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Pavement Mechanistic-Empirical (ME) Design Verification using APLT Testing

Pavement foundation mechanistic design input values such as resilient modulus and modulus of subgrade reaction can now be directly measured and verified in-situ using the Automated Plate Load Test (APLT).

Background

FHWA considers implementation of mechanistic-empirical (ME) pavement design critical to improving out nation's highway systems. State-by-state verification and calibration of the underlying pavement foundation modulus is required to benefit from AASHTOWare Pavement ME Design capabilities. Yet, direct measurement or verification of in-situ M_r is not part of routine testing or the ME design calibration pro cess. The calibration efforts to-date have largely relied upon limited and time-consuming laboratory testing or adopting conservative values based on empiricism or historical values. ***To properly implement the advantages of the ME method the pavement community needs a means for determining M_r values in-situ.***

APLT Testing for In-Situ Determination of Resilient Modulus

Iowa DOT recently completed the STIC project titled "In situ Modulus Measurement Using Automated Plate Load Testing for State Wide Mechanistic-Empirical Design Calibration" utilizing Automated Plate Load Testing (APLT). Benefits of the APLT results were summed up as follows:

"The Iowa DOT has recognized the opportunity to greatly improve pavement performance by changing our construction requirements for pavement foundations to ensure they meet the minimum support values used in the design process. We have just completed a key first step by using APLT to conduct a state-wide field calibration study to develop the AASHTOWare Pavement ME Design input data needed for typical Iowa foundation layers. The results revealed significant variability in support values using our current specifications, sometimes much lower and other times higher than required. Our next step is to change our construction. We believe that once our specifications have been modernized by establishing requirements using currently available technologies we will see much improved pavement performance and reduced pavement maintenance." - Chris B. Brakke, P.E., Pavement Design & Pavement Management Engineer — Iowa Department of Transportation

Benefits of Field Verification using APLT

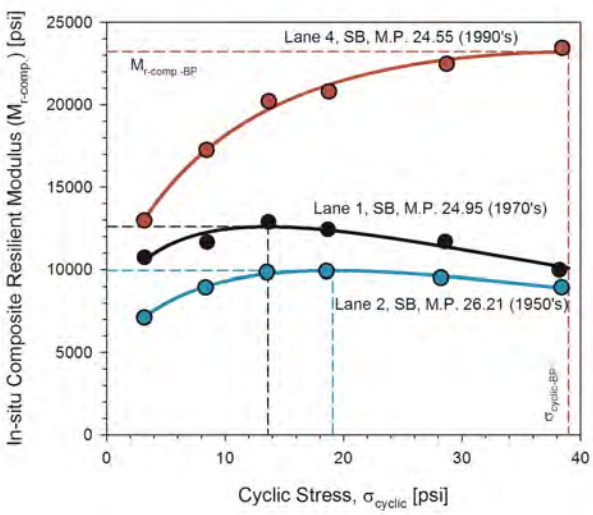
- Only method to provide direct measurement of design-modulus values, i.e., stress-dependent M_r or k-value.
- Better represents boundary conditions and stress states than laboratory testing.
- Higher reliability in the measured values – improved confidence in the values used in design.
- Highly repeatable and reproducible (no operator bias).
- Can determine stress-dependent layered Mr values on a layered foundation from a single test in less than 30 minutes.
- Proven technology used on over 80 projects across the U.S. and Latin America.

Figure 1. APLT setup for stress-dependent cyclic M_r testing with Ingios layered analysis sensor kit on Highway project in Iowa.

Table 1. Summary of pavement foundation layer design input parameters used in highway pavement desing procedures.

Design Guide	Rigid Pavement	Flexible Pavement
AASHTO 1972	Mod. of subgrade reaction, k	Soil support value Structural layer coefficient
AASHTO 1986	k for subgrade, composite k if base layer is present	Resilient modulus (M_r) for subgrade and elastic modulus (E) for base
AASHTO 1993		
AASHTO 2008, 2015	M_r (stress-dependent constitutive model) for subgrade and base	
PCA 1984	k for subgrade, composite k if base layer is present	N/A
Asphalt Institute	N/A	Resilient modulus (M_r) for subgrade

Figure 2. Stress-dependent composite M_r values from Interstate 294 Central Tri-State Corridor project in Illinois with "universal" model input parameters for ME deisgn.



AASHTO Universal Modeling Parameters					
TEST POINT	K_1^*	K_2^*	K_3^*	$M_{r\text{-comp-BP}}$ [psi]	$\sigma_{cyclic\text{-BP}}$ [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	1,072	0.523	-1.62	23,239	39.0

Figure 3. Static plate load test setup with 30 in. diameter loading plate, per ASTM and AASHTO testing standards.

APLT System and Capabilities

APLT is a state-of-the-art testing system used to determine a variety of in situ mechanistic parameter values for pavement and pavement foundation layers. APLT uses state-of-the-art control and data collection systems combined with advanced stress control capability to simultaneously measure stress-dependent permanent deformation, stress-dependent elastic and resilient modulus, and load-pulse and frequency-dependent responses (essential for visco-elastic materials).

The APLT is used to perform static Plate Load Tests (e.g., AASHTO T222) and cyclic/repetitive plate load tests (e.g., ASTM 1195) with up to 10,000 cycles test (2+ hrs) 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, unlike other testing methods (e.g., light/falling weight deflectometer) that only apply a few cycles/dynamic load pulses on the foundation materials, APLT modulus measurements better represent the true field modulus value.

The APLT system can be used to provide confining and deviator stress-dependent constitutive models used in the ME design (example results in Figure 2). The results provide 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. Further, the cyclic APLT performed using Ingios layered analysis sensor kit (Figure 1) is the only such method that can be used to measure stress-dependent layered Mr values directly in situ (i.e., base/sub-base over subgrade). 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.

> *" With the APLT technology, we now have actual measurements of how well the subgrade will support the pavement, so we can avoid over design."* - Steve Gillen, PE — formerly IL Tollway Materials Manager

Additional Resources

Please contact us at **info@ingios.com** if you are interested in knowing more information about how to setup a mechanistic field verification or ME calibration program for your state/agency.