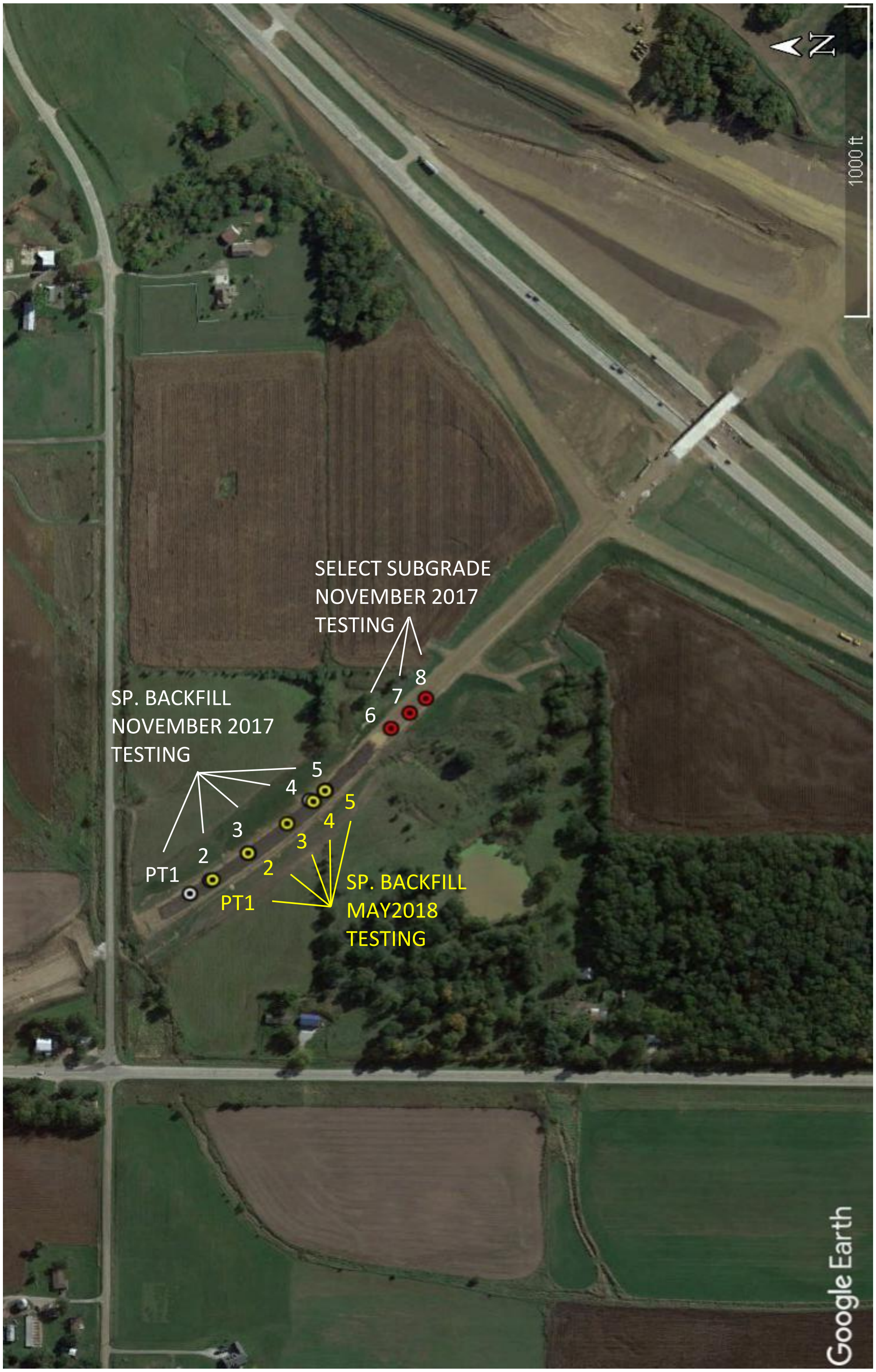
Project Location and Test Locations



Test Locations

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 330 near Hwy 65 (Project #10)

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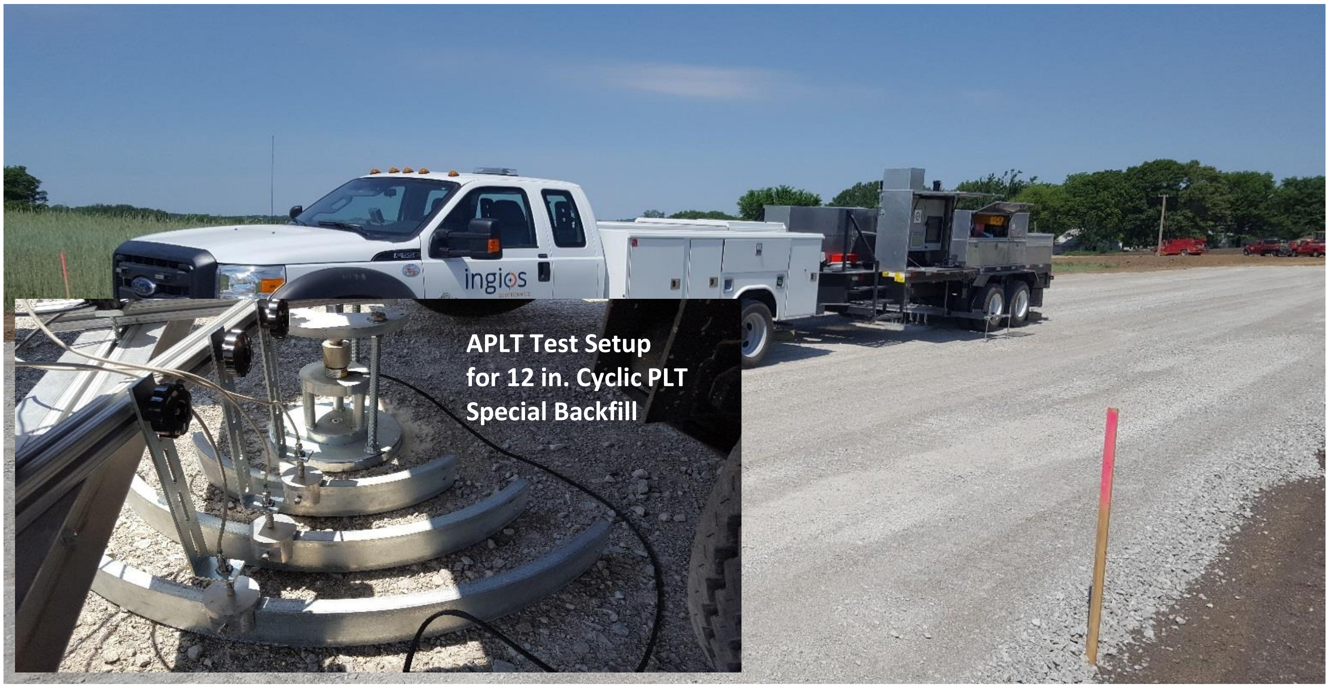
Site Conditions and Pictures



Pictures

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 330 near Hwy 65 (Project #10)

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Summary of Test Results

Summary of Cyclic APLT Test Results

	4 psi cyclic stress @ surface				8 psi plate cyclic stress @ surface			
Point #	$M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)	$M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)
PT1	44,516	50,000	25,139	0.0001	46,557	52,566	25,088	0.0001
PT2	32,783	31,422	40,315	0.0001	41,376	41,449	39,450	0.0003
PT3	40,988	39,856	47,681	0.0000	41,783	41,742	43,089	0.0003
PT4	41,392	43,680	29,402	0.0000	39,569	40,917	31,941	0.0002
PT5	41,176	42,910	31,421	0.0006	43,699	48,114	26,294	0.0005
AVG	**40,171**	**41,573**	**34,792**	**0.0002**	**42,597**	**44,958**	**33,172**	**0.0003**
COV	11%	16%	26%	154%	6%	11%	24%	49%

	13 psi cyclic stress @ surface				18 psi plate cyclic stress @ surface			
Point #	$M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)	$M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)
PT1	53,839	63,720	24,614	0.0007	49,869	58,019	24,389	0.0025
PT2	47,413	49,056	38,625	0.0014	50,992	53,656	38,471	0.0042
PT3	46,948	47,335	43,904	0.0009	50,647	51,658	44,287	0.0030
PT4	47,075	50,754	31,292	0.0008	48,250	52,070	32,084	0.0026
PT5	53,037	59,842	29,743	0.0009	51,505	56,657	31,773	0.0025
AVG	**49,662**	**54,141**	**33,636**	**0.0009**	**50,252**	**54,412**	**34,201**	**0.0030**
COV	7%	13%	23%	28%	3%	5%	22%	25%

	28 psi cyclic stress @ surface				38 psi plate cyclic stress @ surface			
Point #	$M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)	$M_{r\text{-}Comp}$ (psi)	$M_{r\text{-}Base}$ (psi)	$M_{r\text{-}SG}$ (psi)	$\Delta\delta_p$ ([in.)
PT1	48,326	56,386	23,256	0.0081	49,306	58,651	22,182	0.0143
PT2	53,518	57,028	37,966	0.0121	53,198	57,126	35,850	0.0203
PT3	52,683	55,137	40,455	0.0081	51,716	54,049	38,130	0.0127
PT4	47,969	52,343	30,308	0.0089	48,009	53,158	28,442	0.0151
PT5	49,706	55,041	30,352	0.0076	49,597	55,289	28,872	0.0136
AVG	**50,440**	**55,187**	**32,468**	**0.0090**	**50,365**	**55,655**	**30,695**	**0.0152**
COV	5%	3%	21%	20%	4%	4%	21%	20%

Summary of Test Results

Summary of AASHTO (2015) universal model parameters

			$M_{r\text{-}Comp}$				
Point #	**$k^*_{1(Comp)}$**	**$k^*_{2(Comp)}$**	**$k^*_{3(Comp)}$**	**R^2(Adj.)**	**Std. Error (psi)**	**$M_{r\text{-}Comp(pred)\text{-}BP}$ (psi)**	**$\sigma_{cyclic\text{-}BP}$ (psi)**
PT1	3,513.4	0.230	-1.416	0.586	1,655	51,255	18.2
PT2	2,982.1	0.465	-1.896	0.982	1,108	53,486	30.4
PT3	2,996.2	0.189	-0.476	0.941	1,199	52,650	39.0
PT4	2,993.5	0.181	-0.680	0.782	1,622	48,327	33.8
PT5	3,446.5	0.346	-1.925	0.882	1,506	52,046	20.5
AVG	**3,186.3**	**0.282**	**-1.278**	**0.835**	**1,418**	**51,553**	**28.4**
COV	8%	43%	-0.528	19%	18%	4%	31%

			$M_{r\text{-}Base}$		
Point #	**$k^*_{1(Base)}$**	**$k^*_{2(Base(}$**	**$k^*_{3(Base)}$**	**R^2(Adj.)**	**Std. Error (psi)**
PT1	4,031.1	0.274	-1.564	0.584	2,533
PT2	3,007.7	0.553	-2.179	0.984	1,291
PT3	2,963.4	0.222	-0.482	0.960	1,253
PT4	3,121.2	0.189	-0.548	0.790	2,160
PT5	3,834.6	0.430	-2.386	0.878	2,075
AVG	**3,391.6**	**0.334**	**-1.432**	**0.839**	**1,862**
COV	15%	46%	-0.622	19%	30%

			$M_{r\text{-}SG}$		
Point #	**$k^*_{1(SG)}$**	**$k^*_{2(SG)}$**	**$k^*_{3(SG)}$**	**R^2(Adj.)**	**Std. Error (psi)**
PT1	5,108.1	0.529	-14.962	0.994	87
PT2	3,703.7	0.117	-5.093	0.894	474
PT3	6,713.6	0.339	-11.241	0.753	1,466
PT4	47,047.2	1.772	-36.167	0.781	621
PT5	13,099.6	1.086	-21.301	-0.092	755
AVG	**15,134.4**	**0.768**	**-17.753**	**0.666**	**681**
COV	120%	87%	-0.668	65%	74%

Summary of Test Results

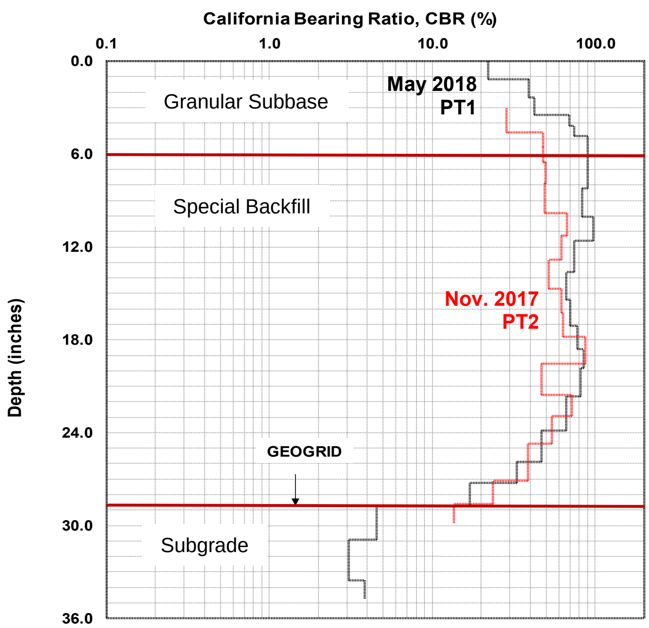
Summary of DCP and LWD test results

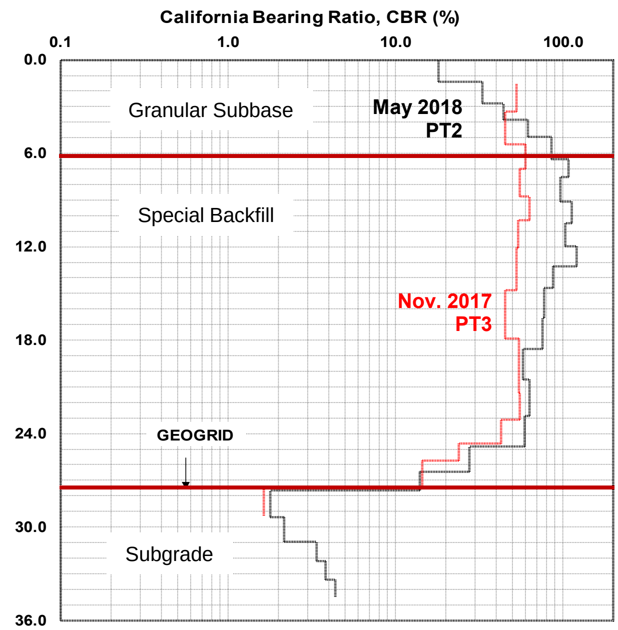
Point #	Special Backfill + Granular Subbase: Thickness, H_1 (in.)	Avg. CBR (%)	St. Dev CBR (%)	Subgrade Layer: Thickness, H_2 (in.)	Avg. CBR (%)	St. Dev CBR (%)	Ratio CBR_1/CBR_2
PT1	28.7	65.4	25.2	6.0	3.7	0.7	17.5
PT2	27.6	68.4	34.1	6.9	2.9	1.1	24.0
PT3	28.6	69.2	30.1	5.5	17.2	14.1	4.0
PT4	28.2	76.7	35.7	7.1	15.4	5.8	5.0
PT5	27.0	76.7	30.7	7.8	16.3	3.4	4.7
AVG	**28.0**	**71.3**	**31.2**	**6.6**	**11.1**	**5.0**	**11.0**
COV	3%	7%	0.131	14%	65%	108%	83%

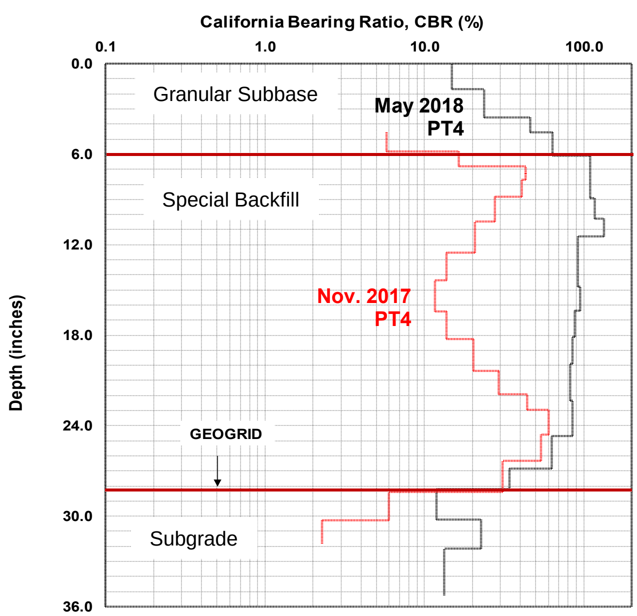
Note: Subgrade CBR calculated based on measurements obtained from bottom of special backfill to the maximum penetration depth.

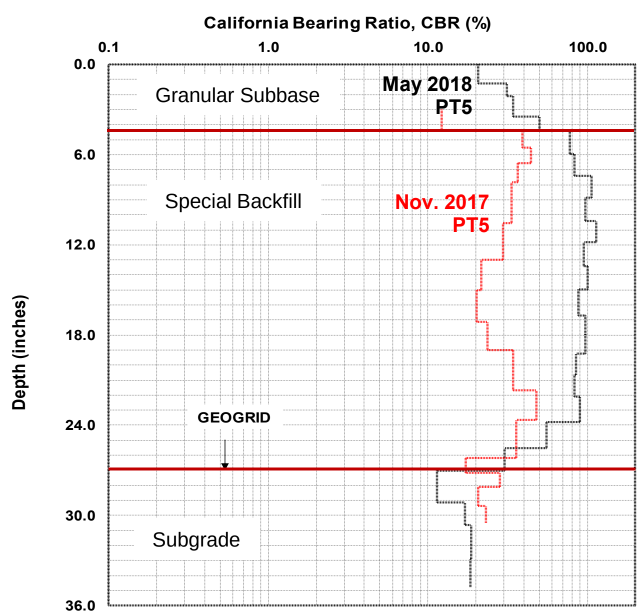
Summary of Test Results

COMPARISON OF DCP PROFILES FROM NOVEMBER 2017 AND MAY 2018 TESTING









Summary of Test Results

Project Name: Iowa DOT STIC

Project ID: SIA-00001

Location: Hwy 330 near Hwy 65 (Project #10)

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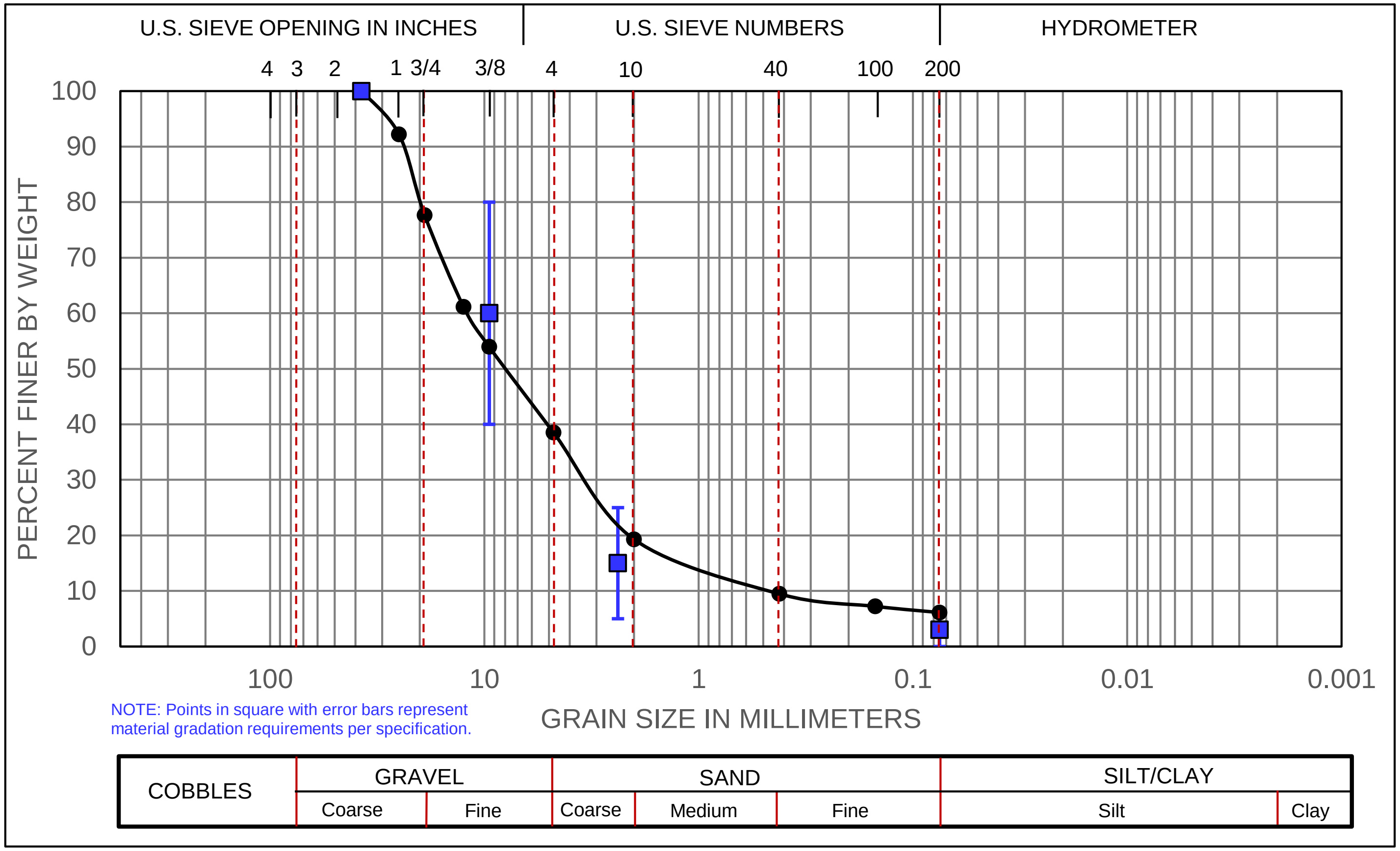
GRAIN SIZE DISTRIBUTION
ASTM D422/C136



Gradation Summary

% Gravel	61.5
% Sand	32.4
% Fines	6.1
D_{10} (mm)	0.505
D_{30} (mm)	3.534
D_{50} (mm)	8.284
D_{60} (mm)	12.027
D_{85} (mm)	22.032
C_u	23.8
C_c	2.1

Atterberg Limits

LL	NP
PL	NP
PI	NP

Classification

AASHTO:	A-1-a
USCS:	GW

MATERIAL: Gray Crushed Limestone Granular Subbase (Iowa DOT Gradation 4121 - Virgin Material)

LOCATION: Hwy 330 near Hwy 65 (Project #10) **TESTED BY:** DW

SAMPLE DATE: 5/29/2018 **TEST DATE:** 9/6/2018

Gradation and Soil Classification Test Results

Project Name: Iowa DOT STIC

Project ID: SIA-00001

Location: Hwy 330 near Hwy 65 (Project #10)

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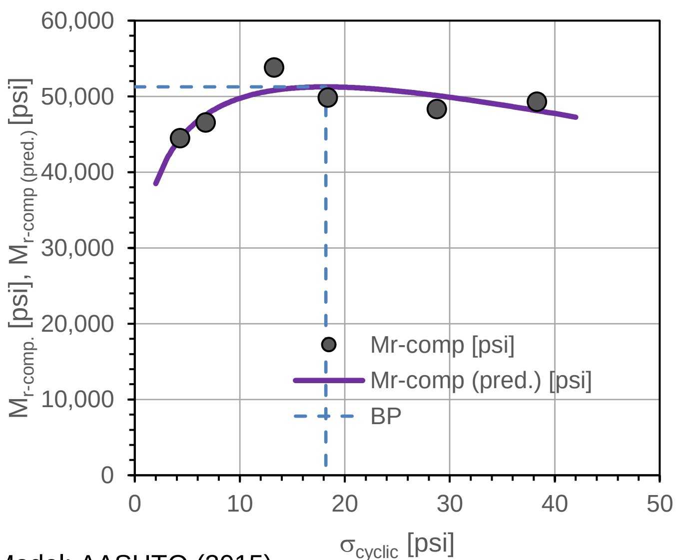
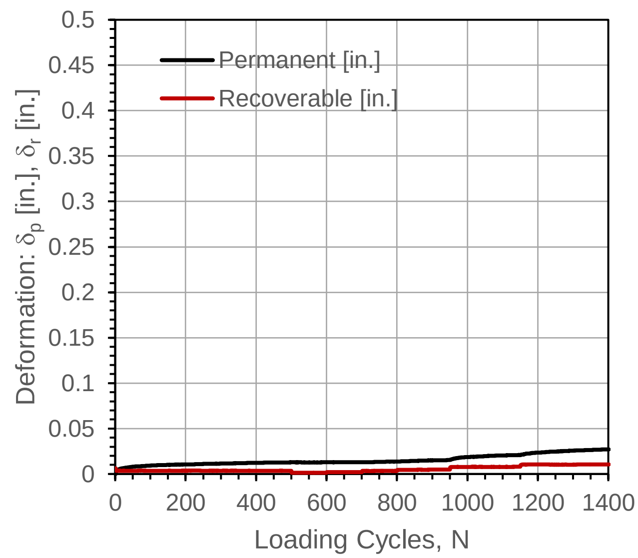
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	5/29/2018	Time:	11:26:12 AM	Test ID	**STIC_10__12_pt1**
Tested By	DW	Location:	Hwy 330	Sta.	NA
Latitude,N:	41.819336	Longitude,W:	93.307190	Elev. (ft):	895
Comments:	6 inch granaular subbase over 2ft special backfill over geogrid				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.27	---	---	0.0128	---	0.289	---
1	100	4.31	44,516	44,403	0.0129	0.0001	-0.030	Y
2	100	6.75	46,557	47,548	0.0129	0.0001	0.110	Y
3	100	13.27	53,839	50,805	0.0135	0.0007	0.537	Y
4	150	18.39	49,869	51,255	0.0153	0.0025	0.563	Y
5	200	28.76	48,326	50,111	0.0209	0.0081	0.506	Y
6	250	38.30	49,306	48,127	0.0271	0.0143	0.596	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	3,513.4	6.65E-07
k^*_2	0.230	1.02E-01
k^*_3	-1.416	1.44E-01
Adj. R^2	0.586	
Std. Error [psi]	1,655	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	51,255
$\sigma_{cyclic\text{-}BP}$ [psi]	18.2

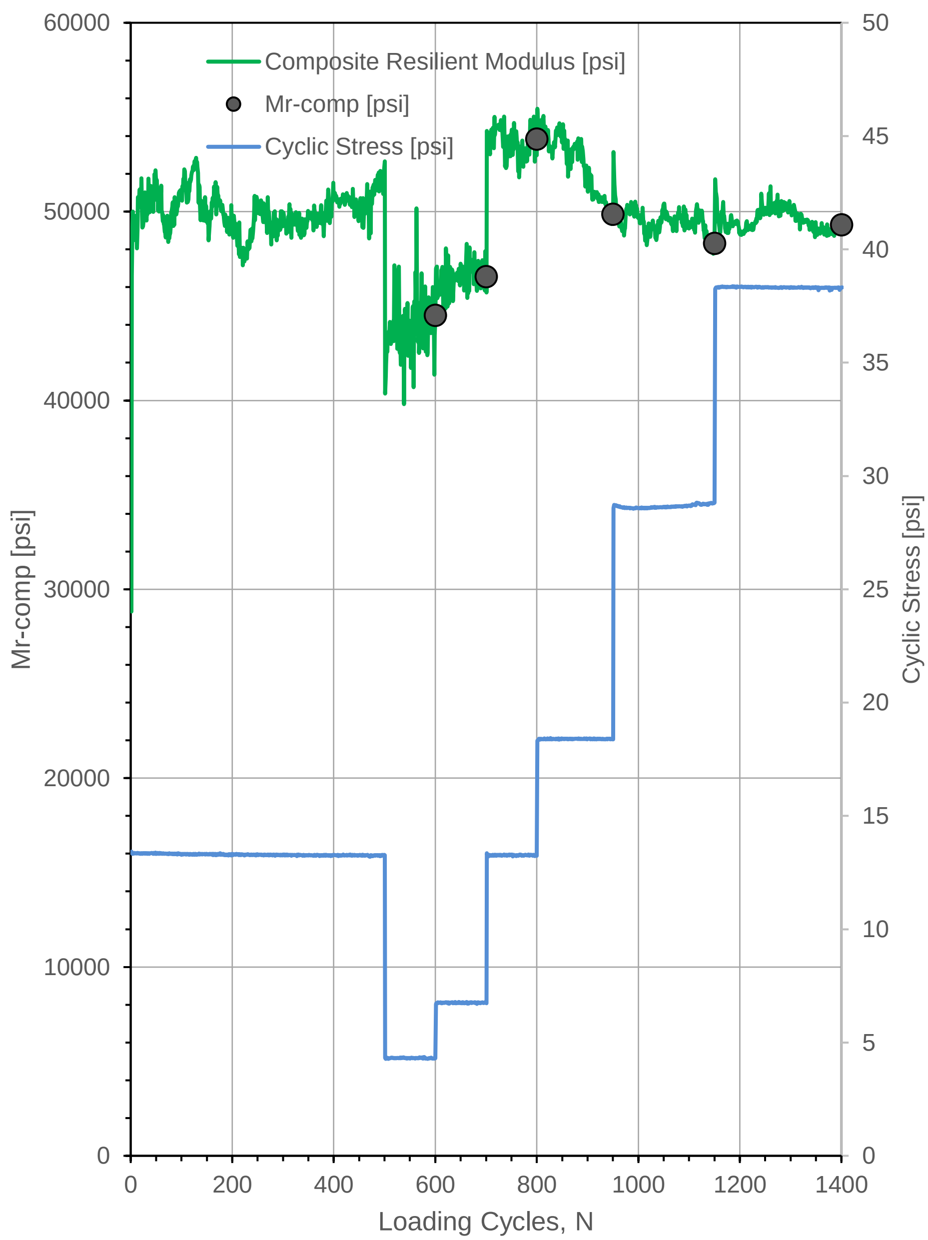
In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 330 near Hwy 65 (Project #10)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	5/29/2018	Time:	11:26:12 AM	Test ID	**STIC_10__12_pt1**
Tested By	DW	Location:	Hwy 330	Sta.	NA
Latitude,N:	41.819336	Longitude,W:	93.307190	Elev. (ft):	895
Comments:	6 inch granaular subbase over 2ft special backfill over geogrid				

σ_{cyclic} [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]
2	38,493
3	41,638
4	43,843
5	45,492
6	46,767
7	47,775
8	48,580
9	49,227
10	49,747
11	50,162
12	50,492
13	50,748
14	50,942
15	51,084
16	51,179
17	51,235
18	51,255
21	51,147
22	51,065
23	50,965
24	50,847
25	50,715
26	50,570
27	50,413
28	50,245
29	50,068
30	49,883
31	49,691
32	49,491
33	49,286
34	49,076
35	48,861
36	48,642
37	48,420
38	48,194
39	47,966
40	47,736



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

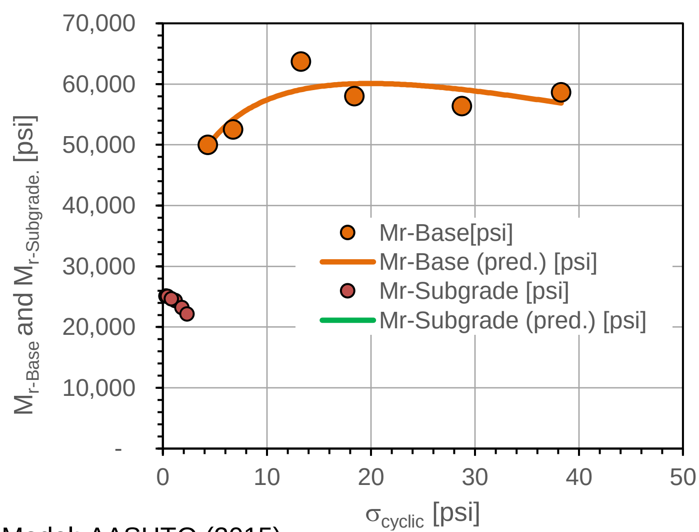
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 330 near Hwy 65 (Project #10)

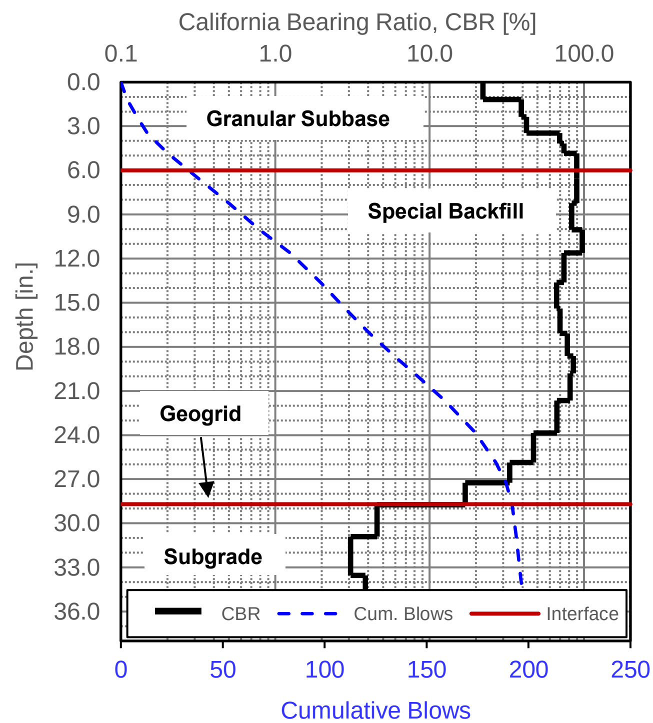
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	5/29/2018	Time:	11:26:12 AM	Test ID	**STIC_10__12_pt1**
Tested By	DW	Location:	Hwy 330	Sta.	NA
Latitude,N:	41.819336	Longitude,W:	93.307190	Elev. (ft):	895
Comments:	6 inch granaular subbase over 2ft special backfill over geogrid				

Note: Granular subbase and special backfill assumed as one layer (base) in layered analysis.

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	13.27	---	---	---	---	---	---
1	100	4.31	50,000	49,762	0.29	25,139	25,120	1.99
2	100	6.75	52,566	54,161	0.45	25,088	25,054	2.10
3	100	13.27	63,720	59,078	0.81	24,614	24,756	2.59
4	100	18.39	58,019	60,052	1.17	24,389	24,307	2.38
5	100	28.76	56,386	59,108	1.81	23,256	23,224	2.42
6	100	38.30	58,651	56,857	2.33	22,182	22,207	2.64

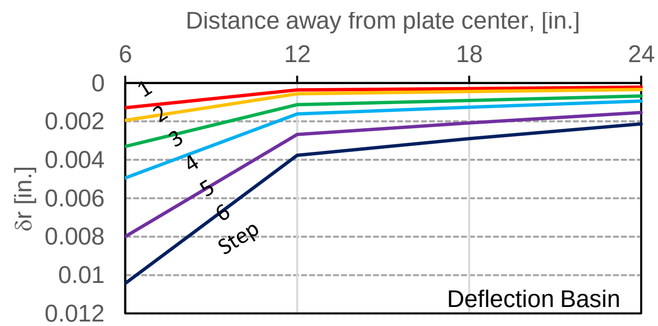




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\ (Base)}$	4031.1	1.40E-06
$k^*_{2\ (Base)}$	0.274	1.23E-01
$k^*_{3\ (Base)}$	-1.564	1.94E-01
Adj. R^2	0.584	
Std. Error [psi]	2533	
$k^*_{1\ (Subgrade)}$	5108.1	2.48E-05
$k^*_{2\ (Subgrade)}$	0.529	1.71E-02
$k^*_{3\ (Subgrade)}$	-14.962	6.63E-03
Adj. R^2	0.994	
Std. Error [psi]	87	



In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 330 near Hwy 65 (Project #10)

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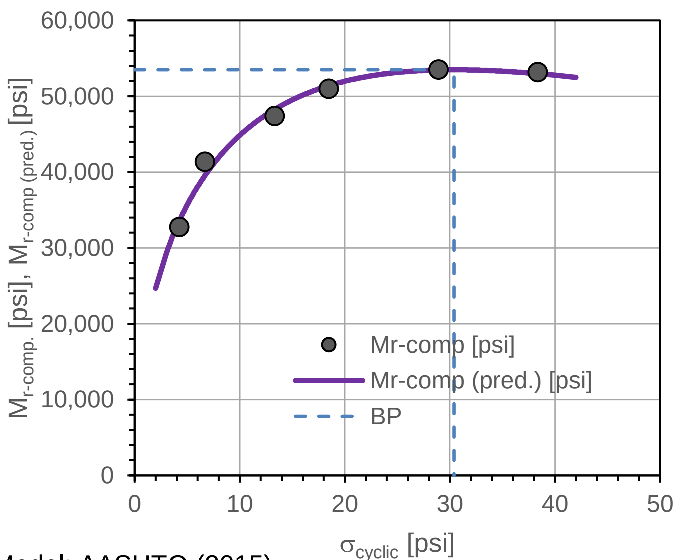
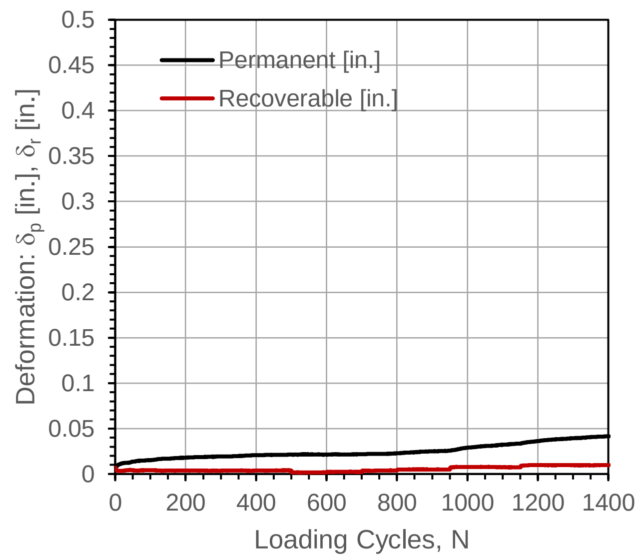
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	5/29/2018	Time:	12:12:17 PM	Test ID	**STIC_10__12_pt2**
Tested By	DW	Location:	Hwy 330	Sta.	NA
Latitude,N:	41.819046	Longitude,W:	93.306847	Elev. (ft):	893
Comments:	6 inch granaular subbase over 2ft special backfill over geogrid				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.34	---	---	0.0213	---	0.199	---
1	100	4.27	32,783	33,599	0.0214	0.0001	0.073	Y
2	100	6.70	41,376	39,560	0.0216	0.0003	0.138	Y
3	100	13.34	47,413	48,269	0.0227	0.0014	0.498	Y
4	150	18.48	50,992	51,393	0.0255	0.0042	0.658	N
5	200	28.93	53,518	53,462	0.0334	0.0121	0.701	N
6	250	38.37	53,198	52,965	0.0416	0.0203	0.680	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	2,982.1	2.26E-07
k^*_2	0.465	6.09E-03
k^*_3	-1.896	3.02E-02
Adj. R^2	0.982	
Std. Error [psi]	1,108	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	53,486
$\sigma_{cyclic\text{-}BP}$ [psi]	30.4

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 330 near Hwy 65 (Project #10)

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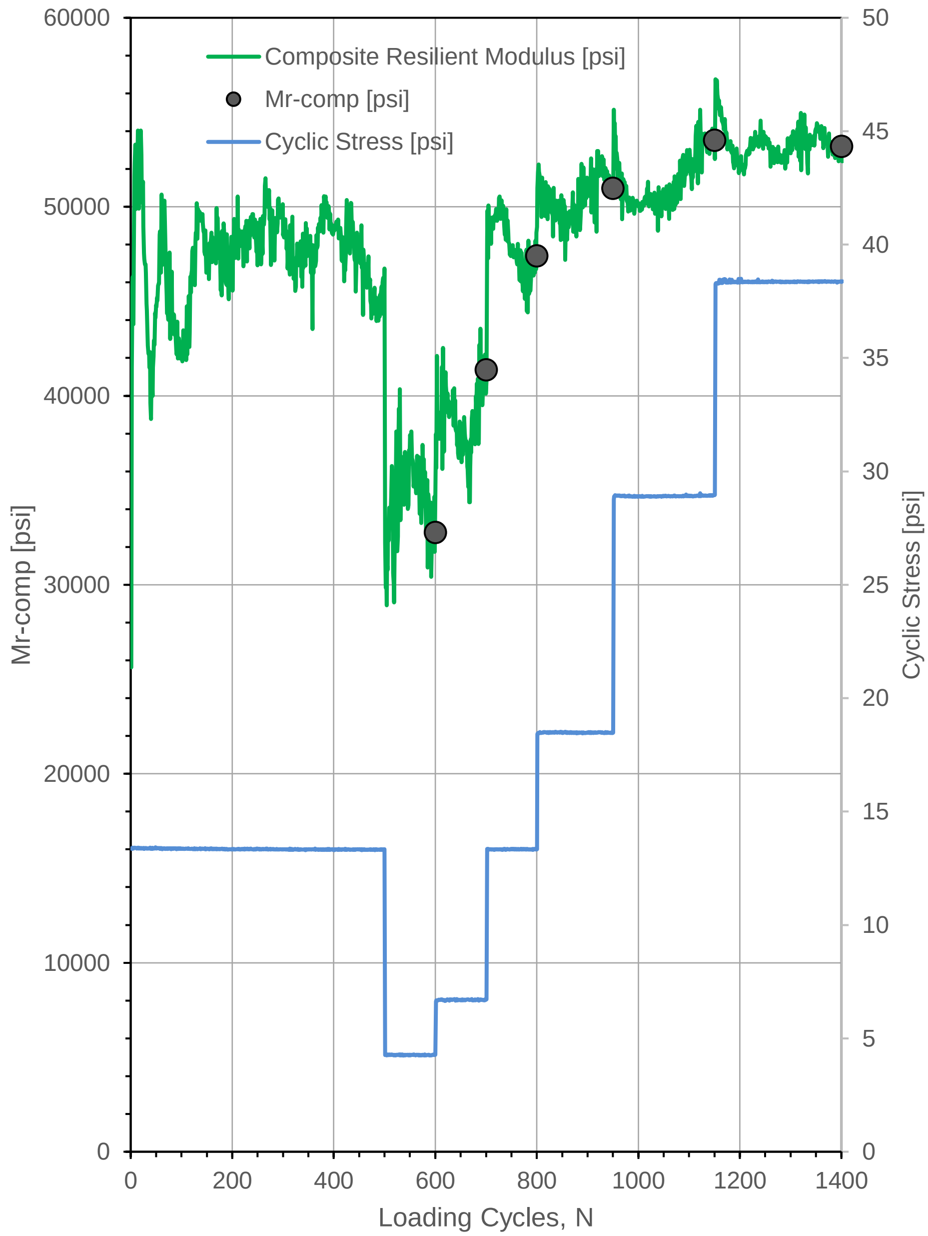
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	5/29/2018	Time:	12:12:17 PM	Test ID	**STIC_10__12_pt2**
Tested By	DW	Location:	Hwy 330	Sta.	NA
Latitude,N:	41.819046	Longitude,W:	93.306847	Elev. (ft):	893
Comments:	6 inch granaular subbase over 2ft special backfill over geogrid				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	24,690
3	29,235
4	32,776
5	35,666
6	38,088
7	40,153
8	41,933
9	43,480
10	44,833
11	46,020
12	47,065
13	47,985
14	48,797
15	49,513
16	50,143
17	50,697
18	51,182
21	52,290
22	52,561
23	52,790
24	52,981
25	53,137
26	53,261
27	53,355
28	53,422
29	53,465
30	53,484
31	53,483
32	53,462
33	53,424
34	53,369
35	53,299
36	53,214
37	53,117
38	53,008
39	52,888
40	52,757



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

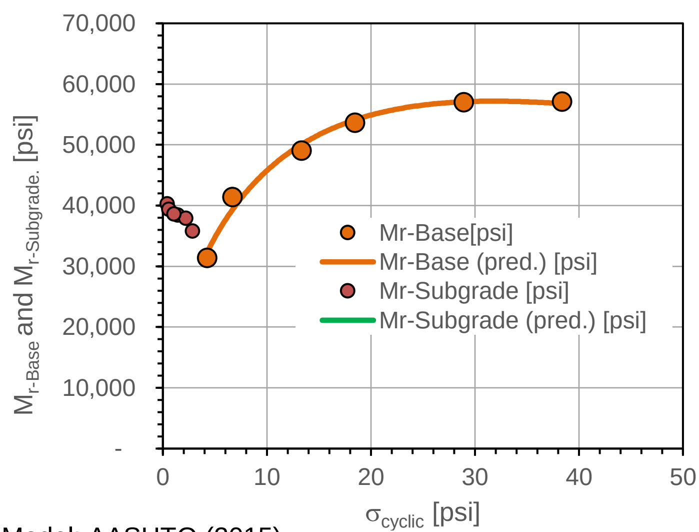
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 330 near Hwy 65 (Project #10)

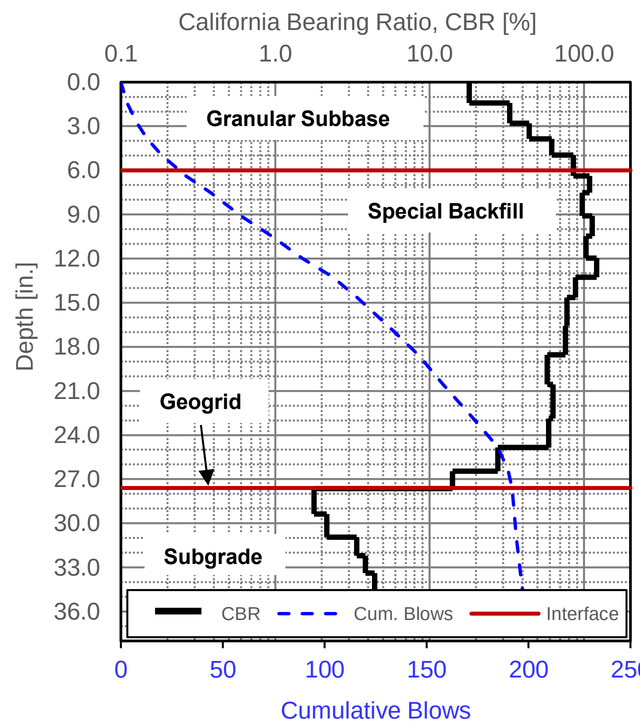
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	5/29/2018	Time:	12:12:17 PM	Test ID	**STIC_10__12_pt2**
Tested By	DW	Location:	Hwy 330	Sta.	NA
Latitude,N:	41.819046	Longitude,W:	93.306847	Elev. (ft):	893
Comments:	6 inch granaular subbase over 2ft special backfill over geogrid				

Note: Granular subbase and special backfill assumed as one layer (base) in layered analysis.

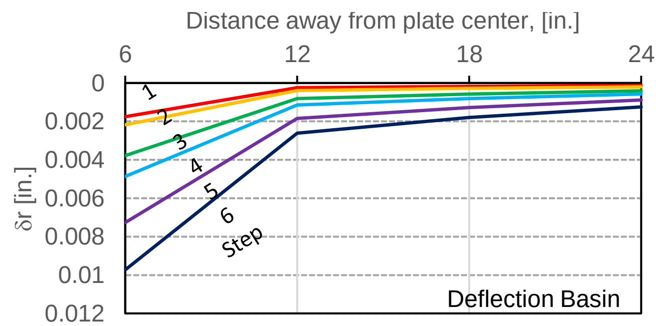
Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	13.34	---	---	---	---	---	---
1	100	4.27	31,422	32,342	0.40	40,315	39,920	0.78
2	100	6.70	41,449	39,336	0.57	39,450	39,716	1.05
3	100	13.34	49,056	50,059	1.07	38,625	39,048	1.27
4	100	18.48	53,656	54,116	1.44	38,471	38,503	1.39
5	100	28.93	57,028	57,086	2.20	37,966	37,291	1.50
6	100	38.37	57,126	56,765	2.86	35,850	36,186	1.59





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
$k^*_{1\ (Base)}$	3007.7	3.56E-07
$k^*_{2\ (Base)}$	0.553	5.75E-03
$k^*_{3\ (Base)}$	-2.179	3.12E-02
Adj. R^2	0.984	
Std. Error [psi]	1291	
$k^*_{1\ (Subgrade)}$	3703.7	5.12E-04
$k^*_{2\ (Subgrade)}$	0.117	7.22E-01
$k^*_{3\ (Subgrade)}$	-5.093	4.40E-01
Adj. R^2	0.894	
Std. Error [psi]	474	

In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 330 near Hwy 65 (Project #10)

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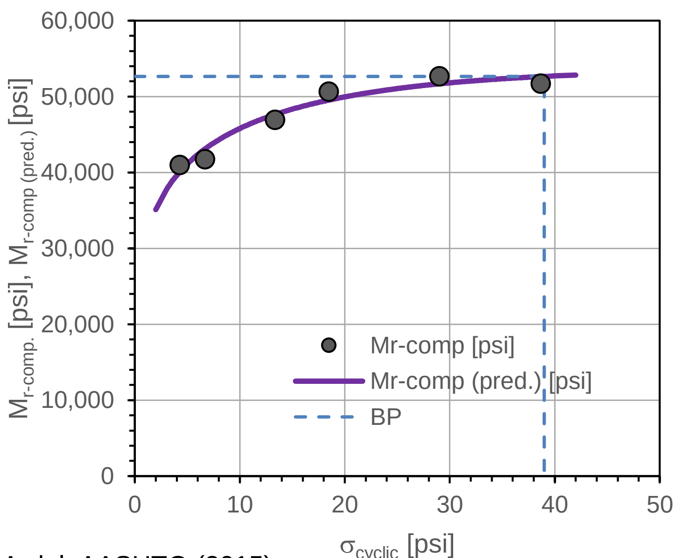
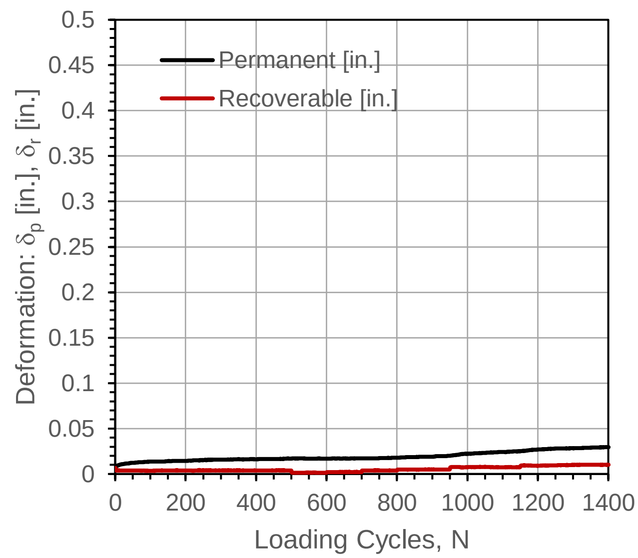
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	5/29/2018	Time:	12:50:25 PM	Test ID	**STIC_10__12_pt3**
Tested By	DW	Location:	Hwy 330	Sta.	NA
Latitude,N:	41.818714	Longitude,W:	93.306503	Elev. (ft):	892
Comments:	6 inch granaular subbase over 2ft special backfill over geogrid				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.37	---	---	0.0170	---	0.143	---
1	100	4.29	40,988	40,091	0.0170	0.0000	-0.097	Y
2	100	6.70	41,783	43,114	0.0173	0.0003	0.109	Y
3	100	13.37	46,948	47,641	0.0179	0.0009	0.448	Y
4	150	18.49	50,647	49,536	0.0199	0.0030	0.542	Y
5	200	29.02	52,683	51,681	0.0251	0.0081	0.641	N
6	250	38.68	51,716	52,629	0.0297	0.0127	0.552	Y





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	2,996.2	2.01E-07
k^*_2	0.189	6.18E-02
k^*_3	-0.476	3.86E-01
Adj. R^2	0.941	
Std. Error [psi]	1,199	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	52,650
$\sigma_{cyclic\text{-}BP}$ [psi]	39.0

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 330 near Hwy 65 (Project #10)

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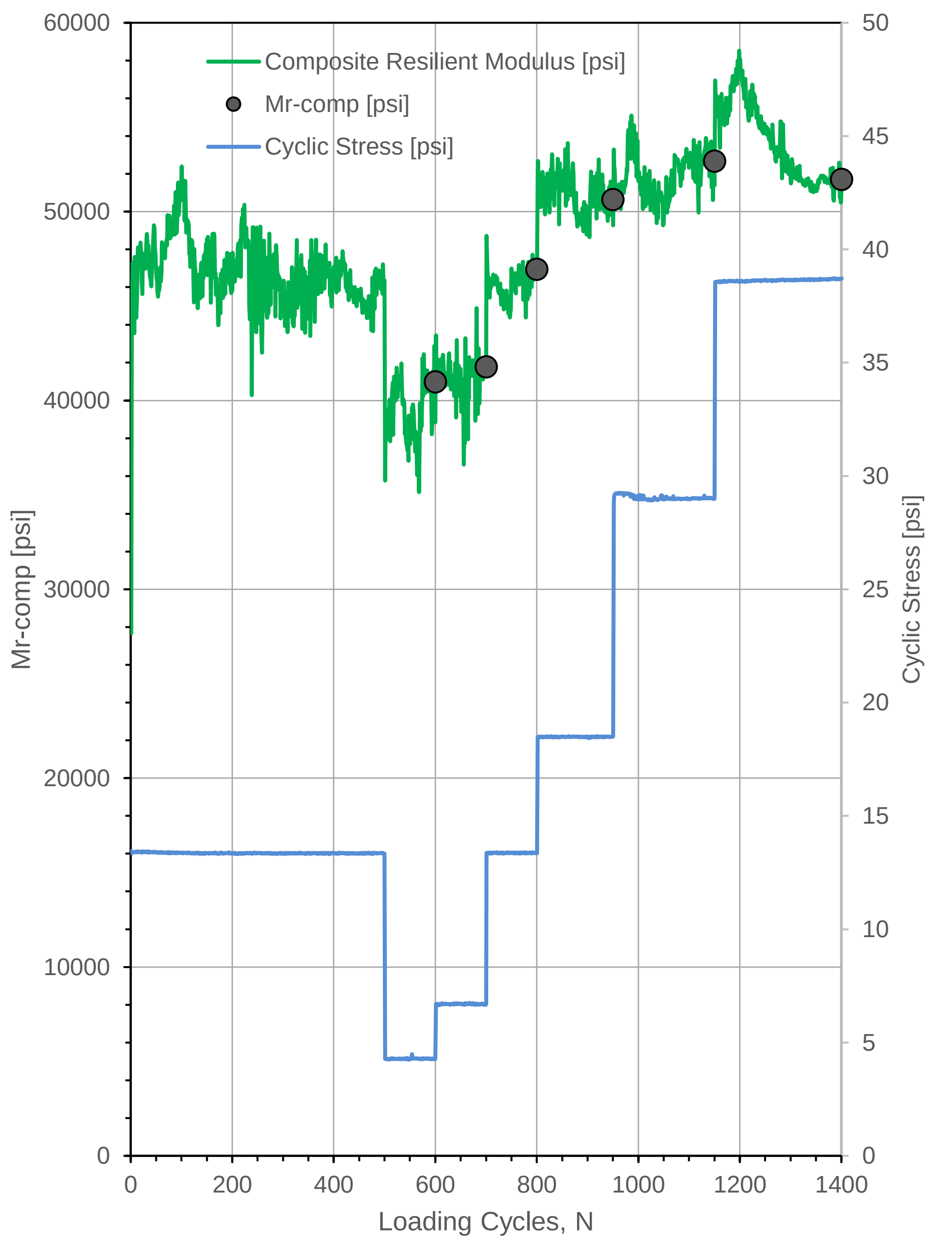
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	5/29/2018	Time:	12:50:25 PM	Test ID	**STIC_10__12_pt3**
Tested By	DW	Location:	Hwy 330	Sta.	NA
Latitude,N:	41.818714	Longitude,W:	93.306503	Elev. (ft):	892
Comments:	6 inch granaular subbase over 2ft special backfill over geogrid				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	35,105
3	37,712
4	39,624
5	41,130
6	42,367
7	43,412
8	44,312
9	45,098
10	45,792
11	46,411
12	46,967
13	47,469
14	47,925
15	48,340
16	48,720
17	49,069
18	49,389
21	50,210
22	50,444
23	50,661
24	50,863
25	51,050
26	51,225
27	51,387
28	51,538
29	51,679
30	51,810
31	51,932
32	52,046
33	52,152
34	52,251
35	52,343
36	52,428
37	52,508
38	52,582
39	52,650
40	52,713



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

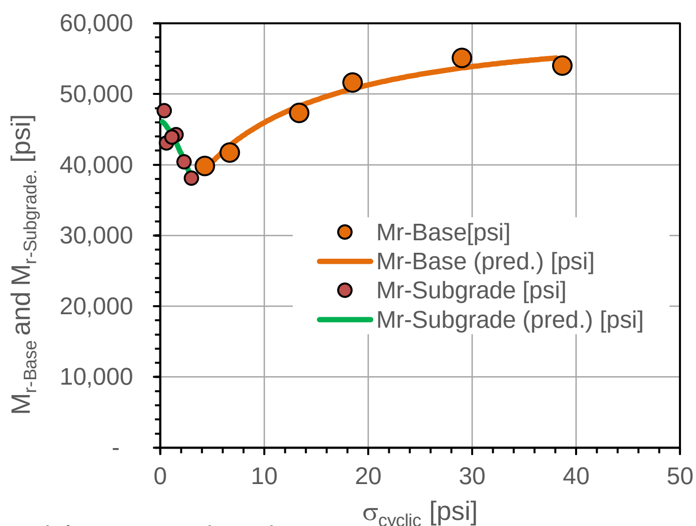
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 330 near Hwy 65 (Project #10)

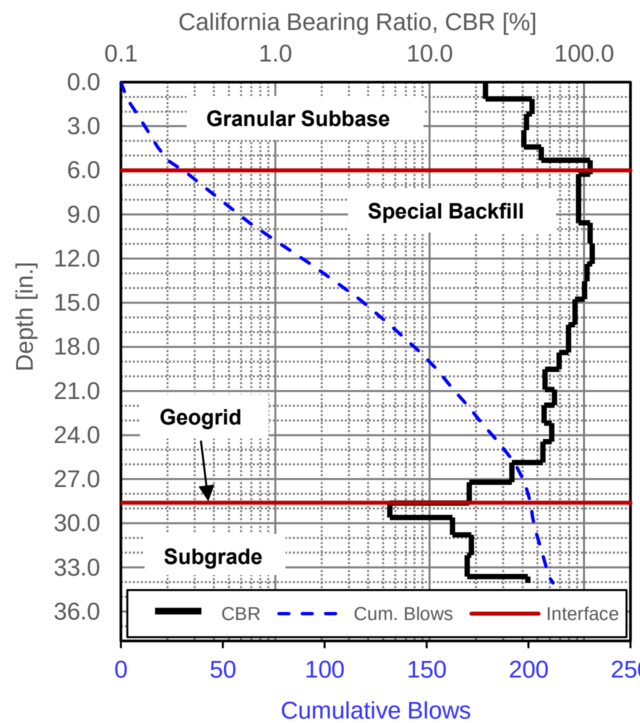
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	5/29/2018	Time:	12:50:25 PM	Test ID	**STIC_10__12_pt3**
Tested By	DW	Location:	Hwy 330	Sta.	NA
Latitude,N:	41.818714	Longitude,W:	93.306503	Elev. (ft):	892
Comments:	6 inch granaular subbase over 2ft special backfill over geogrid				

Note: Granular subbase and special backfill assumed as one layer (base) in layered analysis.

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-Base}}$[psi]	$M_{r\text{-Base (pred.)}}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-Subgrade}}$ [psi]	$M_{r\text{-Subgrade (pred.)}}$ [psi]	Modulus Ratio
Conditioning	500	13.37	---	---	---	---	---	---
1	100	4.29	39,856	39,139	0.39	47,681	45,810	0.84
2	100	6.70	41,742	42,712	0.59	43,089	45,464	0.97
3	100	13.37	47,335	48,273	1.14	43,904	44,188	1.08
4	100	18.49	51,658	50,721	1.53	44,287	43,067	1.17
5	100	29.02	55,137	53,687	2.28	40,455	40,676	1.36
6	100	38.68	54,049	55,171	3.00	38,130	38,222	1.42

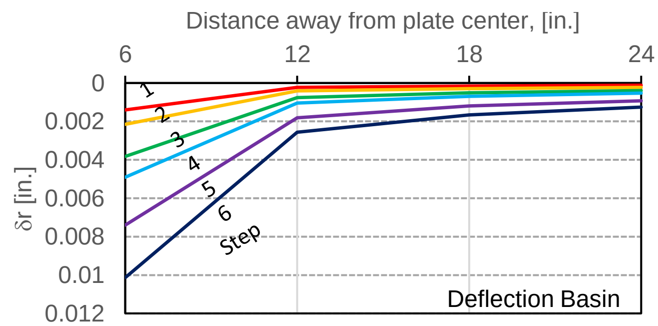




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\ (Base)}$	2963.4	1.87E-07
$k^*_{2\ (Base)}$	0.222	3.90E-02
$k^*_{3\ (Base)}$	-0.482	3.70E-01
Adj. R^2	0.960	
Std. Error [psi]	1253	
$k^*_{1\ (Subgrade)}$	6713.6	7.02E-03
$k^*_{2\ (Subgrade)}$	0.339	7.00E-01
$k^*_{3\ (Subgrade)}$	-11.241	5.04E-01
Adj. R^2	0.753	
Std. Error [psi]	1466	



In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 330 near Hwy 65 (Project #10)

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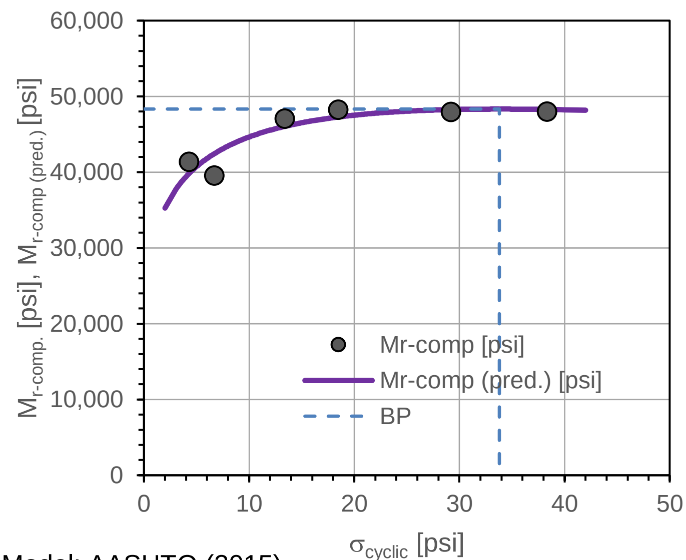
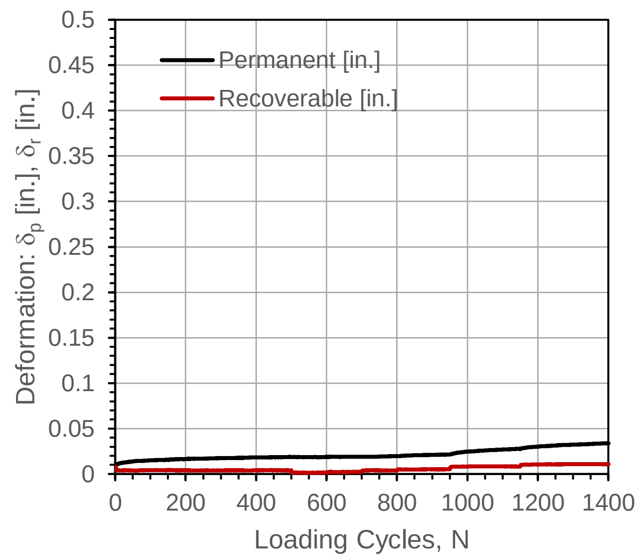
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	5/29/2018	Time:	1:29:22 PM	Test ID	**STIC_10__12_pt4**
Tested By	DW	Location:	Hwy 330	Sta.	NA
Latitude,N:	41.818508	Longitude,W:	93.306244	Elev. (ft):	894
Comments:	6 inch granaular subbase over 2ft special backfill over geogrid				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.38	---	---	0.0188	---	0.136	---
1	100	4.28	41,392	39,804	0.0188	0.0000	-0.050	Y
2	100	6.69	39,569	42,446	0.0189	0.0002	0.150	Y
3	100	13.38	47,075	46,038	0.0195	0.0008	0.483	Y
4	150	18.47	48,250	47,278	0.0214	0.0026	0.630	N
5	200	29.20	47,969	48,259	0.0277	0.0089	0.586	N
6	250	38.34	48,009	48,277	0.0339	0.0151	0.540	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	2,993.5	8.74E-07
k^*_2	0.181	1.85E-01
k^*_3	-0.680	4.41E-01
Adj. R^2	0.782	
Std. Error [psi]	1,622	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	48,327
$\sigma_{cyclic\text{-}BP}$ [psi]	33.8

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 330 near Hwy 65 (Project #10)

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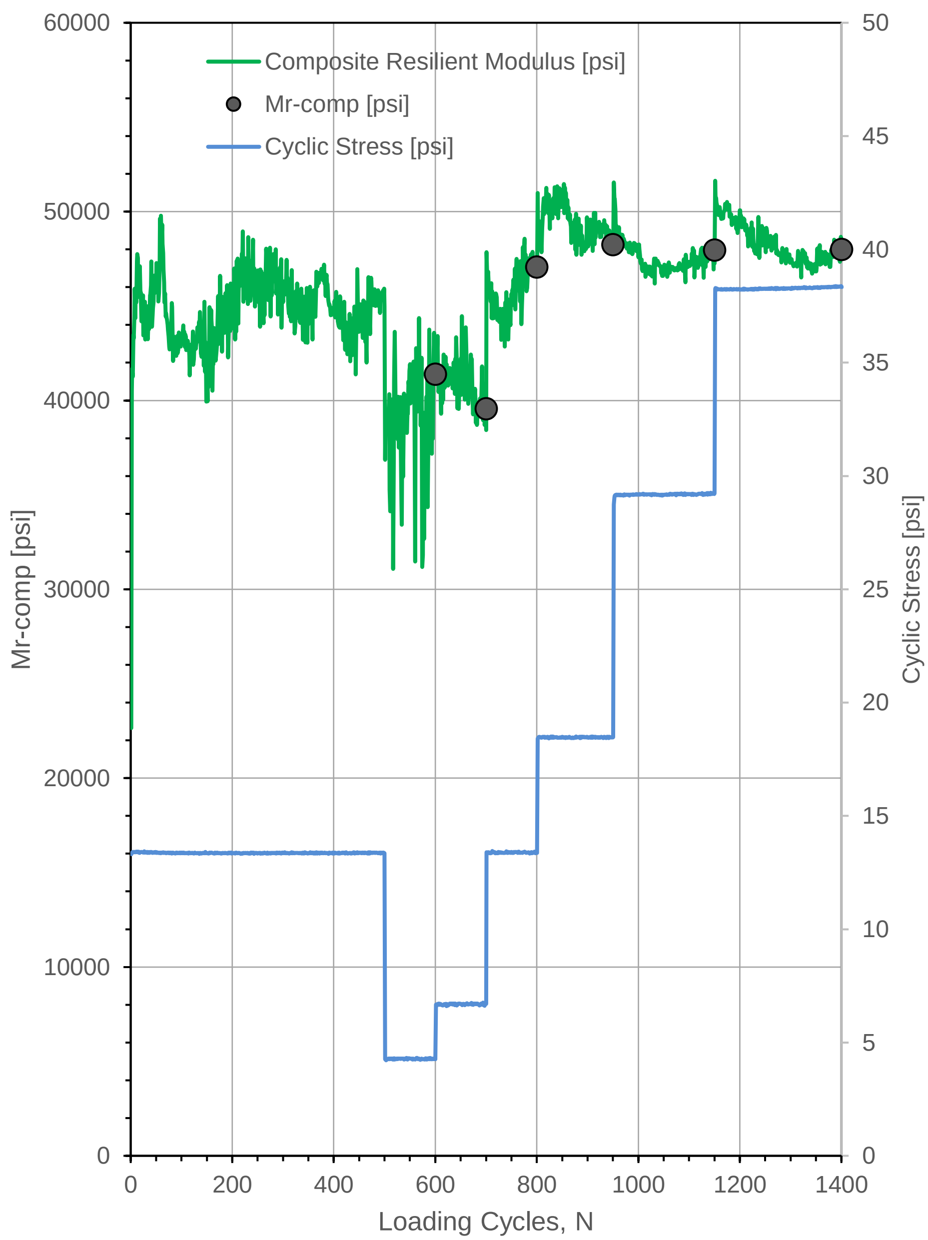
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	5/29/2018	Time:	1:29:22 PM	Test ID	**STIC_10__12_pt4**
Tested By	DW	Location:	Hwy 330	Sta.	NA
Latitude,N:	41.818508	Longitude,W:	93.306244	Elev. (ft):	894
Comments:	6 inch granaular subbase over 2ft special backfill over geogrid				

σ_{cyclic} [psi]	$M_{r\text{-comp (pred.)}}$ [psi]
2	35,259
3	37,670
4	39,401
5	40,738
6	41,814
7	42,703
8	43,452
9	44,091
10	44,643
11	45,122
12	45,541
13	45,909
14	46,233
15	46,519
16	46,771
17	46,995
18	47,193
21	47,658
22	47,777
23	47,881
24	47,971
25	48,048
26	48,114
27	48,170
28	48,216
29	48,253
30	48,281
31	48,303
32	48,317
33	48,325
34	48,327
35	48,324
36	48,315
37	48,301
38	48,284
39	48,262
40	48,236



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 330 near Hwy 65 (Project #10)

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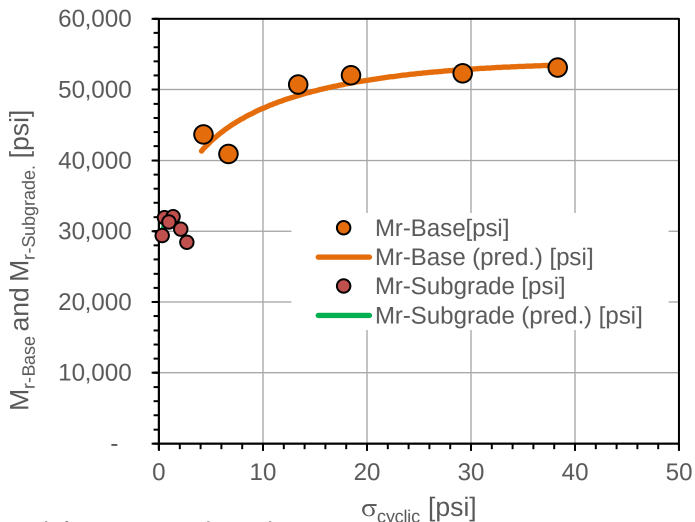
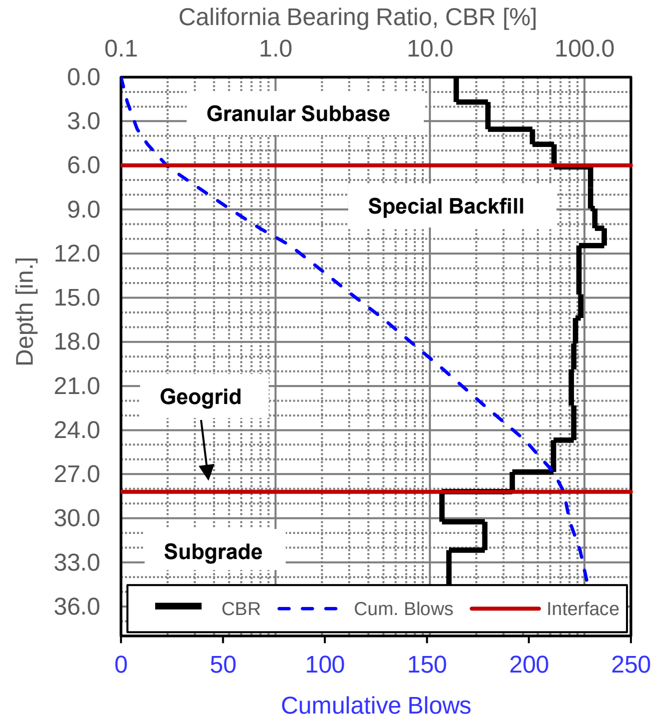
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	5/29/2018	Time:	1:29:22 PM	Test ID	**STIC_10__12_pt4**
Tested By	DW	Location:	Hwy 330	Sta.	NA
Latitude,N:	41.818508	Longitude,W:	93.306244	Elev. (ft):	894
Comments:	6 inch granaular subbase over 2ft special backfill over geogrid				

Note: Granular subbase and special backfill assumed as one layer (base) in layered analysis.

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	13.38	---	---	---	---	---	---
1	100	4.28	43,680	41,612	0.33	29,402	29,990	1.49
2	100	6.69	40,917	44,683	0.54	31,941	30,876	1.28
3	100	13.38	50,754	49,159	0.99	31,292	31,870	1.62
4	100	18.47	52,070	50,928	1.37	32,084	31,906	1.62
5	100	29.20	52,343	52,814	2.11	30,308	30,433	1.73
6	100	38.34	53,158	53,454	2.69	28,442	28,363	1.87

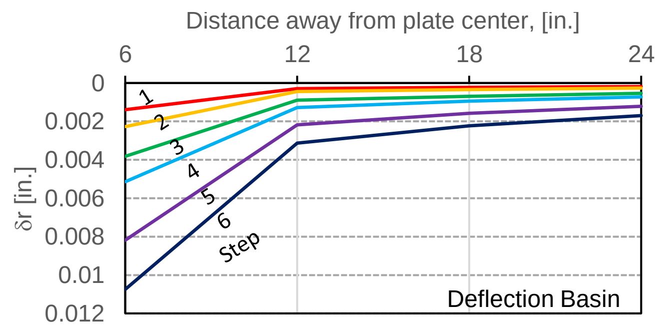




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\ (Base)}$	3121.2	1.71E-06
$k^*_{2\ (Base)}$	0.189	2.48E-01
$k^*_{3\ (Base)}$	-0.548	6.09E-01
Adj. R^2	0.790	
Std. Error [psi]	2160	
$k^*_{1\ (Subgrade)}$	47047.2	1.34E-03
$k^*_{2\ (Subgrade)}$	1.772	4.59E-02
$k^*_{3\ (Subgrade)}$	-36.167	4.08E-02
Adj. R^2	0.781	
Std. Error [psi]	621	



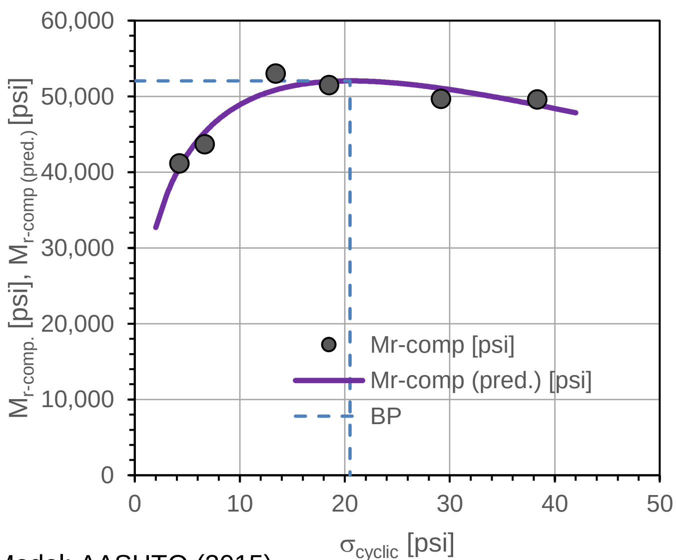
In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

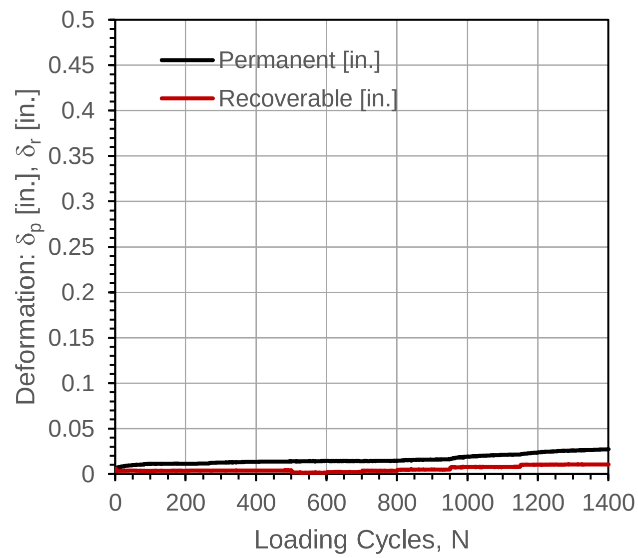
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 330 near Hwy 65 (Project #10)

Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	5/29/2018	Time:	2:06:58 PM	Test ID	**STIC_10__12_pt5**
Tested By	DW	Location:	Hwy 330	Sta.	NA
Latitude,N:	41.818413	Longitude,W:	93.306114	Elev. (ft):	900
Comments:	6 inch granaular subbase over 2ft special backfill over geogrid				

Step	N	σ_{cyclic} [psi]	$M_{r\text{-}comp}$ [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]	δ_p [in.]	$\Delta\delta_p$ [in.]	$=\Delta\log(\delta_p)/\Delta\log(N)$	Near-linear Elastic
Conditioning	500	13.41	---	---	0.0137	---	0.157	---
1	100	4.25	41,176	40,597	0.0143	0.0006	0.192	Y
2	100	6.67	43,699	45,266	0.0141	0.0005	-0.074	Y
3	100	13.41	53,037	50,846	0.0146	0.0009	0.194	Y
4	150	18.50	51,505	51,970	0.0162	0.0025	0.502	Y
5	200	29.18	49,706	51,067	0.0213	0.0076	0.541	N
6	250	38.34	49,597	48,866	0.0273	0.0136	0.573	N





Model: AASHTO (2015)

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

Parameter	Value	P-Value
k^*_1	3,446.5	3.60E-07
k^*_2	0.346	2.22E-02
k^*_3	-1.925	4.47E-02
Adj. R^2	0.882	
Std. Error [psi]	1,506	

$M_{r\text{-}comp\ (pred.)\text{-}BP}$ [psi]	52,046
$\sigma_{cyclic\text{-}BP}$ [psi]	20.5

In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 330 near Hwy 65 (Project #10)

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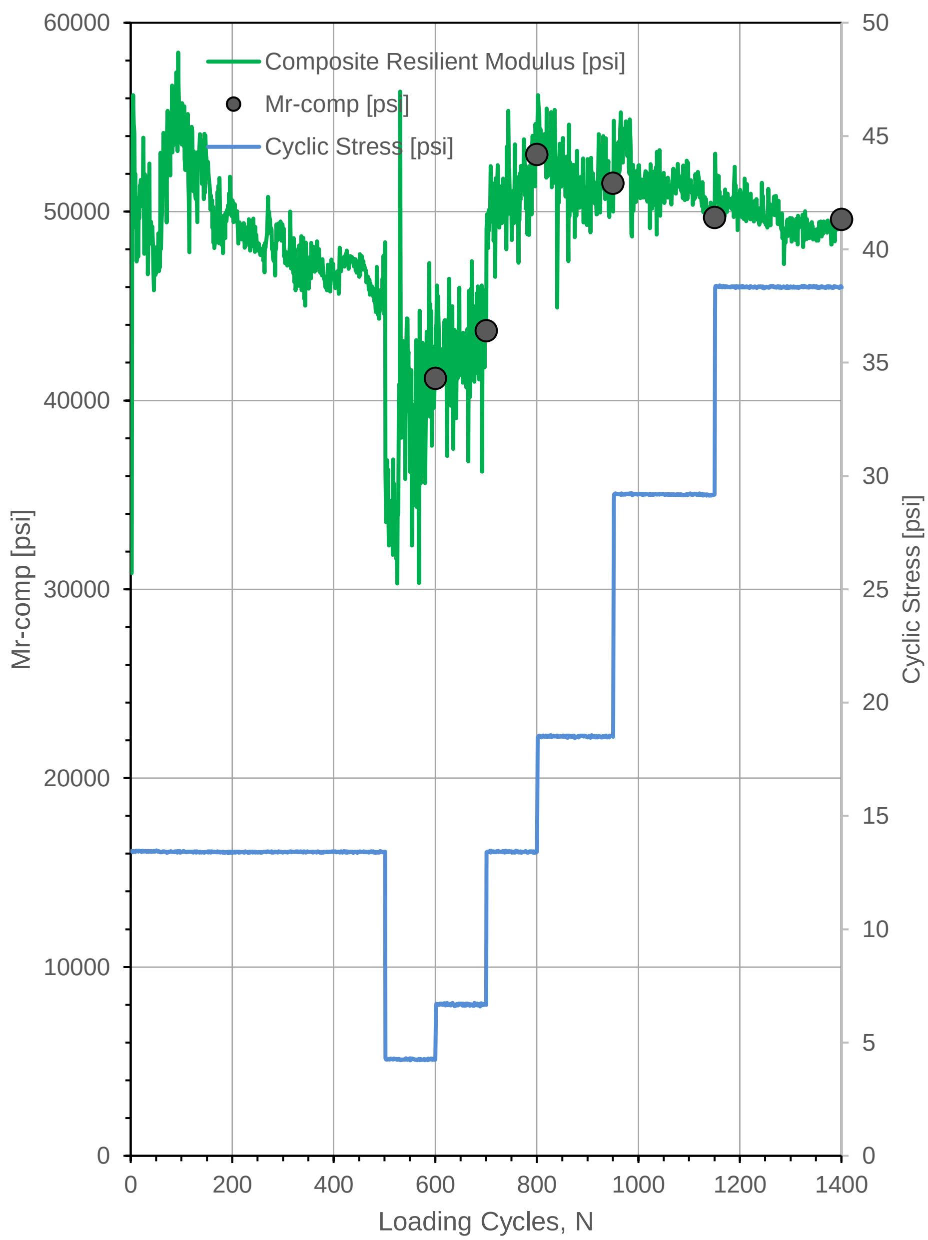
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	5/29/2018	Time:	2:06:58 PM	Test ID	**STIC_10__12_pt5**
Tested By	DW	Location:	Hwy 330	Sta.	NA
Latitude,N:	41.818413	Longitude,W:	93.306114	Elev. (ft):	900
Comments:	6 inch granaular subbase over 2ft special backfill over geogrid				

σ_{cyclic} [psi]	$M_{r\text{-}comp\ (pred.)}$ [psi]
2	32,702
3	36,881
4	39,942
5	42,310
6	44,198
7	45,731
8	46,990
9	48,031
10	48,892
11	49,606
12	50,194
13	50,675
14	51,065
15	51,376
16	51,617
17	51,797
18	51,924
21	52,042
22	52,009
23	51,947
24	51,858
25	51,745
26	51,611
27	51,458
28	51,287
29	51,102
30	50,902
31	50,690
32	50,468
33	50,235
34	49,993
35	49,744
36	49,488
37	49,225
38	48,957
39	48,685
40	48,408



In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent

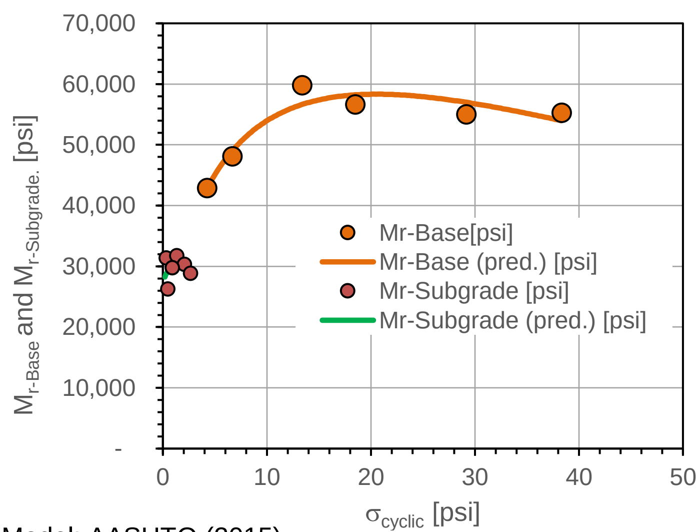
Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 330 near Hwy 65 (Project #10)

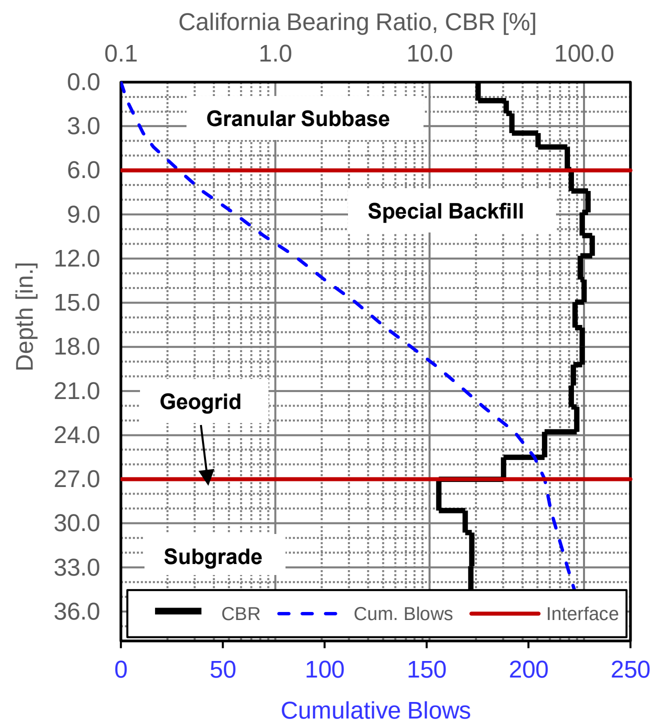
Automated Plate Load Test [APLT]

Test:	In-situ Resilient Modulus [Mr]: Cyclic Loading, Composite, Stress-Dependent (5, 10, 15, 20, 30, 40)				
Date:	5/29/2018	Time:	2:06:58 PM	Test ID	**STIC_10__12_pt5**
Tested By	DW	Location:	Hwy 330	Sta.	NA
Latitude,N:	41.818413	Longitude,W:	93.306114	Elev. (ft):	900
Comments:	6 inch granaular subbase over 2ft special backfill over geogrid				

Note: Granular subbase and special backfill assumed as one layer (base) in layered analysis.

Step	N	$\sigma_{cyclic\_surface}$ [psi]	$M_{r\text{-}Base}$[psi]	$M_{r\text{-}Base\ (pred.)}$ [psi]	$\sigma_{cyclic\_Int.}$ [psi]	$M_{r\text{-}Subgrade}$ [psi]	$M_{r\text{-}Subgrade\ (pred.)}$ [psi]	Modulus Ratio
Conditioning	500	13.41	---	---	---	---	---	---
1	100	4.25	42,910	42,819	0.33	31,421	28,772	1.37
2	100	6.67	48,114	49,023	0.47	26,294	29,233	1.83
3	100	13.41	59,842	56,654	0.91	29,743	30,222	2.01
4	100	18.50	56,657	58,226	1.32	31,773	30,574	1.78
5	100	29.18	55,041	56,994	2.07	30,352	30,173	1.81
6	100	38.34	55,289	53,976	2.66	28,872	29,177	1.91

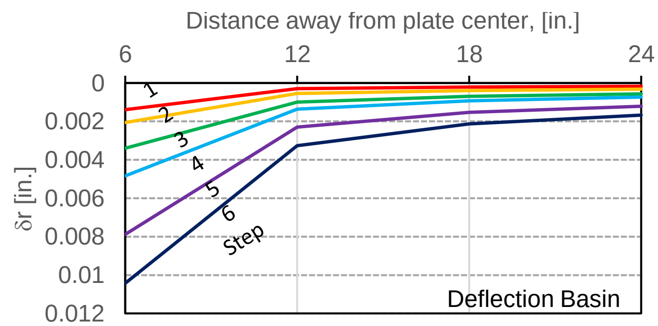




Model: AASHTO (2015)

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

Parameter	Value	P-Value
$k^*_{1\ (Base)}$	3834.6	5.65E-07
$k^*_{2\ (Base)}$	0.430	1.92E-02
$k^*_{3\ (Base)}$	-2.386	3.93E-02
Adj. R^2	0.878	
Std. Error [psi]	2075	
$k^*_{1\ (Subgrade)}$	13099.6	5.01E-02
$k^*_{2\ (Subgrade)}$	1.086	5.70E-01
$k^*_{3\ (Subgrade)}$	-21.301	5.79E-01
Adj. R^2	-0.092	
Std. Error [psi]	755	



In-situ Resilient Modulus [Mr]: Cyclic Loading, Layered Analysis, Stress-Dependent

Project Name: Iowa DOT STIC
Project ID: SIA-00001
Location: Hwy 330 near Hwy 65 (Project #10)

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Date of Test	5/29/2018	Test ID	STIC_10__12_pt1	Operator	DW	ASTM	D6951
Latitude, N	41.8193360		Longitude, W	93.3071900		Elevation (ft)	895
Location	Hwy 330		Station	NA			
Comments	6 inch granaular subbase over 2ft special backfill over geogrid						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	S_{u-CBR}, Bearing Capacity (psf)
Avg. Subbase + Sp. Backfill layer	3.8	65.4	37.1	8,773
Avg. Subgrade Layer	30.4	3.7	5.9	1,311
Ratio of Avg. Top/Bottom Layer	0.1	17.5	6.2	6.7
Std.Dev.Subbase+Sp. Backfill Layer	2.9	25.2	20.1	4,651
Std. Dev. Subgrade Layer	3.0	0.7	2.1	449

NOTES:

Subgrade is assumed as sandy clay.

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

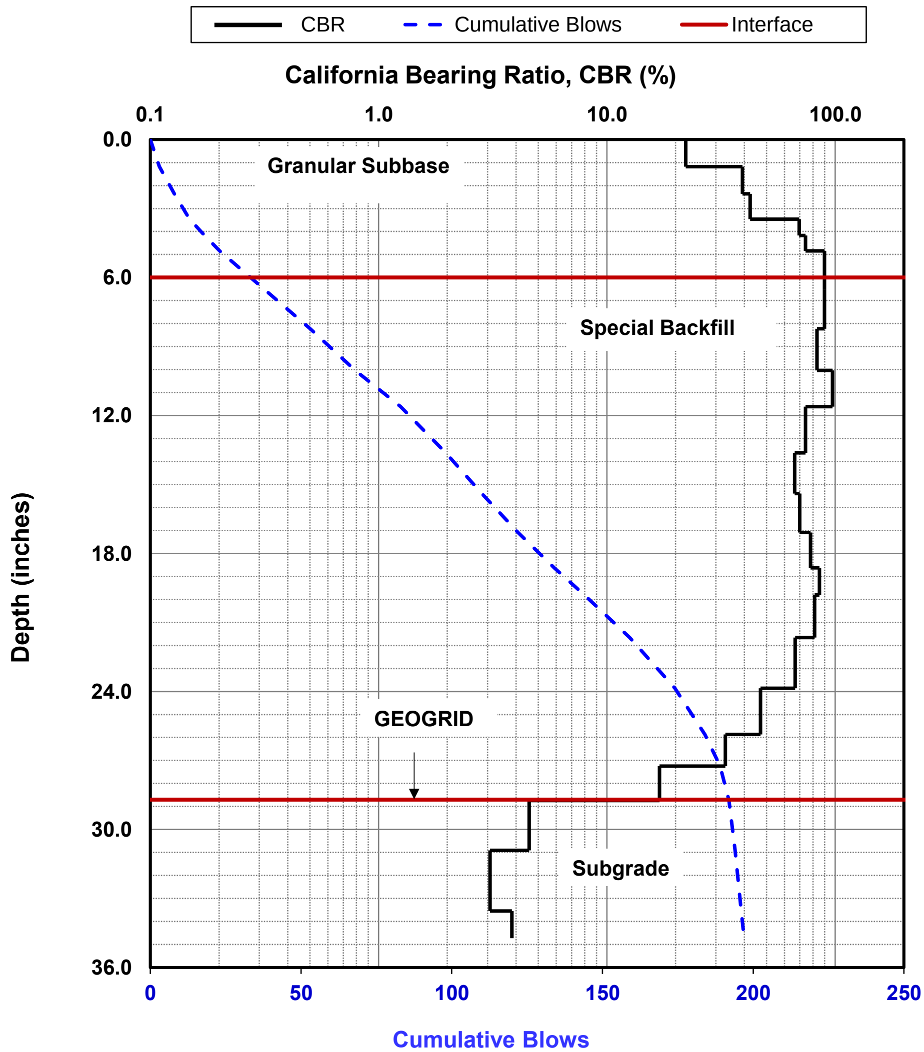
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 330 near Hwy 65 (Project #10)

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Date of Test	5/29/2018	Test ID	STIC_10__12_pt2	Operator	DW	ASTM	D6951
Latitude, N	41.8190460		Longitude, W	93.3068470		Elevation (ft)	893
Location	Hwy 330		Station	NA			
Comments	6 inch granaular subbase over 2ft special backfill over geogrid						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	S_{u-CBR}, Bearing Capacity (psf)
Avg. Subbase + Sp. Backfill layer	3.7	68.4	38.1	9,031
Avg. Subgrade Layer	34.8	2.9	5.0	1,095
Ratio of Avg. Top/Bottom Layer	0.1	24.0	7.6	8.2
Std.Dev.Subbase+Sp. Backfill Layer	3.8	34.1	24.4	5,692
Std. Dev. Subgrade Layer	6.9	1.1	2.7	586

NOTES:

Subgrade is assumed as sandy clay.

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

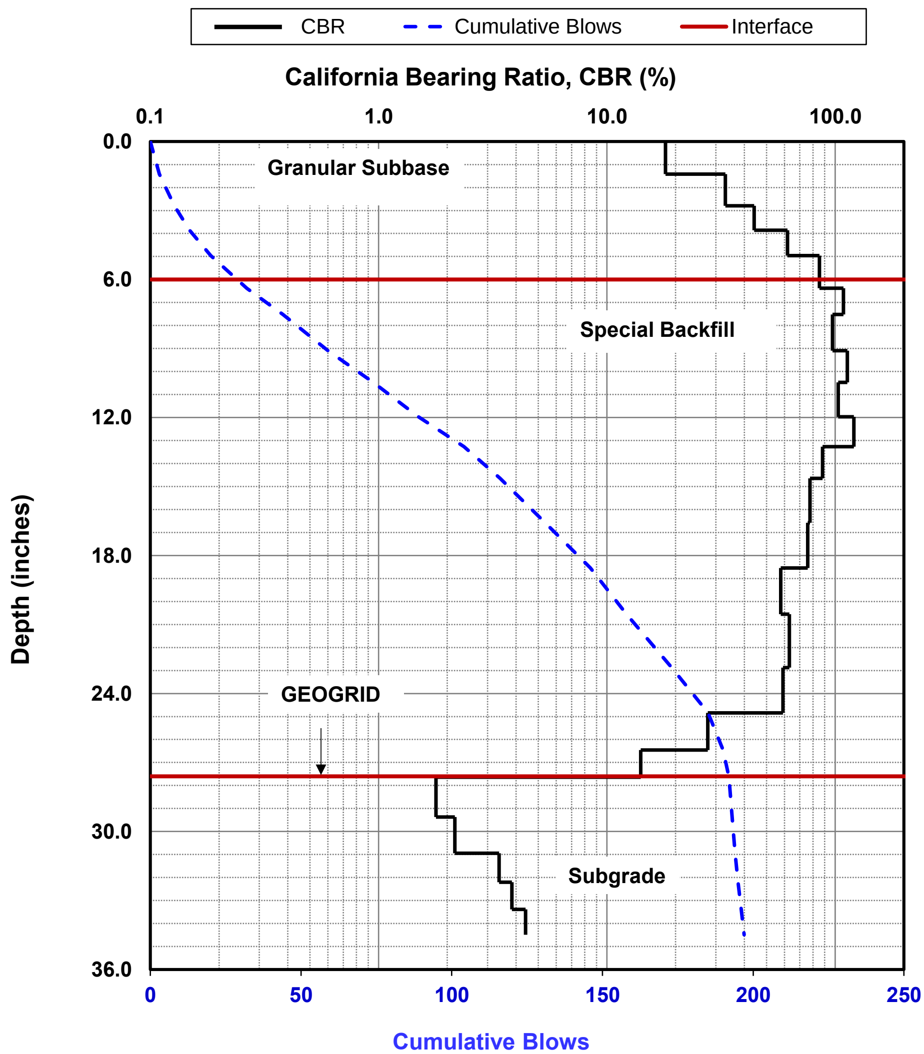
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2] Powell et al. (1986)

[3] Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name: Iowa DOT STIC

Project ID: SIA-00001

Location: Hwy 330 near Hwy 65 (Project #10)

ingios GEOTECHNICS

Date of Test	5/29/2018	Test ID	STIC_10__12_pt3	Operator	DW	ASTM	D6951
Latitude, N	41.8187140		Longitude, W	93.3065030		Elevation (ft)	892
Location	Hwy 330		Station	NA			
Comments	6 inch granaular subbase over 2ft special backfill over geogrid						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase + Sp. Backfill layer	3.6	69.2	38.4	9,104
Avg. Subgrade Layer	12.5	17.2	15.8	3,610
Ratio of Avg. Top/Bottom Layer	0.3	4.0	2.4	2.5
Std.Dev.Subbase+Sp. Backfill Layer	2.6	30.1	22.5	5,234
Std. Dev. Subgrade Layer	7.1	14.1	13.9	3,165

NOTES:

Subgrade is assumed as sandy clay.

[1] $CBR = 292/DPI^{1.12}$

[1] $CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

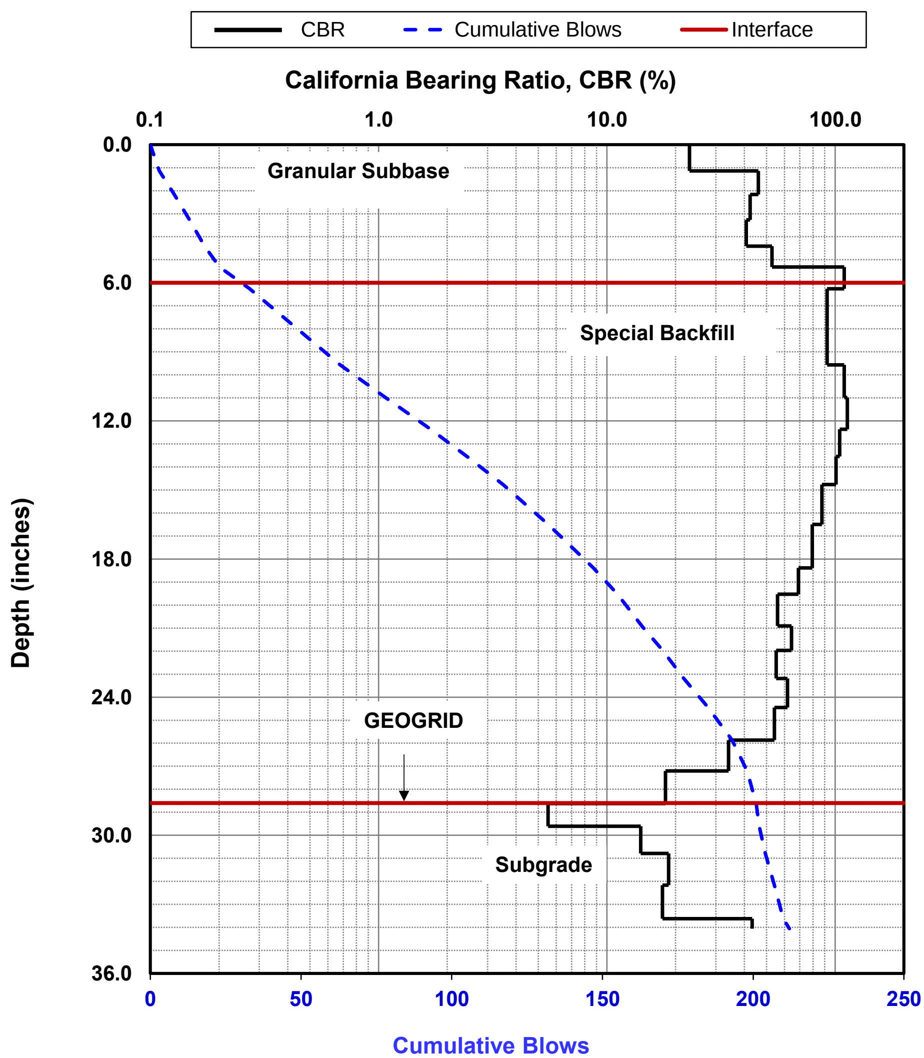
[2] $E\text{ (ksi)} = (17.6\ CBR^{0.64}) \times 0.1450377$

[3] $S_u\text{ (psf)} = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2] Powell et al. (1986)

[3] Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results	
Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 330 near Hwy 65 (Project #10)

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Date of Test	5/29/2018	Test ID	STIC_10__12_pt4	Operator	DW	ASTM	D6951
Latitude, N	41.8185080		Longitude, W	93.3062440		Elevation (ft)	894
Location	Hwy 330		Station	NA			
Comments	6 inch granaular subbase over 2ft special backfill over geogrid						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	S_{u-CBR}, Bearing Capacity (psf)
Avg. Subbase + Sp. Backfill layer	3.3	76.7	41.0	9,748
Avg. Subgrade Layer	13.8	15.4	14.7	3,355
Ratio of Avg. Top/Bottom Layer	0.2	5.0	2.8	2.9
Std.Dev.Subbase+Sp. Backfill Layer	3.9	35.7	25.2	5,871
Std. Dev. Subgrade Layer	4.0	5.8	7.9	1,762

NOTES:

Subgrade is assumed as sandy clay.

[1] $CBR = 292/DPI^{1.12}$

[1] $CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

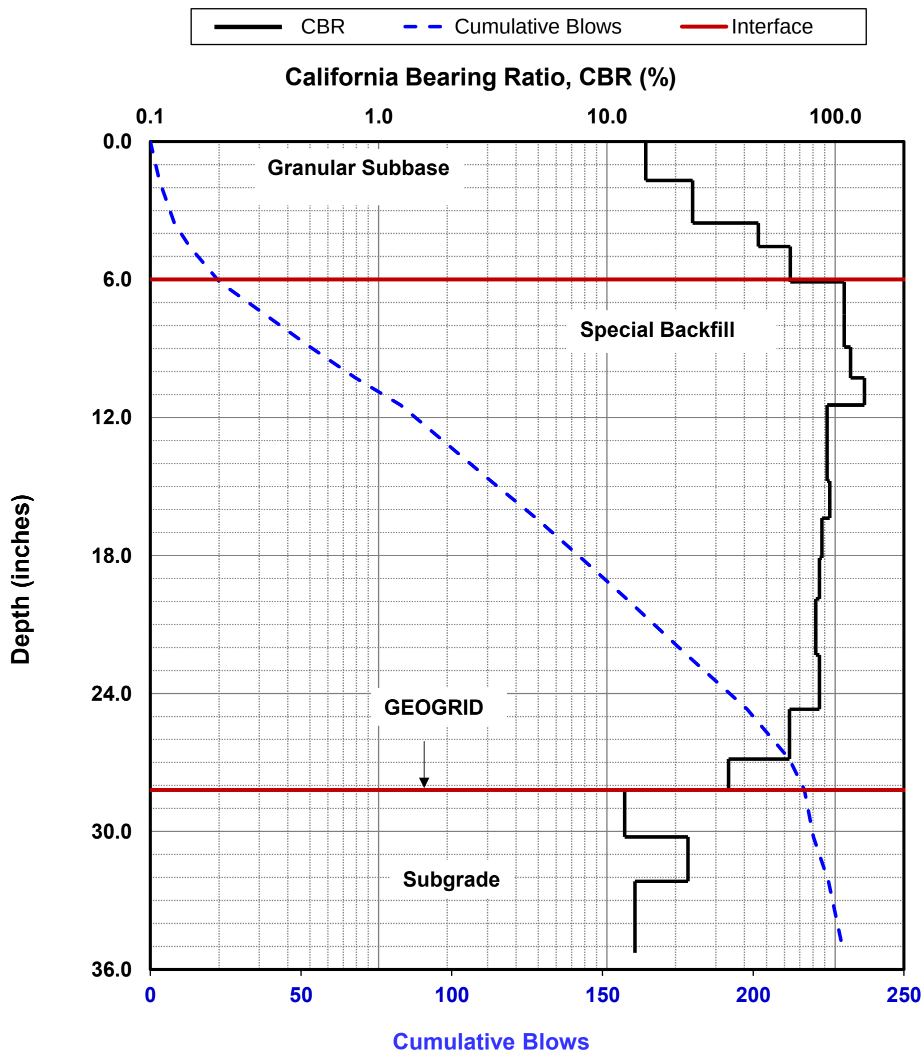
[2] $E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3] $S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2] Powell et al. (1986)

[3] Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 330 near Hwy 65 (Project #10)

Date of Test	5/29/2018	Test ID	STIC_10__12_pt5	Operator	DW	ASTM	D6951
Latitude, N	41.8184130	Longitude, W		93.3061140		Elevation (ft)	900
Location	Hwy 330	Station		NA			
Comments	6 inch granaular subbase over 2ft special backfill over geogrid						

Parameter	DPI (mm/blow)	CBR (%)	E_{CBR}, Elastic Modulus (ksi) (non stress-dependent)	$S_{u\text{-}CBR}$, Bearing Capacity (psf)
Avg. Subbase + Sp. Backfill layer	3.3	76.7	41.1	9,751
Avg. Subgrade Layer	13.1	16.3	15.2	3,489
Ratio of Avg. Top/Bottom Layer	0.3	4.7	2.7	2.8
Std.Dev.Subbase+Sp. Backfill Layer	2.7	30.7	22.9	5,311
Std. Dev. Subgrade Layer	3.0	3.4	5.6	1,230

NOTES:

Subgrade is assumed as sandy clay.

[1]$CBR = 292/DPI^{1.12}$

[1]$CBR = 1/(0.017019DPI)^2$

for CL soils with CBR < 10

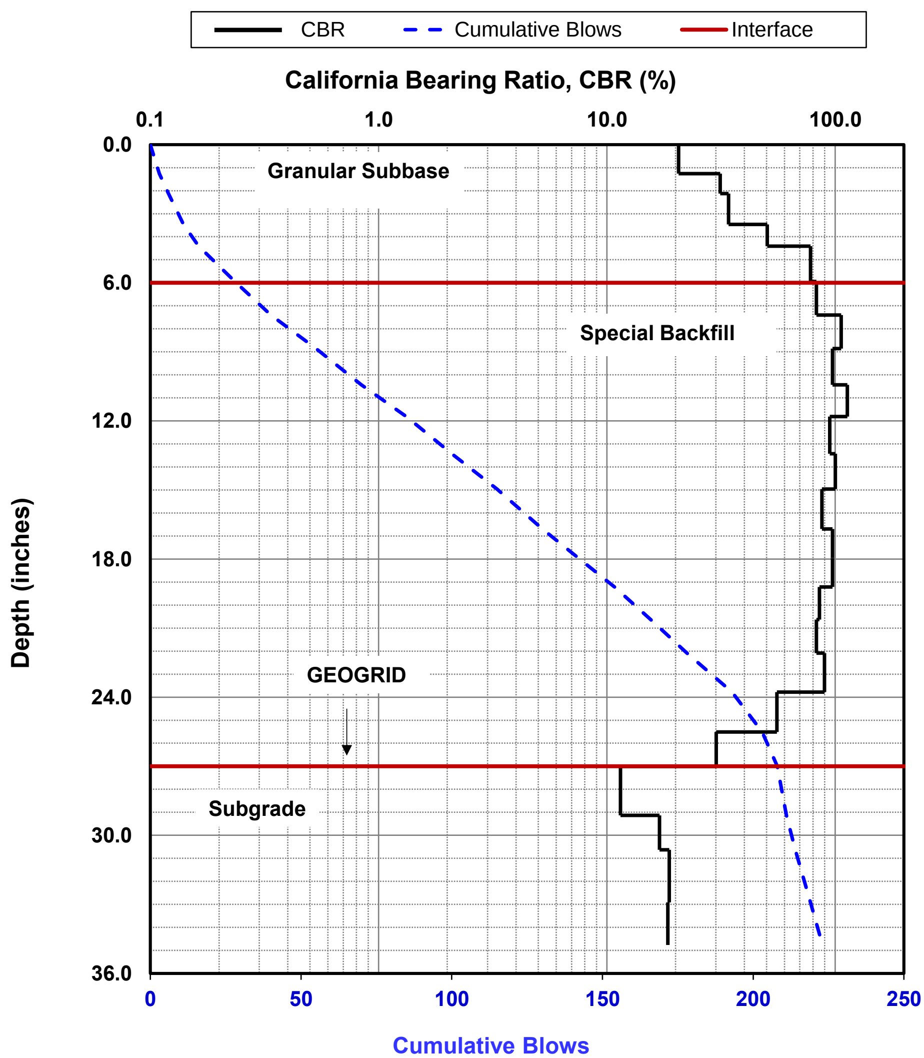
[2]$E\ (ksi) = (17.6\ CBR^{0.64}) \times 0.1450377$

[3]$S_u\ (psf) = (3.794 \times CBR^{0.664}) \times 144$

[1] ASTM D6951-03

[2]Powell et al. (1986)

[3]Portland Cement Assoc. (1955)



Dynamic Cone Penetrometer (DCP) Test Results

Project Name:	Iowa DOT STIC
Project ID:	SIA-00001
Location:	Hwy 330 near Hwy 65 (Project #10)

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