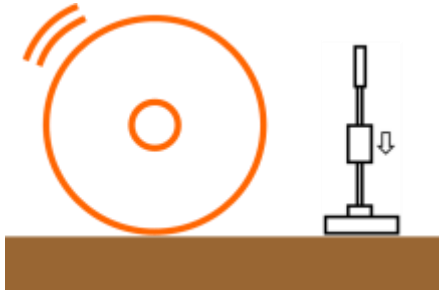
Pavement Evaluation 2019
VIRGINIA TECH
September 17-20, 2019
Roanoke, Virginia

Compaction Quality Assurance of Geomaterials Using the Light Weight Deflectometer



By

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LWD Providers

Dynatest, Zorn, Olson

Material Providers

Luck Stone

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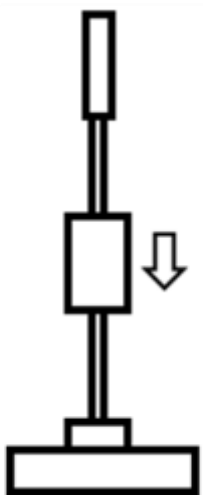
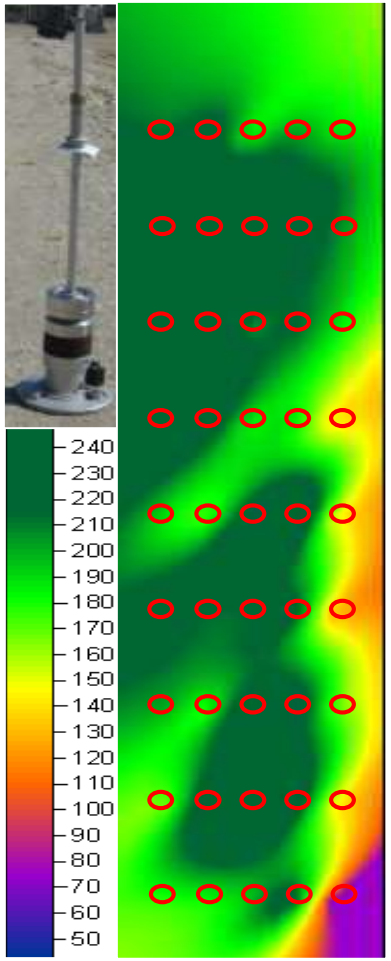
Introduction

- First Light Weight Deflectometers (LWD) date back to the early 1970's
- Specifically designed for unbound or lightly bounded pavement layers
- In-situ tool for measuring Surface Stiffness



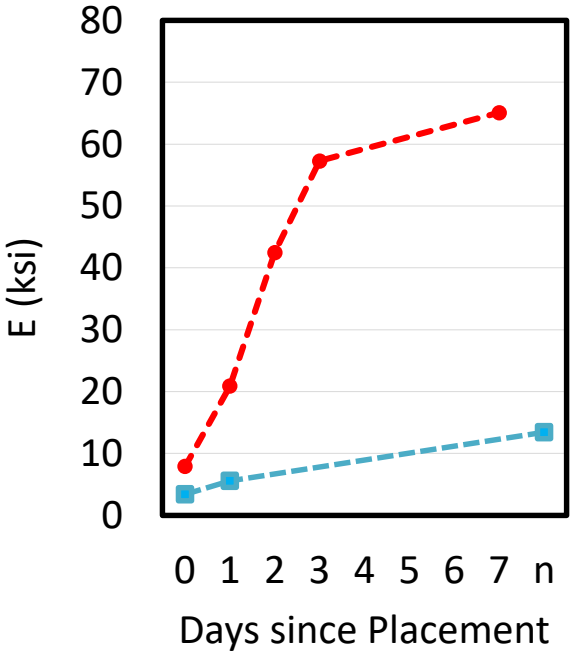
What can be determined from the Dynatest LWD?

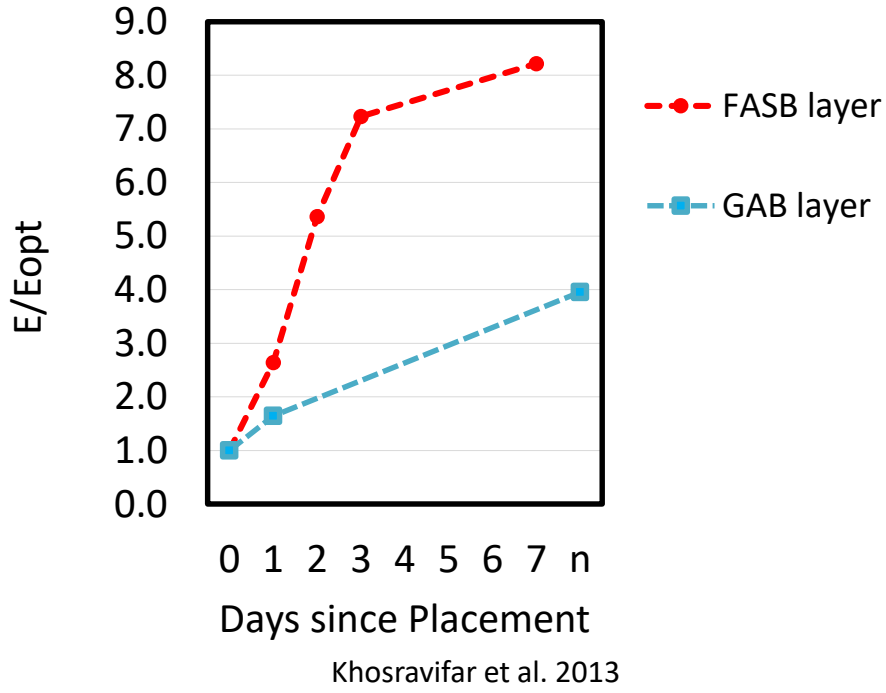
- Surface Modulus
- Determine the Non-linearity
- Calculate the modulus of 2 layers
  - with Dual Plate System (DPS) and additional geophones
- Calculate overlay
- Determine layer thickness
- Quality Control/Quality Assurance (QC/QA)



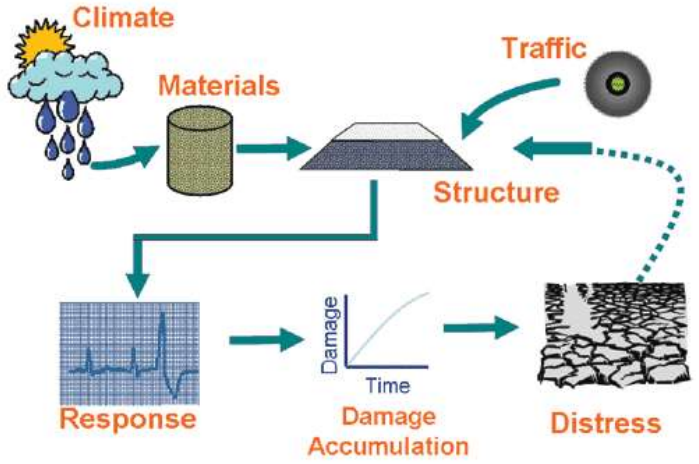
Why LWD for Compaction QA

- Reflects engineering properties of material
- Avoid nuclear QC/QA methods
- Better testing of stabilized materials





Khosravifar et al. 2013



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Key Issues for LWD-based Compaction QA

Stress effects

- Confining stress stiffening effects on M_R
- Deviator stress softening effects on M_R

Moisture effects

- Compaction moisture effects on M_R
- Drying profile history (limited time duration)
- Drying (post-compaction moisture) effects on M_R (stiffening)

Layered system

- Subgrade only
- Stiff base over soft subgrade
- Stiff base over stiff subgrade

Individual LWD device details

- Plate diameter
- Plate rigidity
- Contact area stress distribution
- Loading rate
- Deflection measurement type and location(s)

Moisture measurement devices

- Reliability
- Speed in giving the results

What is an Ideal Modulus-Based Specification

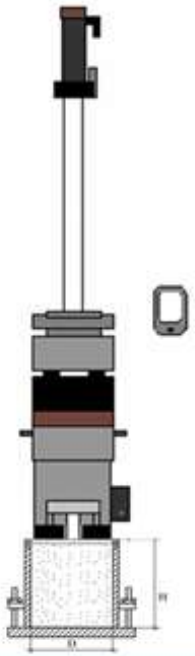
1) Smooth transition from density-based methods to modulus-based QC/QA
2) Applicability to a variety of geomaterials
3) Cost efficient for organizational implementation
4) Based on field moisture and modulus measurements immediately after placement
5) Easy-to-determine target modulus values

FHWA Transportation Pooled Fund Study (TPF 5-285)

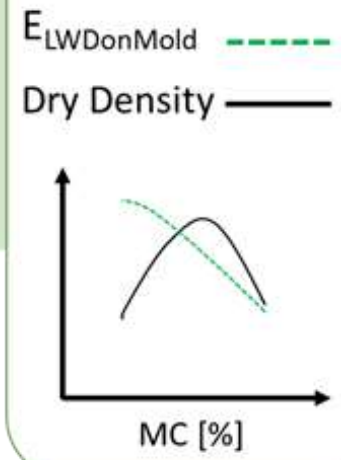
LWD testing on Proctor molds

FHWA TPF 5-285 LWD - Proctor Method

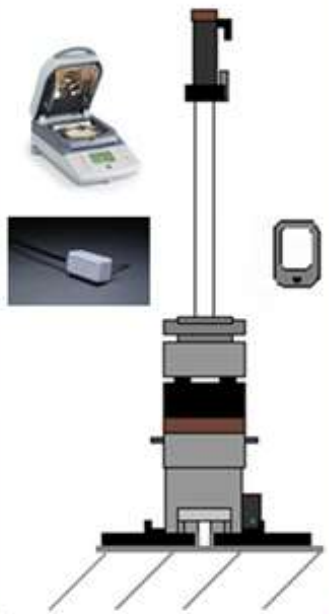
E_{LWD_Mold} at multiple MC and P/P_a



Establish E_{LWD_Target} = f(Structure, MC, P/P_a)



Measure:
- E_{LWD_Field}
- MC



Compaction Criteria:

$$\frac{E_{LWD\_Field}}{E_{LWD\_Target}} \geq 1$$

PWL $\geq$ 80%

MC = OMC $\pm$ Δ

Limit post compaction QA to two hours

Lab **Field**

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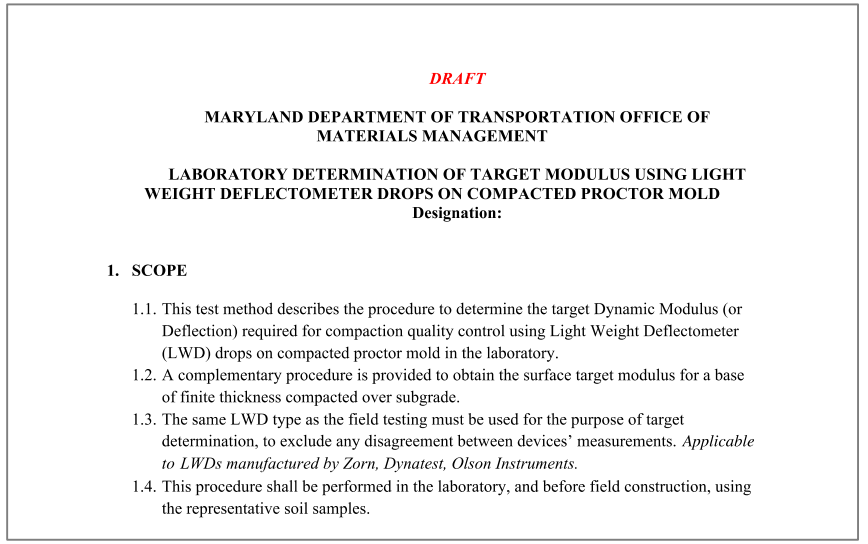
FHWA TPF 5-285 LWD - Proctor Method

1- Laboratory Determination of Target Modulus Using LWD drops on Compacted Proctor Mold:

- Sample preparation
- Testing procedure
- Determination of optimum MC
- Determination of target E_{LWD_Target}

2- Compaction Quality Control Using LWD

- In-situ LWD testing procedure
- In-situ LWD testing frequency
- In situ MC testing
- Adjustment of E_{LWD_Target} for two-layer systems
- Evaluation of in situ MC for acceptance
- Evaluation of $E_{LWD\_Field}/E_{LWD\_Target}$ for acceptance



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MARYLAND DEPARTMENT OF TRANSPORTATION OFFICE OF MATERIALS MANAGEMENT

LABORATORY DETERMINATION OF TARGET MODULUS USING LIGHT WEIGHT DEFLECTOMETER DROPS ON COMPACTED PROCTOR MOLD
Designation:

1. SCOPE

1.1. This test method describes the procedure to determine the target Dynamic Modulus (or Deflection) required for compaction quality control using Light Weight Deflectometer (LWD) drops on compacted proctor mold in the laboratory.
1.2. A complementary procedure is provided to obtain the surface target modulus for a base of finite thickness compacted over subgrade.
1.3. The same LWD type as the field testing must be used for the purpose of target determination, to exclude any disagreement between devices' measurements. *Applicable to LWDs manufactured by Zorn, Dynatest, Olson Instruments.*
1.4. This procedure shall be performed in the laboratory, and before field construction, using the representative soil samples.

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MARYLAND DEPARTMENT OF TRANSPORTATION OFFICE OF MATERIALS MANAGEMENT

COMPACTION QUALITY CONTROL USING LIGHT WEIGHT DEFLECTOMETER (LWD)
Designation:

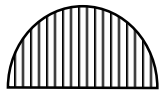
1. SCOPE

1.1. This test method describes the procedure to assess the compaction quality of a road base or subgrade by comparing the field's surface moduli to the lab determined target moduli using a Light Weight Deflectometer (LWD).
1.2. The same LWD type in terms of brand name, buffer stiffness, and deflection measurement location (on top of the plate or on top of the soil layer) as the lab target modulus testing must be used during the field testing, to exclude any disagreement between devices' measurements. *Applicable to LWDs manufactured by Zorn, Dynatest, Olson Instruments.*
1.3. This procedure shall be performed right after compaction to eliminate the effect of

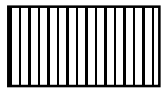
LWD TESTING IN FIELD (SEMI-INFINITE)

$$E_o = \frac{f(1-v^2)\sigma_o r_o}{d_o}$$ + Determination of Moisture Content

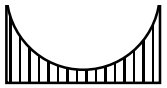
E_o= Surface LWD modulus
f=Stress Distribution Factor
v= Poisson's Ratio
σ_o=Peak Stress Under the Plate
r_o = radius of the LWD plate
d_o=Peak Center Deflection



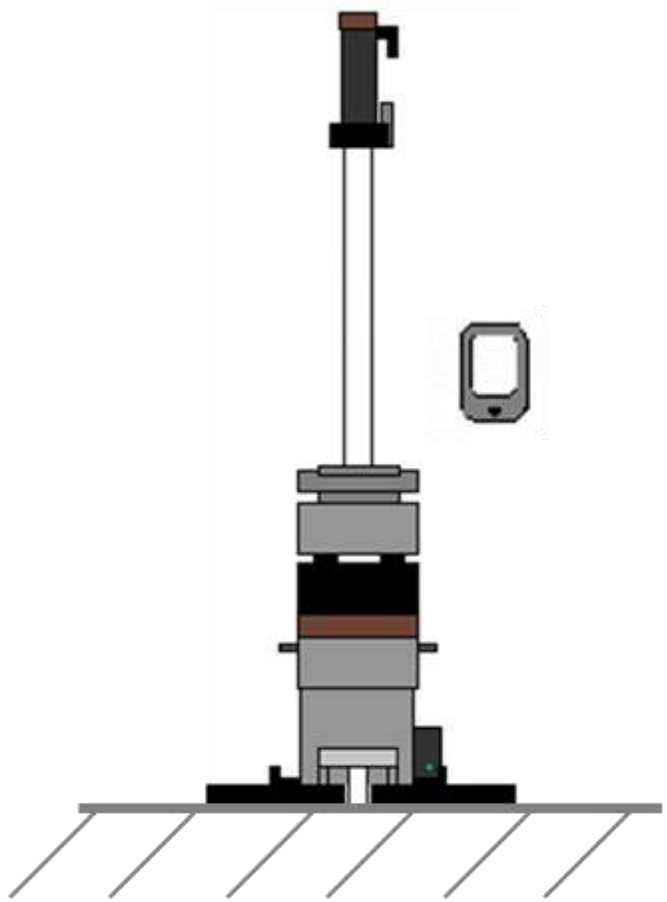
f=Parabolic– for flexible soil-plate system *f=8/3*



f= Uniform– for semi-flexible soil-plate *f=2*



f= Inverse Parabolic– for rigid soil-plate system *f=pi/2*



Target Modulus for 1-Layer System

$$E = (1 - \frac{2v^2}{1-v})\frac{4H}{\pi D^2}k_s \qquad k_s = \left|\frac{F_{peak}}{w_{peak}}\right|$$

Drop height: Adjusted to Achieve the **SAME** Pressure as in Field

~4.16 in for 95.25 kPa

Condition: Confined compression

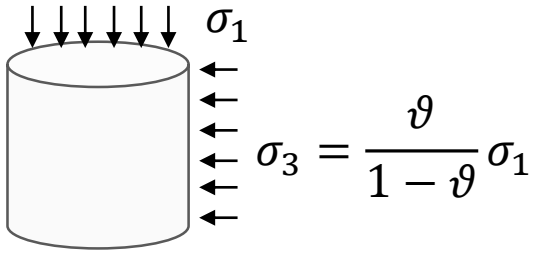
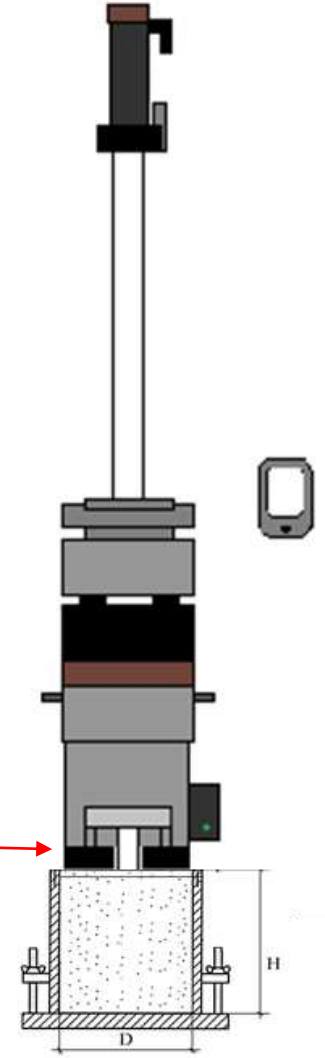


	Plate size	P/Pa	P	Force	Drop Height
	[inch]	-	[kPa]	[kN]	[inch]
Field LWD	12	0.94	95.25	6.73	33.00
Lab LWD	6	0.94	95.25	1.68	4.16

Plate Diameter (D)= 150 mm



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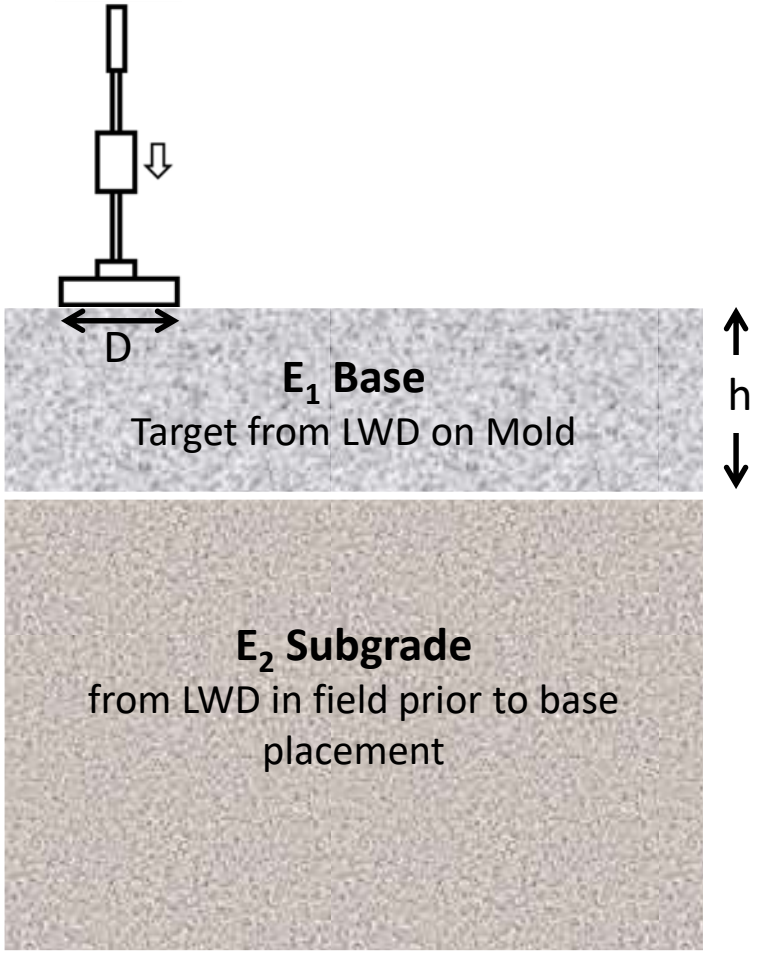
Corrected Target Modulus for 2-Layer System



$$E_{surface-Corrected\ Target} = 1/\left\{\frac{1}{E_2\sqrt{1+\left(\frac{h}{r_0}\sqrt[3]{\frac{E_1}{E_2}}\right)^2}} + \frac{\left[1-\frac{1}{\sqrt{1+\left(\frac{h}{r_0}\right)^2}}\right]}{E_1}\right\}$$

in which:

- E_1 = Target modulus of the top layer (GAB, base, etc.)→ from LWD on Mold
- E_2 = surface modulus of the underlying layer (subgrade, fill, subbase, etc.)
- h = thickness of the top layer
- r_0 = D/2= radius of the LWD plate

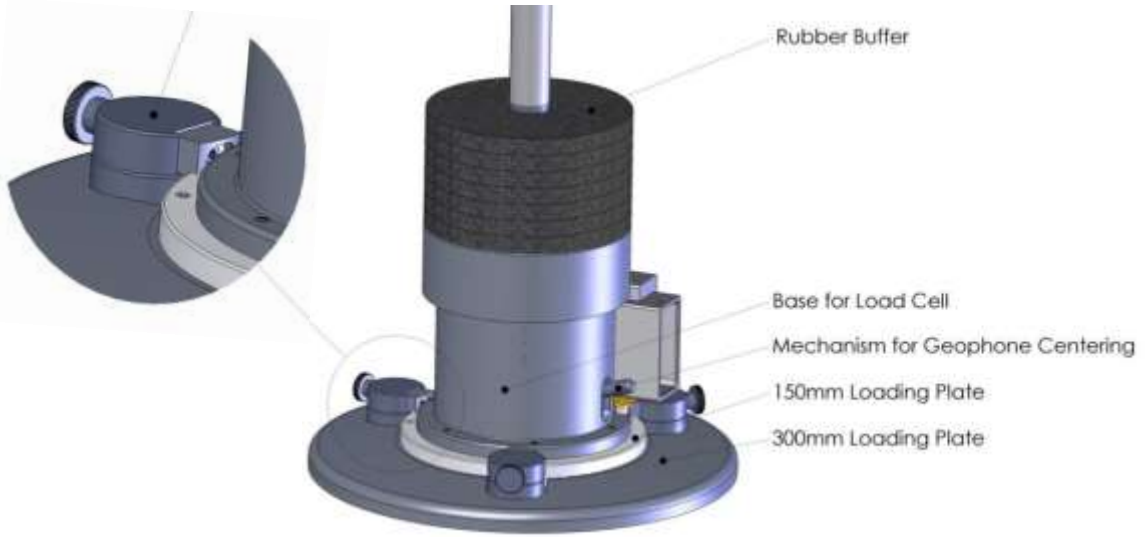
Dynatest LWD and App

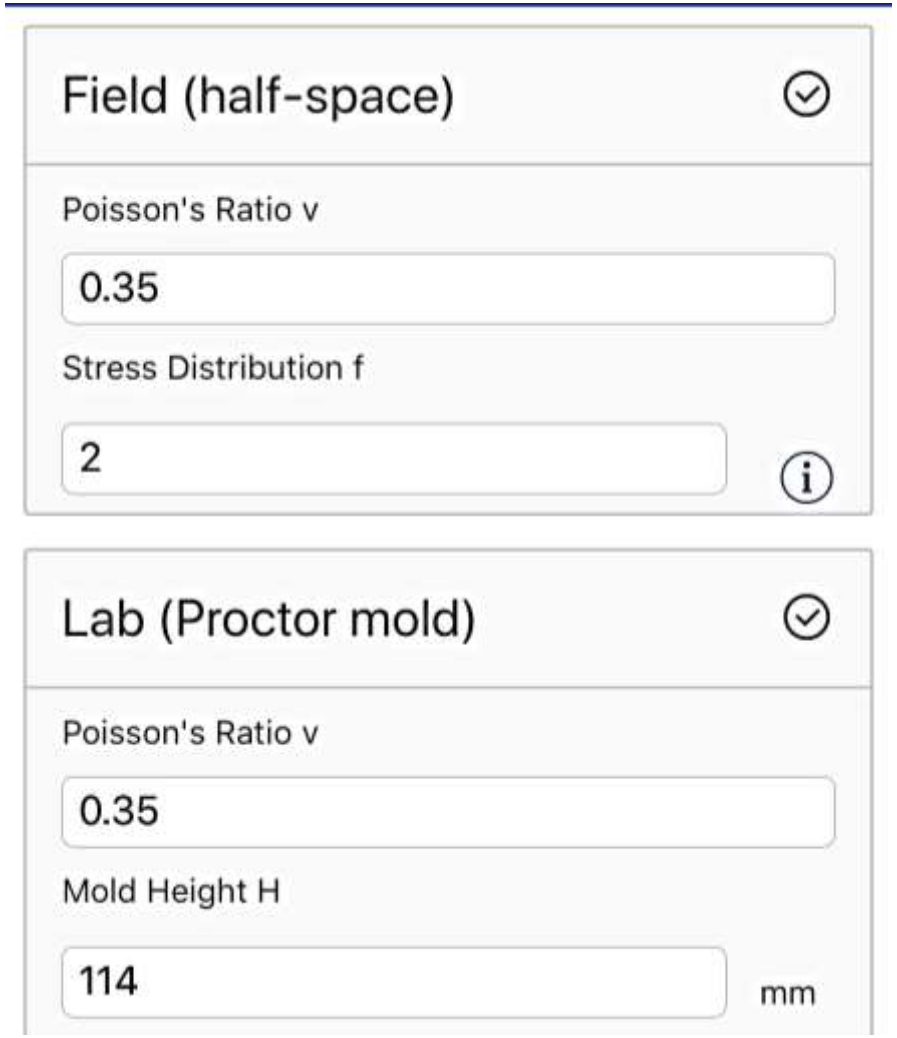
Download on the App Store

GET IT ON Google Play

Easy setting of the desired drop height
Movable release handle
Laser engraved scale on the shaft

Easy Switch between Plate Sizes w DPS
6 in Diameter for Lab
12 in Diameter for Field





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Dynatest LWD and App

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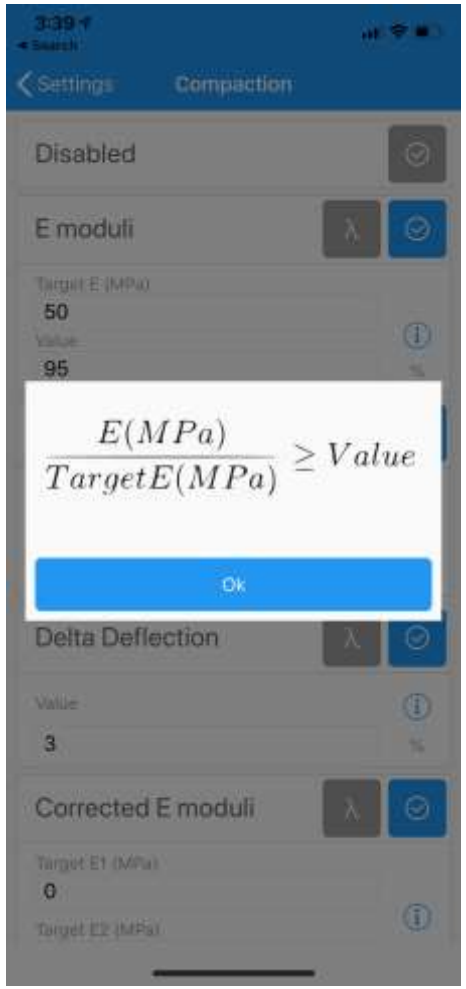

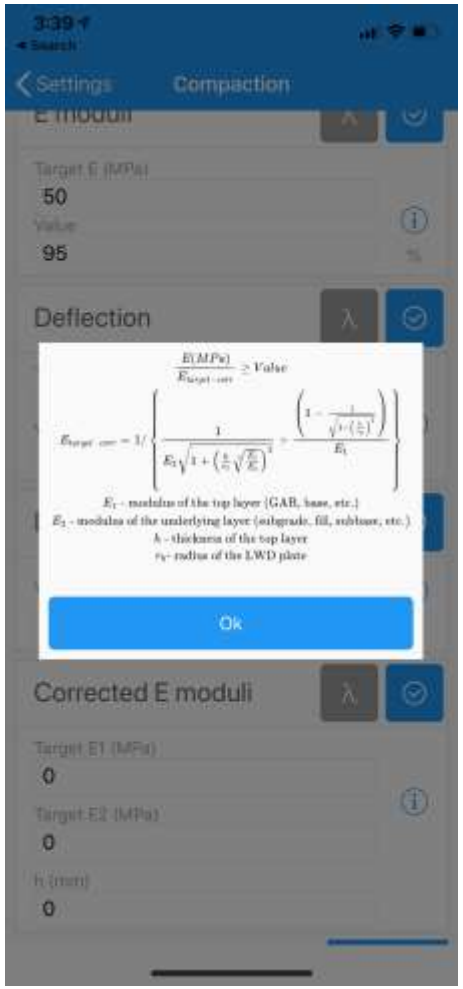

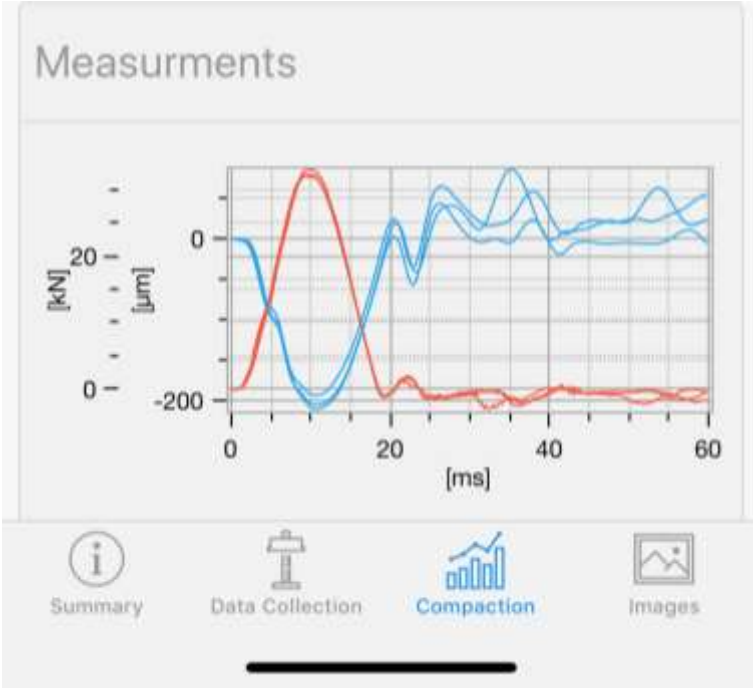

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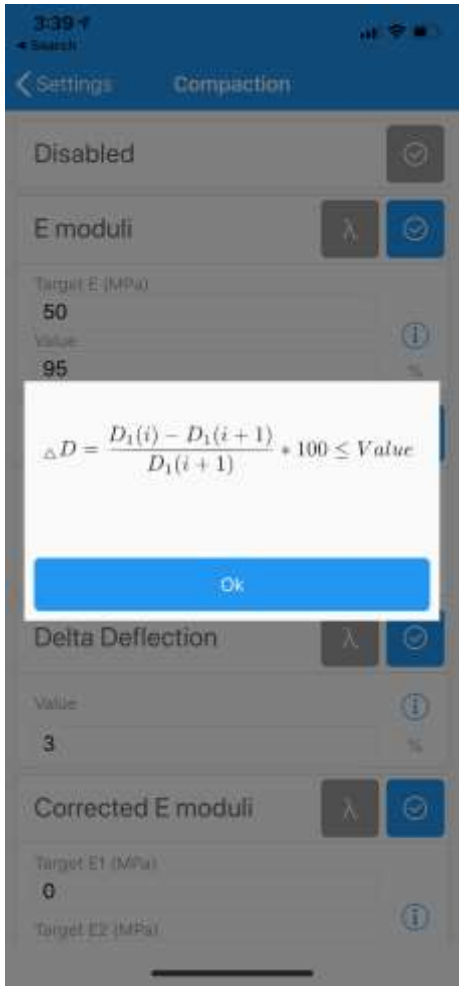

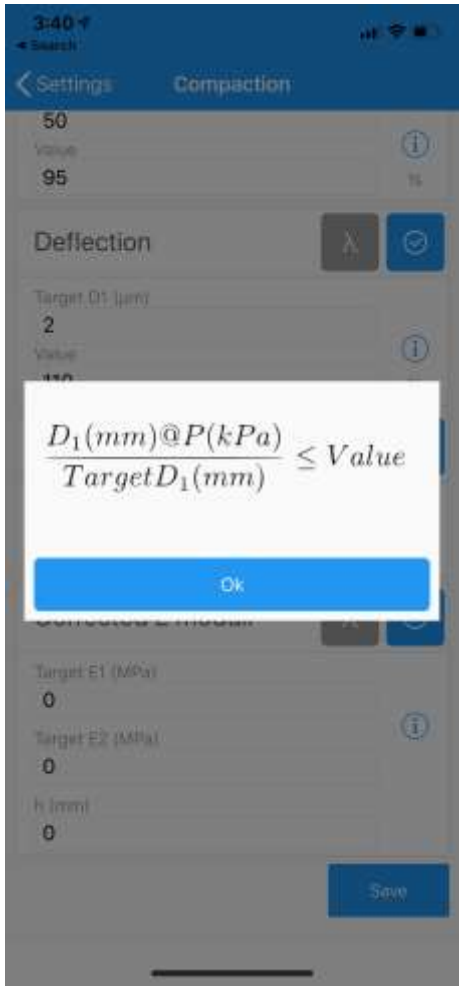

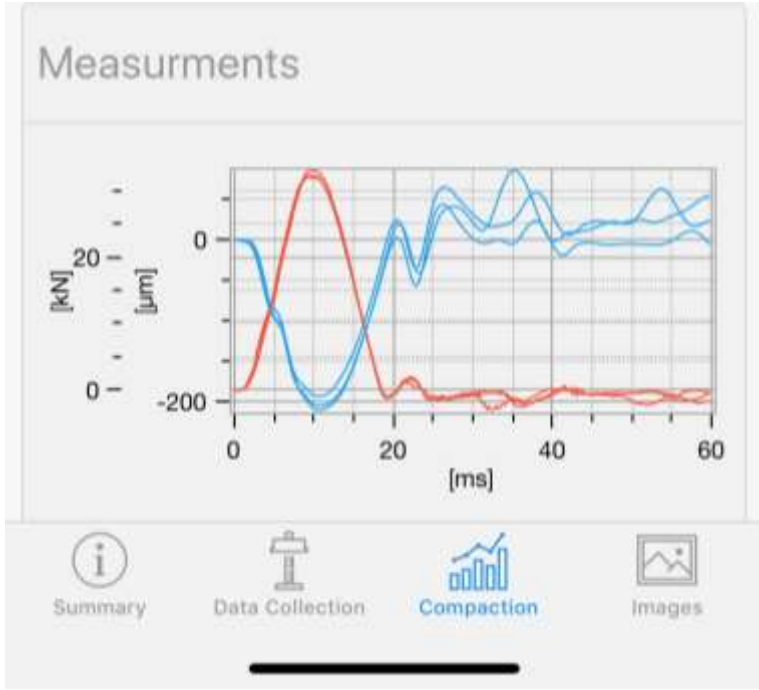

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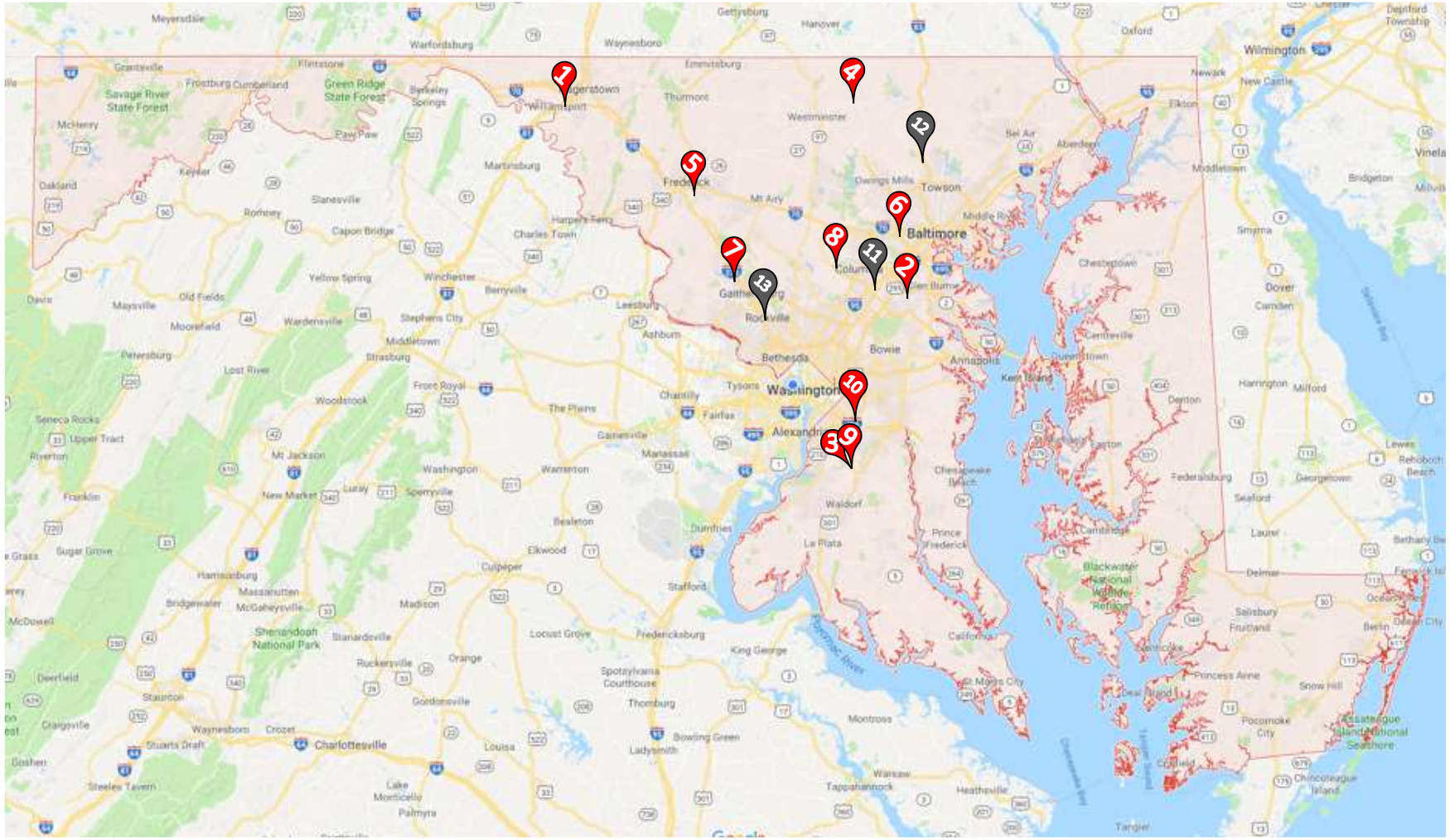
Evaluated sites– TPF 5-285

	Location	Soil Type	AASHTO Classification	Unified Classification	
1	**Virginia**	Subgrade	A-3	SP-SM	Poorly graded sand with silt
2	**Maryland**	MD5 Waste contaminated embankment	A-1-a	SW	Well graded sand with gravel
3		MD5 Subgrade	A-2-7	SP	Poorly graded sand with gravel
4		MD337, Deep GAB	A-2-7	GW-GM	Well graded gravel with silt and sand
5		MD404 sand overlaying Subgrade	A-2-7	SP	Poorly graded sand
6		MD404 Subgrade	A-2-6	SP	Poorly graded sand
7		MD404 GAB	A-2-7	GP-GM	Poorly graded gravel with silt and sand
8	**New York**	Embankment	A-3	SP	Poorly graded sand
9	**Indiana**	Cement modified Subgrade	A-2-4	SW	Well graded sand with gravel
10		Virgin Subgrade	A-2-4	SW-SM	Well graded sand with silt and gravel
11		GAB	A-1-a	GW	Well graded gravel with sand
12	**Missouri**	Subgrade	A-3	SP	Poorly graded sand with gravel
13		Base	A-3	GW	Well graded gravel with sand
14	**Florida**	Subgrade	A-2-7	SP	Poorly graded sand
15		Base	A-3	SP	Poorly graded gravel with sand

Evaluated sites- Maryland Follow-up Study



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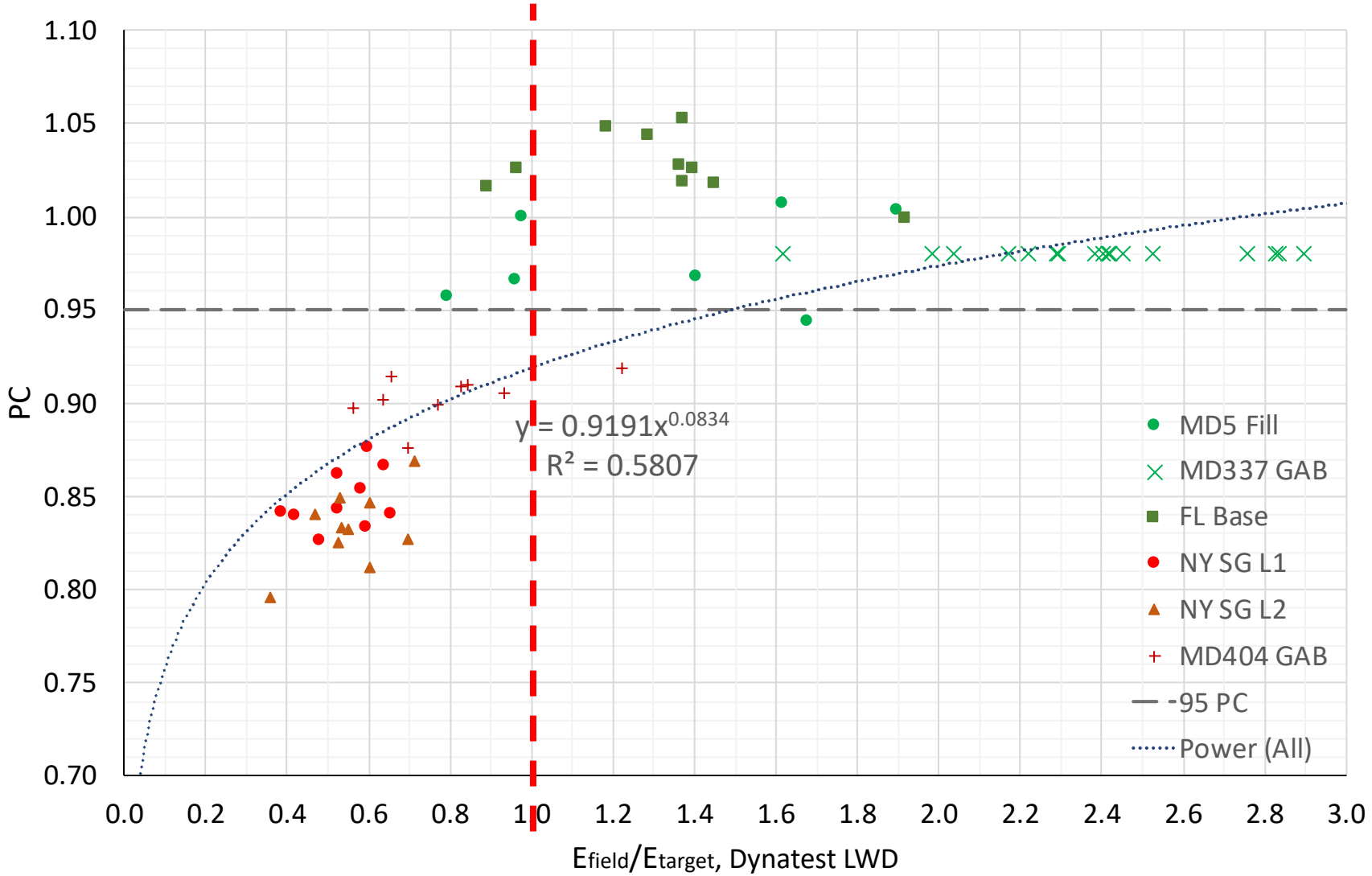
LWD based Compaction QA Results

Pooled fund Dynatest LWD



f factor= 8/3

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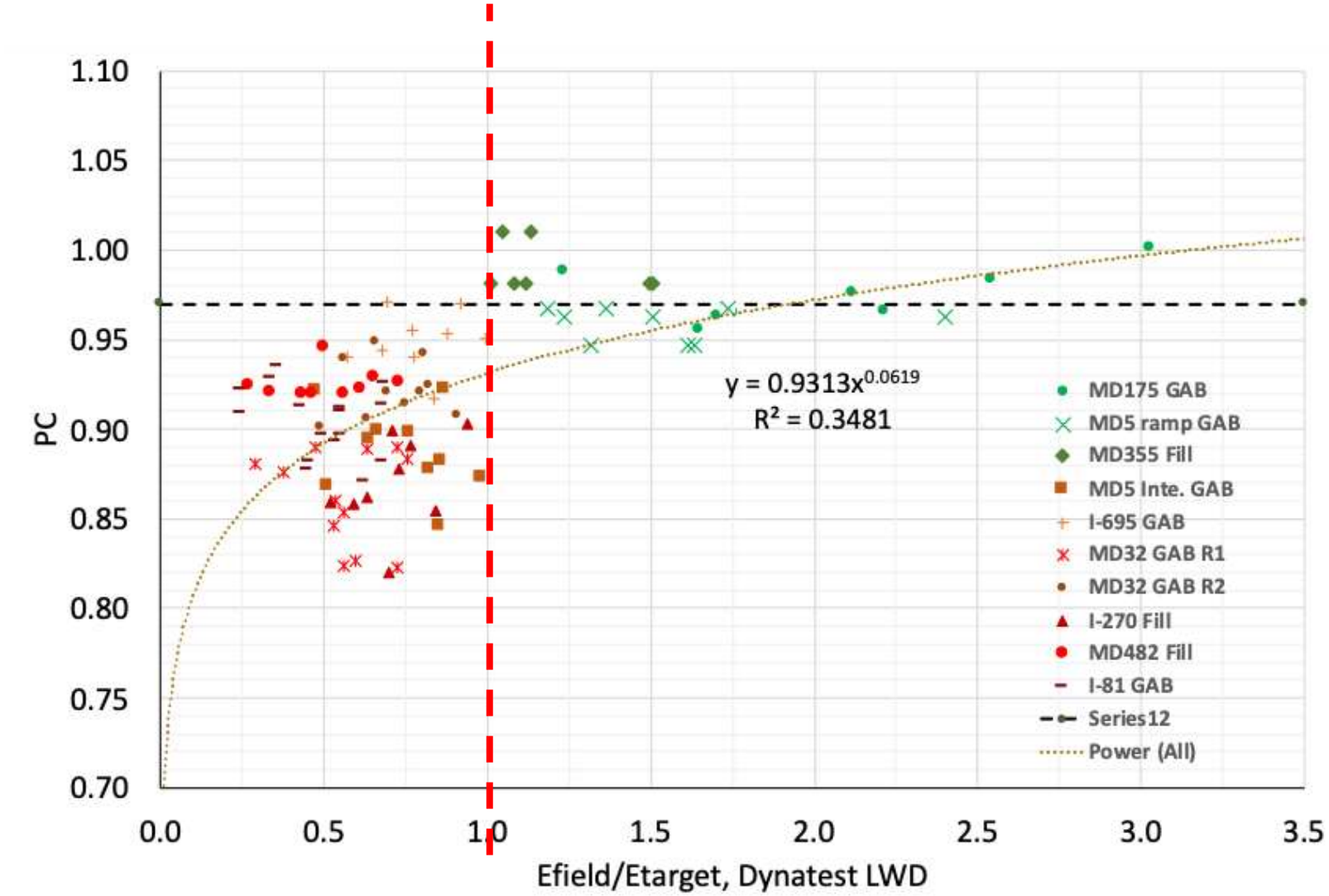
LWD based Compaction QA Results

MDSHA follow-up Study



f factor= 8/3

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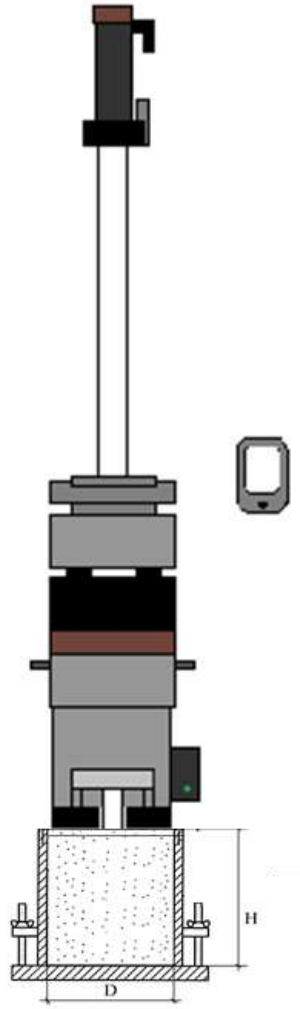
FHWA TPF 5-285 LWD - Proctor Method

- Target Modulus defined using LWD testing on Proctor Mold
- Uses existing contractors/agency equipment
- Accounts for moisture variation
- Accounts for stress levels
- Accounts for pavement structure
- Bridges the gap between QC and Design
- Simple and requires some degree of expertise
- The Compaction Module in the Dynatest® app makes the process easy



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