Methylene Blue Test of Soil Properties:
A Rapid and Accurate Field Test

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Questions

- What is “Methylene Blue”?
- Has it been used as a soil test?
- Are there standard specifications for using “Methylene Blue”?
- What equipment is needed to make a measurement of “Methylene Blue” content?

Questions

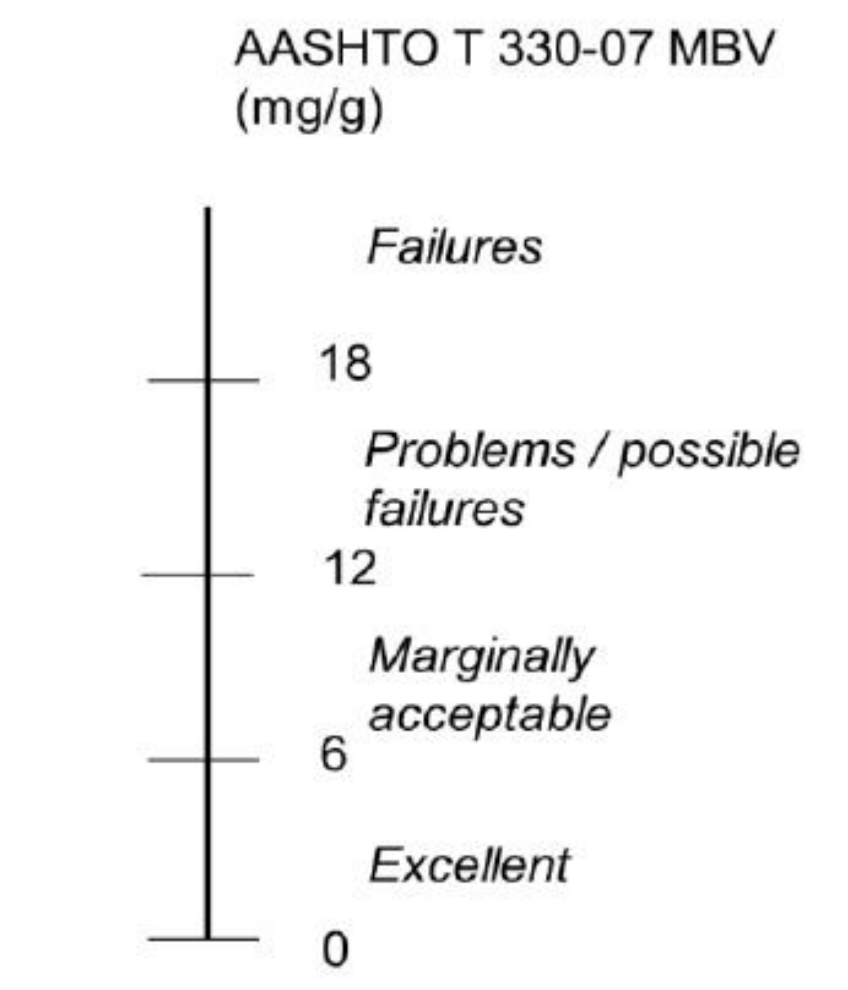
- What is a Per-co-meter?
- What can you measure with it?
- How can you use a “Methylene Blue” test together with a “Percometer” test?

Questions

- Methylene Blue is a large organic molecule that attaches to the surface of a soil particle.
- The amount of Methylene Blue that is adsorbed by soil measures the specific surface area of that soil.

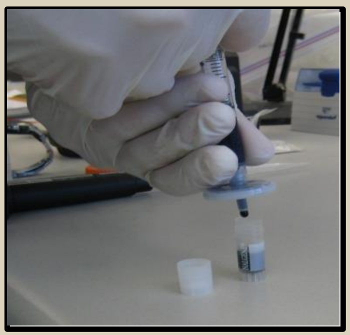
Base Course Aggregate

AASHTO T 330-07 Methylene Blue Scale



Methylene Blue Equipment

Grace Methylene Blue Test



Weigh 20g of sample***and 30g MB solution. Mix them and shake for 5 min.

Take solution into syringe that has 2 micrometer filter.

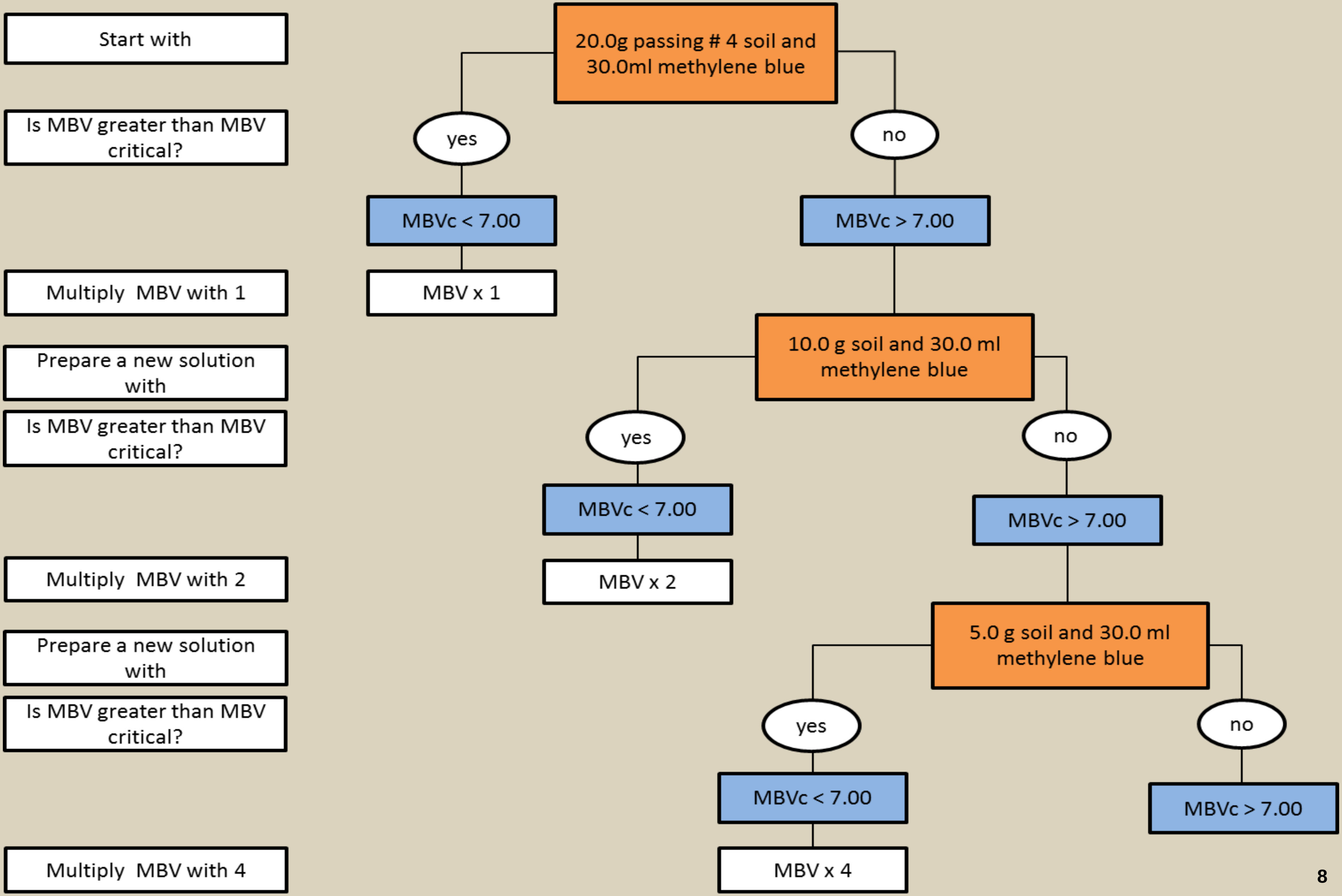
Replace the plunger and push solution to filter into a 1 mL plastic tube.

Dilute the 130 mL aliquot with distilled water to accurately total 45 g.

Fill the glass tube with the diluted solution and place in the colorimeter.

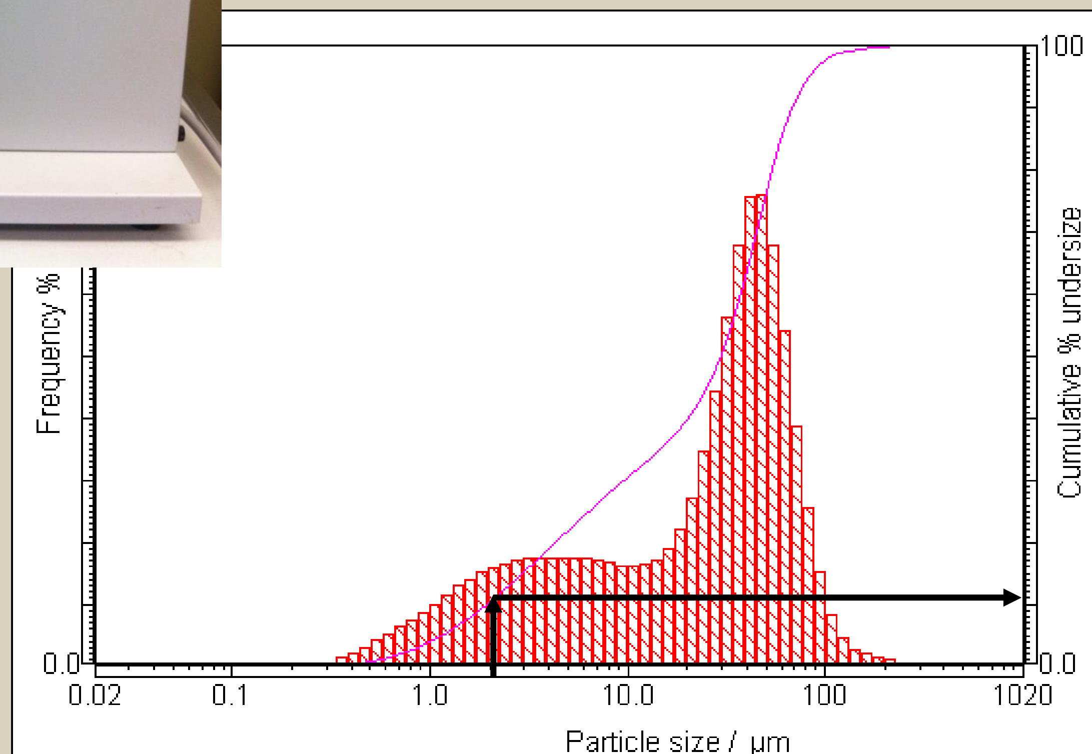
Place cover over the glass tube and take a reading. MB Reading will display in couple seconds.

Determine the percent clay based on MB value from the C-shaped figure.


Start with
Is MBV greater than MBV critical?
Multiply MBV with 1
Prepare a new solution with
Is MBV greater than MBV critical?
Multiply MBV with 2
Prepare a new solution with
Is MBV greater than MBV critical?
Multiply MBV with 4
20.0g passing # 4 soil and 30.0ml methylene blue
yes
no
MBVc < 7.00
MBVc > 7.00
MBV x 1
10.0 g soil and 30.0 ml methylene blue
yes
no
MBVc < 7.00
MBVc > 7.00
MBV x 2
5.0 g soil and 30.0 ml methylene blue
yes
no
MBVc < 7.00
MBVc > 7.00
MBV x 4

HORIBA Particle Size Distribution Analyzer

- Particle size distribution curve of passing No. 200 sieve
- Total measurement time is less than 10 min



- Typical test result of a soil sample
- Determine size of 2 µm particle

What is pfc?

Percent passing
2 micrometer

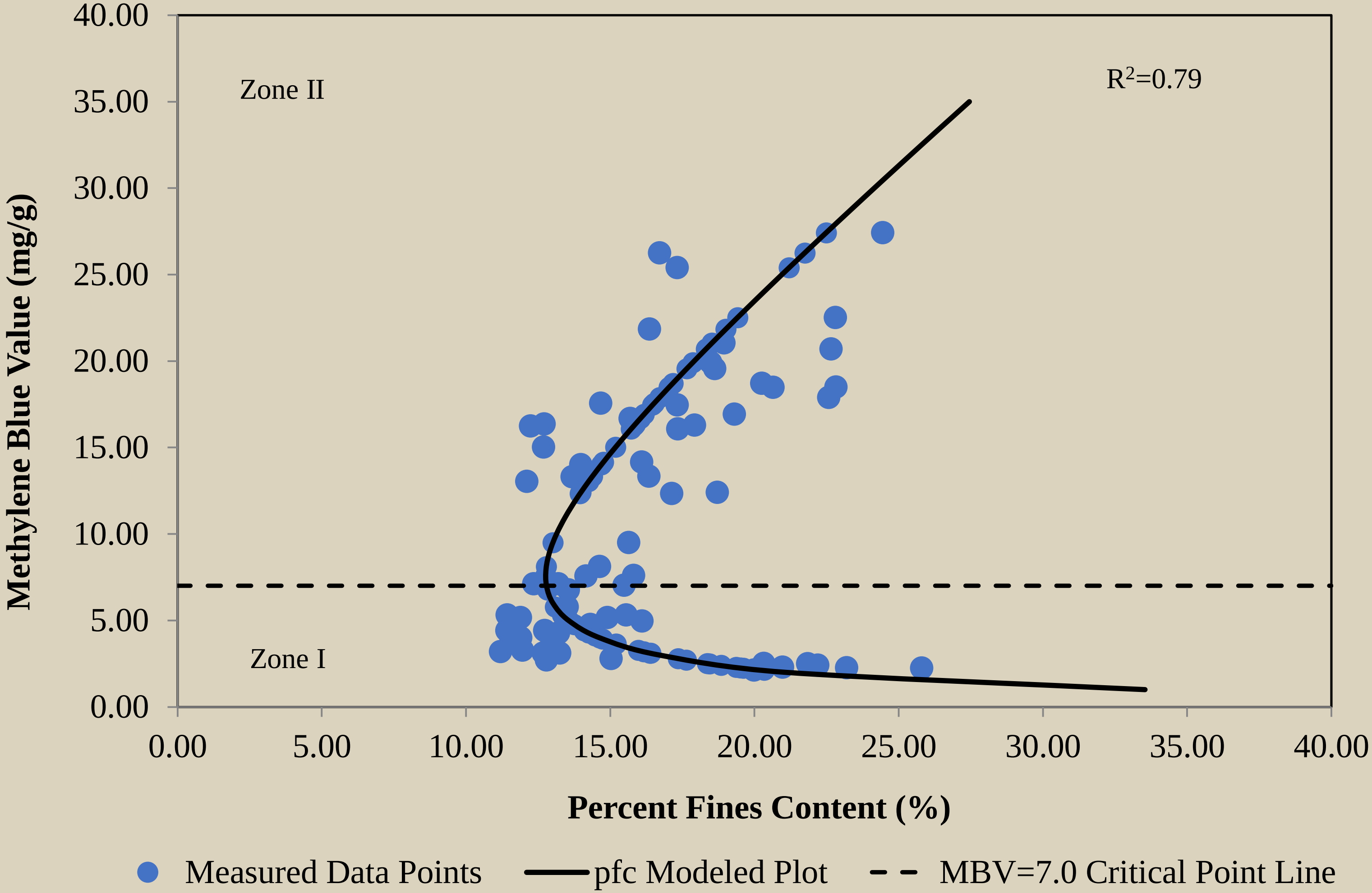
percent
fines
content

$$pfc = \frac{-2\mu m}{-\#200} \times 100$$

Percent passing
No.200 sieve

<u>P</u>ercent <u>F</u>ines <u>C</u>ontent

The Relationship Between MBV and pfc



"C" Shaped Curve Equation

Coefficient parameters depend on soil type

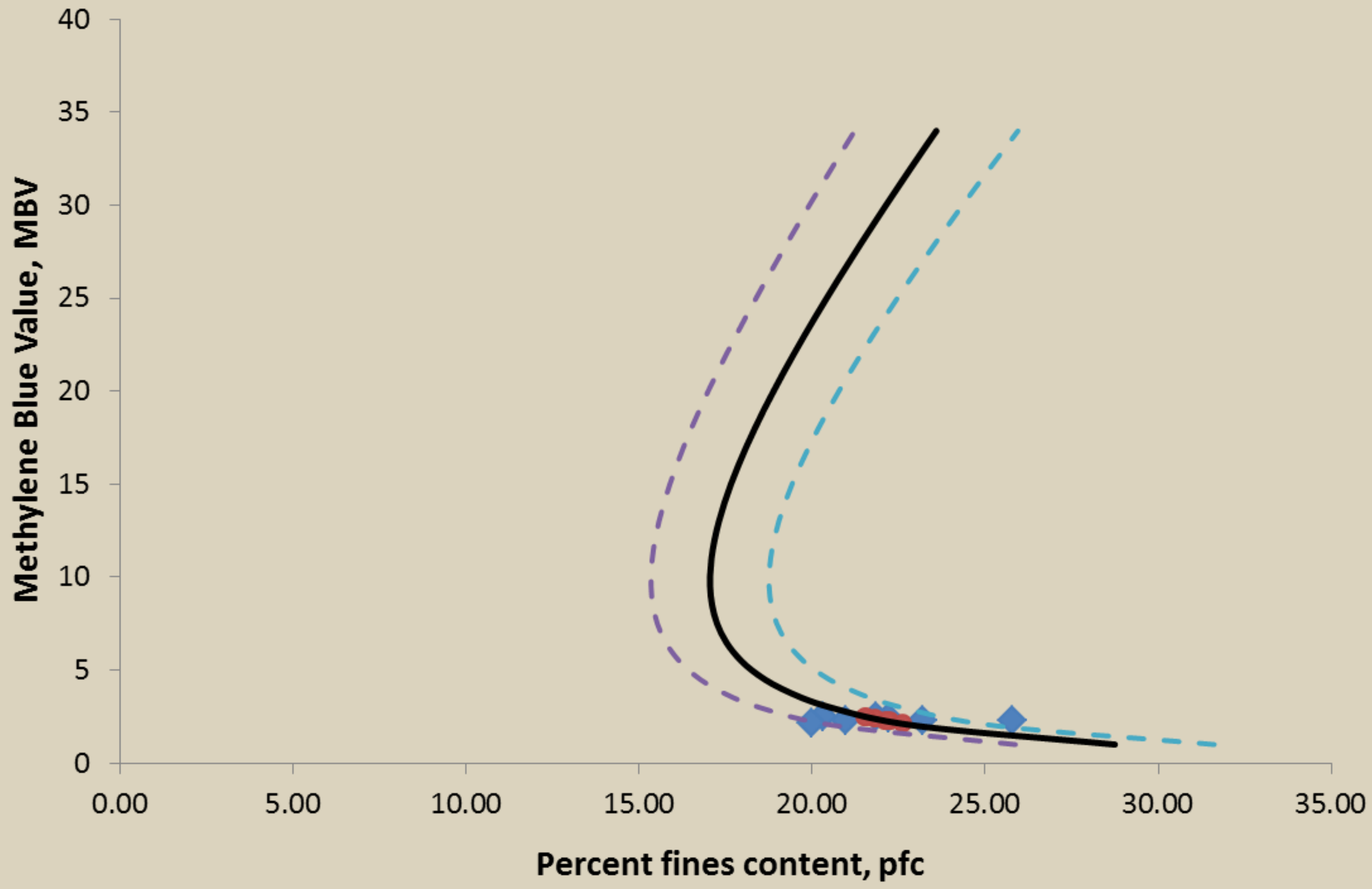
$$pfc = \frac{a}{(MBV)^n} + b(MBV)$$

Percent fines content

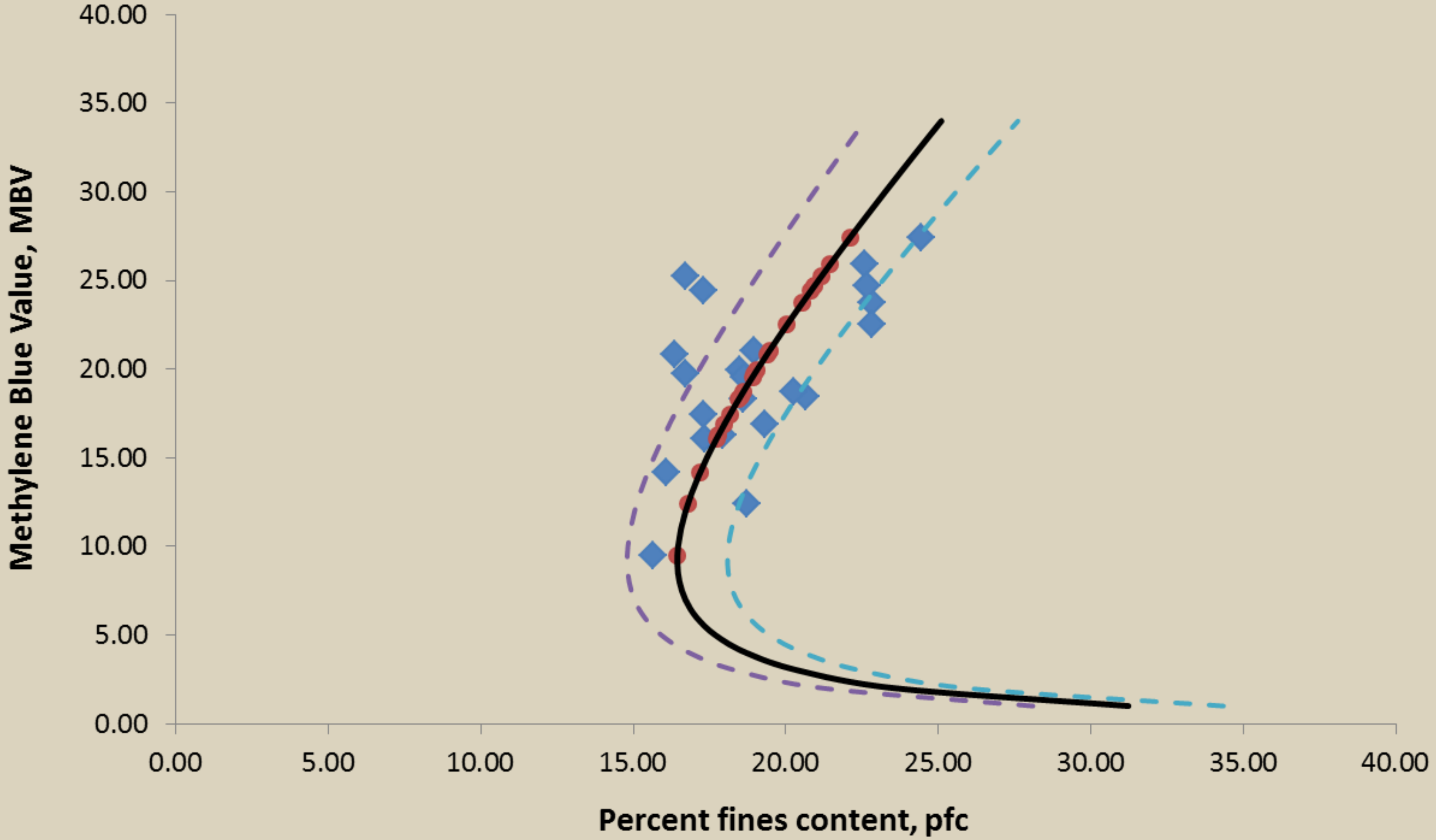
Methylene Blue Value

Typical Values	
a	28.014
b	0.8131
n	0.6288

A Good Quality Base Course

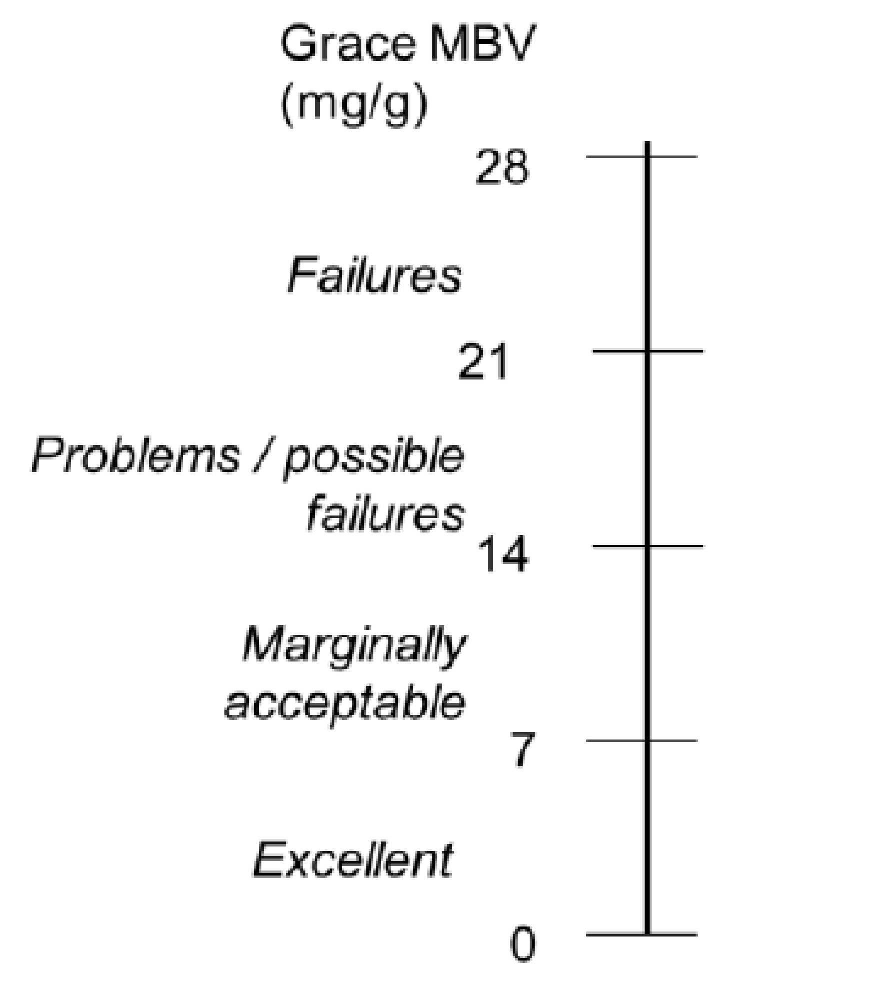


A Poor Quality Base Course



Base Course Aggregate

Grace Methylene Blue Value Scale



Base Course Problems in Design and Implementation

Major Distresses in Pavements

- Asphalt Surfaced (Flexible)
  - Fatigue Cracking
  - Rutting
- Concrete Surfaced (Rigid)
  - Joint Faulting
  - Erosion and Pumping

Most major distresses start with poor support provided by the "**BASE COURSE**"

Problems in Base Course

- Pavement performance and life cycle cost depend on the design of the base course.
- Base course will perform well if the design properties are the same as those when it is built.
- Designed and constructed layer properties are not the same.
- There is a need to ensure properties of the base course in design are close to the base course actually placed.

Problems in Base Course

- Layer modulus and permanent deformation properties are directly related to pavement performance.
- Measuring layer modulus and permanent deformation in the field have major obstacles.

Resilient Modulus and Permanent Deformation Models

Resilient Modulus

$$E_y = k_1 P_a \left(\frac{I_1 - 3\theta f h_m}{P_a} \right)^{k_2} \left(\frac{\tau_{oct}}{P_a} \right)^{k_3}$$

Saturation factor $1 \leq f \leq \frac{1}{\theta}$

Octahedral shear stress

Volumetric water content

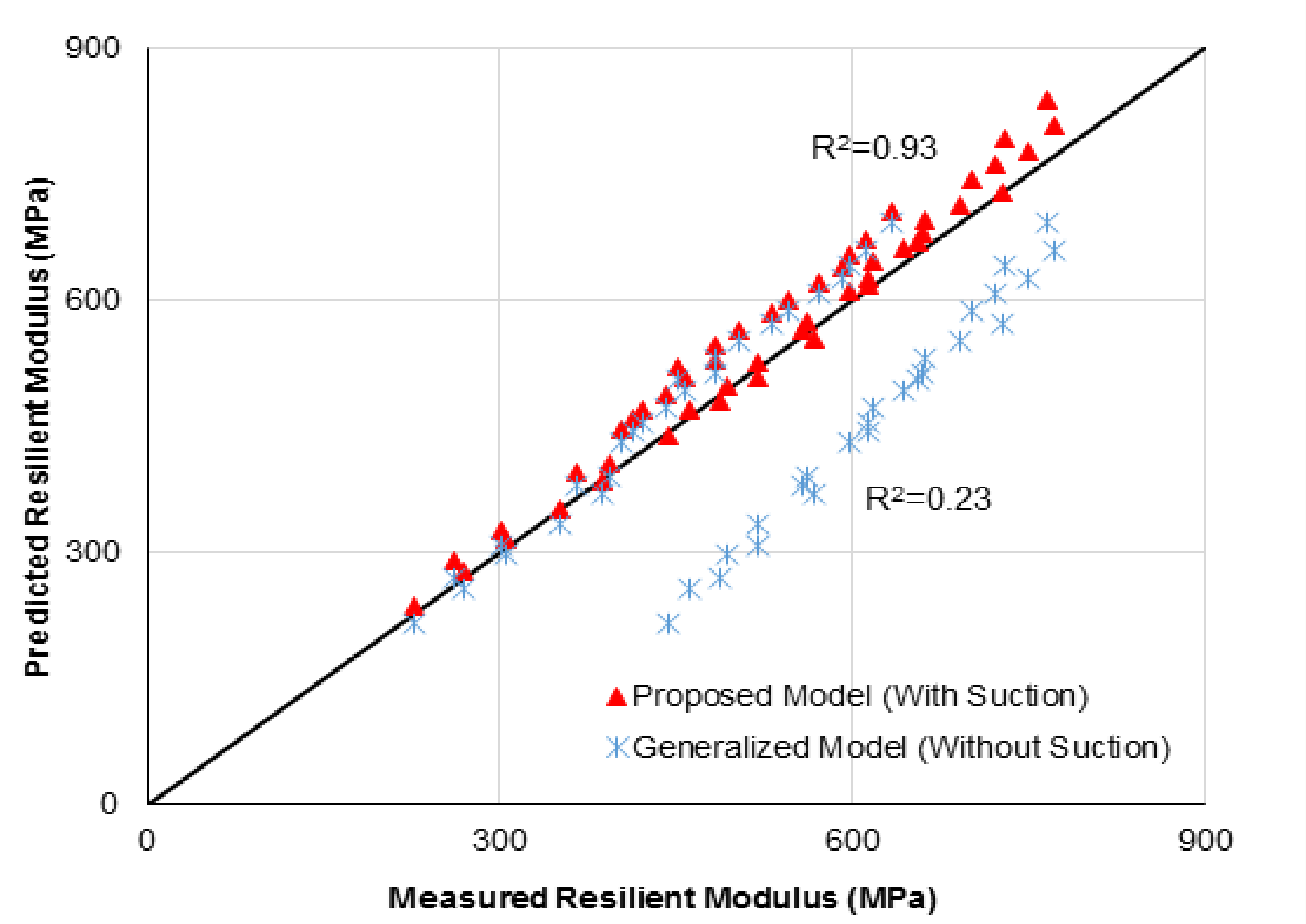
First invariant of the stress tensor

Matric Suction

Atmospheric pressure

k_1, k_2, k_3 – Coefficients of resilient modulus model

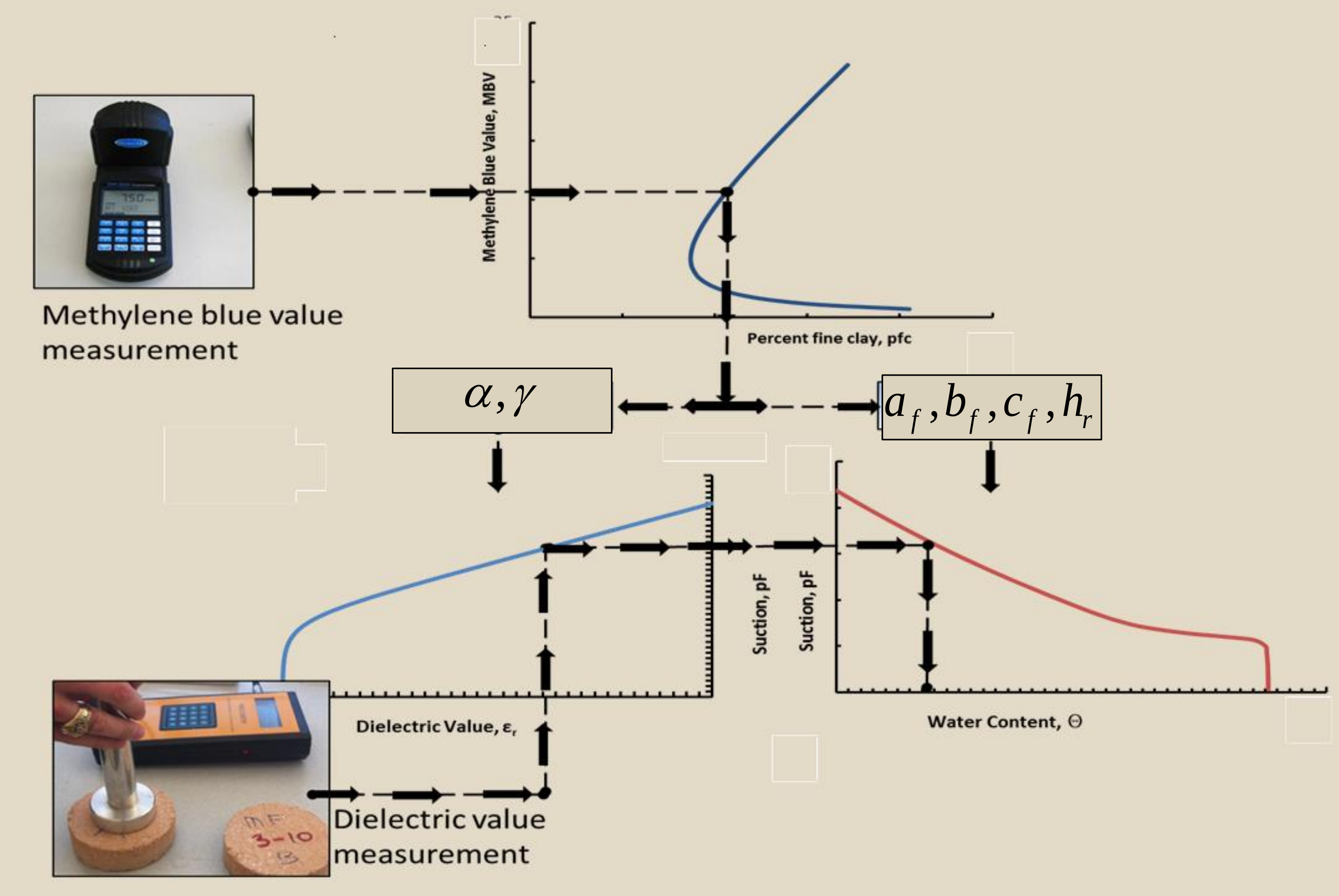
Measured and Predicted Modulus



Aggregate Properties and k Values

Aggregate Property		k Values		
		k_1	k_2	k_3
γ_d (Dry Density)		✓		
ω (Water Content)			✓	
MBV		✓	✓	✓
pfc				
Gradation	a_G			✓
	λ_G			
Angularity	a_A		✓	✓
	λ_A		✓	✓
Shape	a_S	✓	✓	
	λ_S		✓	✓
Texture	a_T	✓		
	λ_T			

Matric Suction and Water Content Measurements



Soil Dielectric Characteristics Curve (SDCC)

Soil Dielectric Characteristics Curve (SDCC)

$$\varepsilon_r = \left[\frac{\varepsilon_{sat} + \varepsilon_{\min} \alpha \left[\frac{h}{\left(1.45x10^5 - h\right)} \right]^{\gamma}}{1 + \alpha \left(\frac{h}{h_m - h} \right)^{\gamma}} \right]$$

Curve fitting parameters (α, γ)

Saturated dielectric constant (ε_{sat})

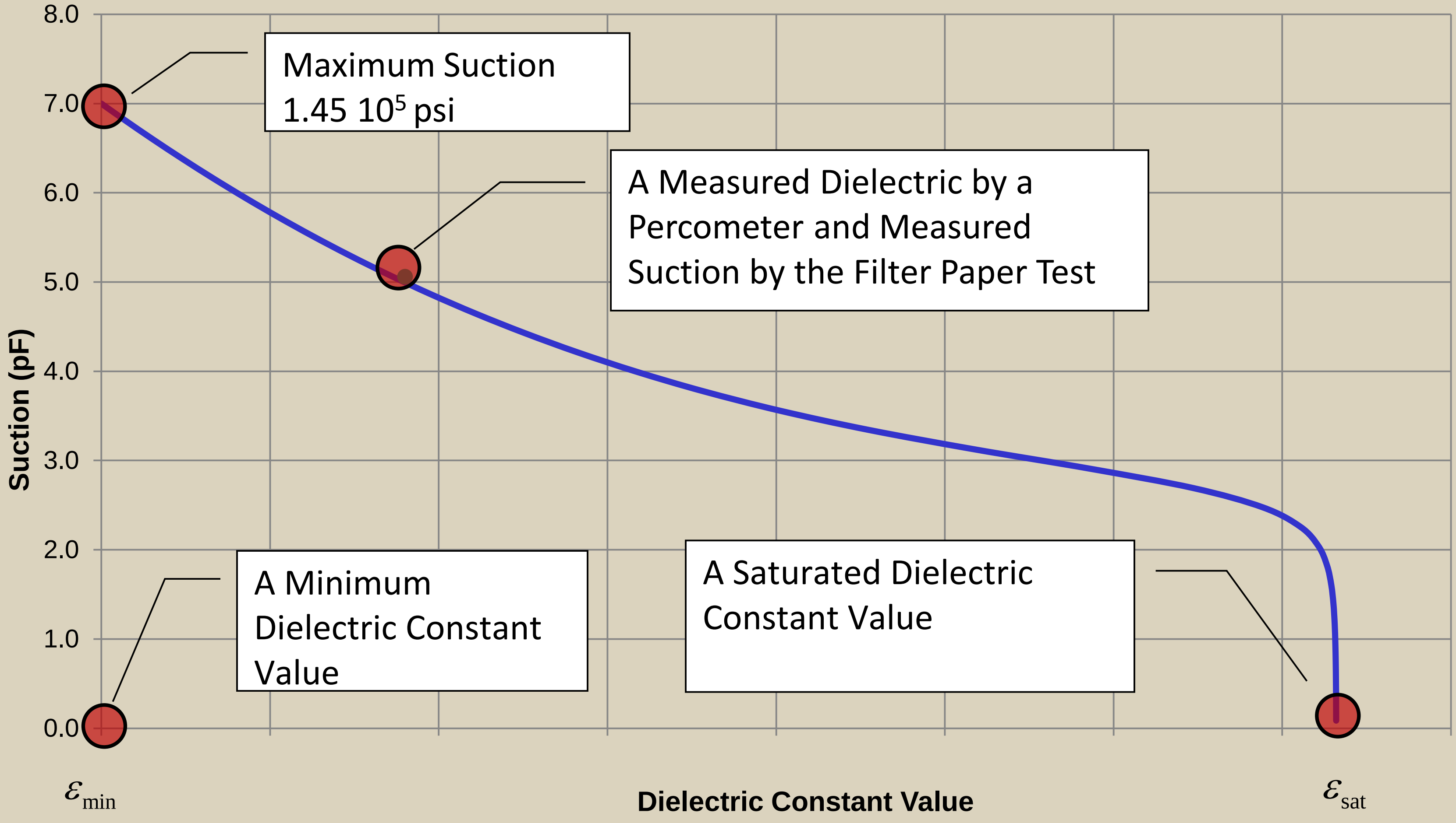
Minimum dielectric constant ($\varepsilon_{\min}$)

Dielectric constant (ε_r)

Suction (h)

Maximum Suction (h_m)

Typical Soil Dielectric Characteristic Curve (SDCC)



A Standard Percometer Device with Surface Probe

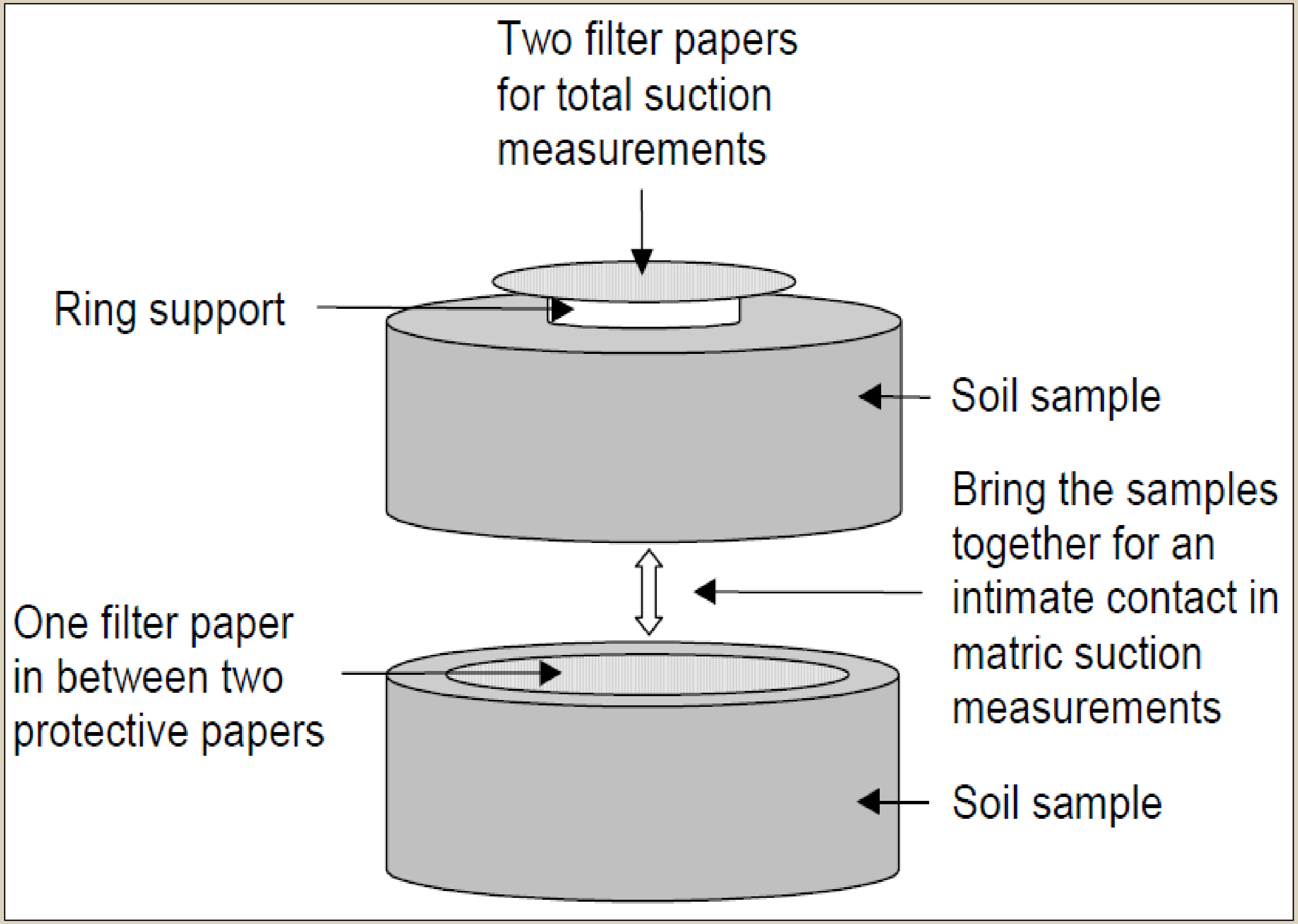
PER-CO-METER

PERMITTIVITY-CONDUCTIVITY-METER

Dielectric Constant Measurements Process with a Percometer

Material	Dielectric Constant
Air	1.0
Water	81.0
Asphalt	4.0-6.0
Concrete	8.0-12.0
Clay	4.0-40.0

Filter Paper Suction Test Setup



Filter Paper Test: Part I






Prepare two generic soil samples by using standard impact compaction machine.

For matric suction measurement insert a No. 589-WH filter paper in between two larger filter paper.

Put other soil sample on top, keeping the filter paper in between in intimate contact with soil samples.

Tape together the two pieces of the soil samples.

Place two 589-WH filter paper on top of the plastic ring on top of the samples.

Put the lid on and tape it tight to prevent moisture lost.

Tape tight to prevent any moisture exchange between the air inside and outside of the jar.

Insert the jar into a well insulated container for suction equilibrium.

Filter Paper Test: Part II (After 1 Week)

Take the dry cold weight of the moisture tins.

Open the jar and carry the filter paper to moisture tin using tweezers, in less than a few seconds.

Immediately close the lid of the moisture tin with wet filter paper and weigh the tin.

(Note: This is for total suction measurement.)

Remove the filter paper that was sandwiched between two samples. and carry into the moisture tin.

Weigh the tin with wet filter paper inside and note this is matric suction.

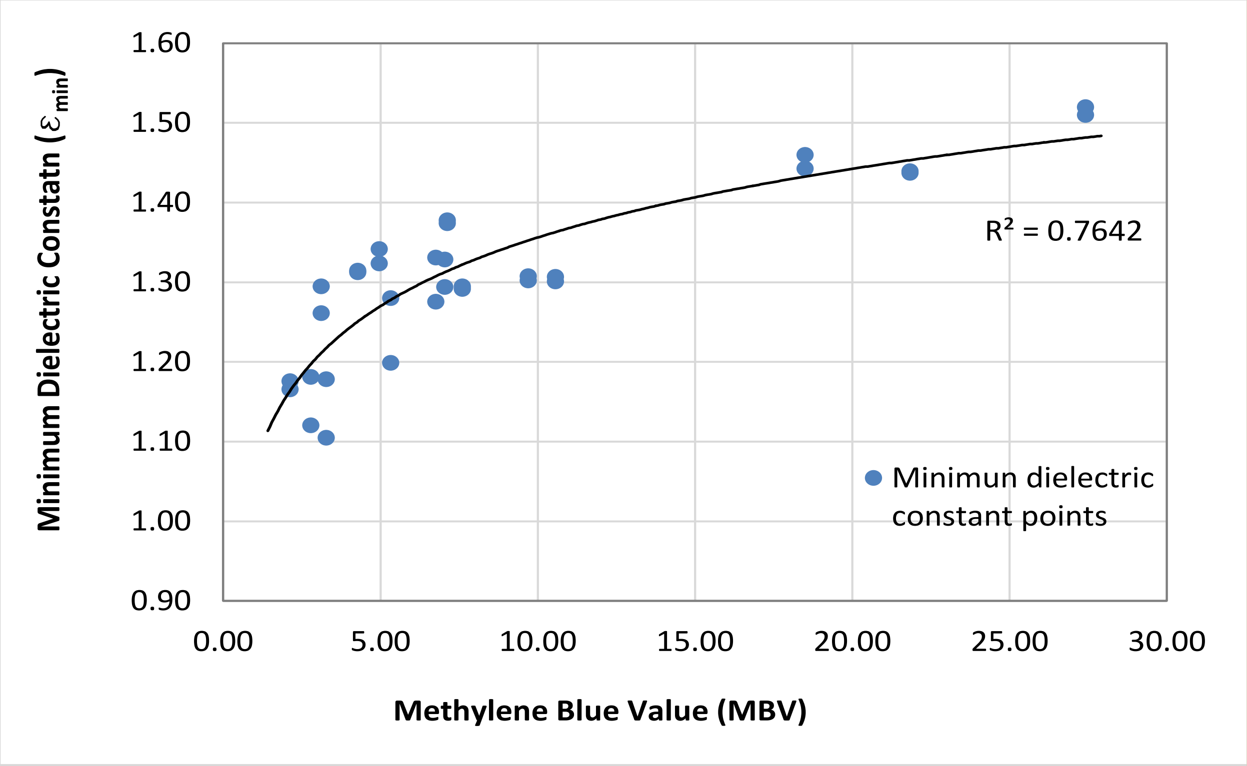
Place all tins in a hot oven at least 10 hours.

Leave the tin on aluminum block 20 seconds and weigh with dry paper inside.

Record all the weights and calculate moisture content of each paper for both matric and total suction.

Minimum Dielectric Value

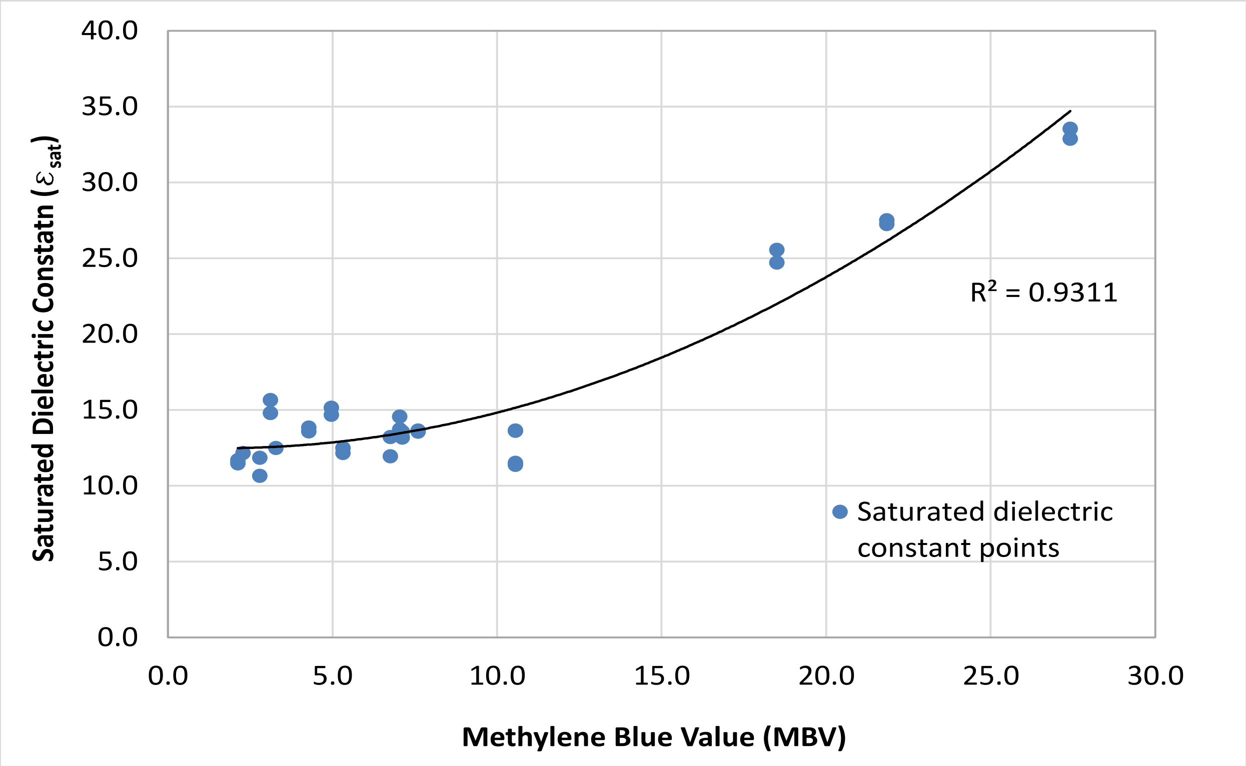
Correlation for minimum dielectric vs MBV



$$\varepsilon_{min} = 0.1243\log(MBV) + 1.0668$$

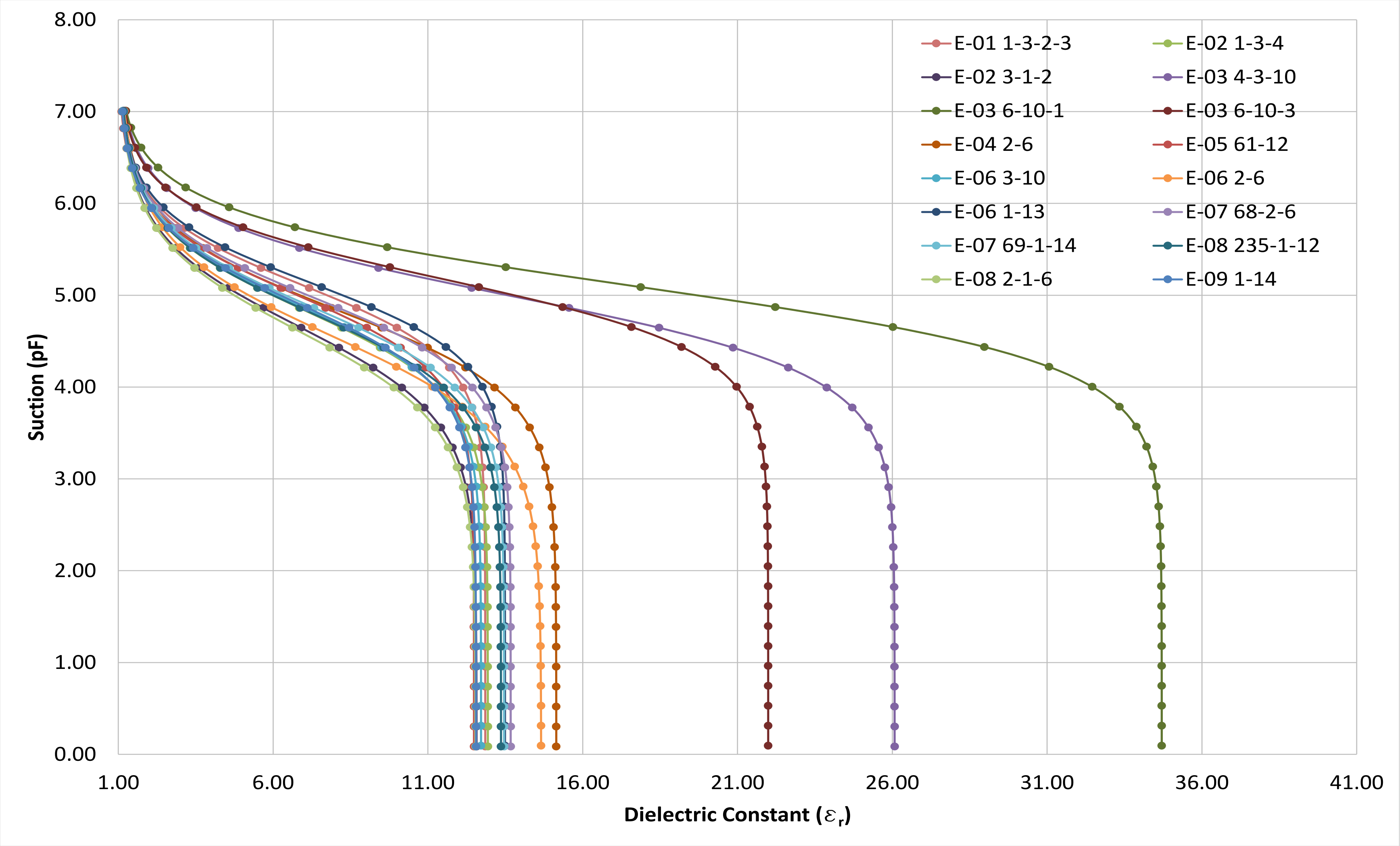
Saturated Dielectric Value

Correlation for saturated dielectric vs MBV

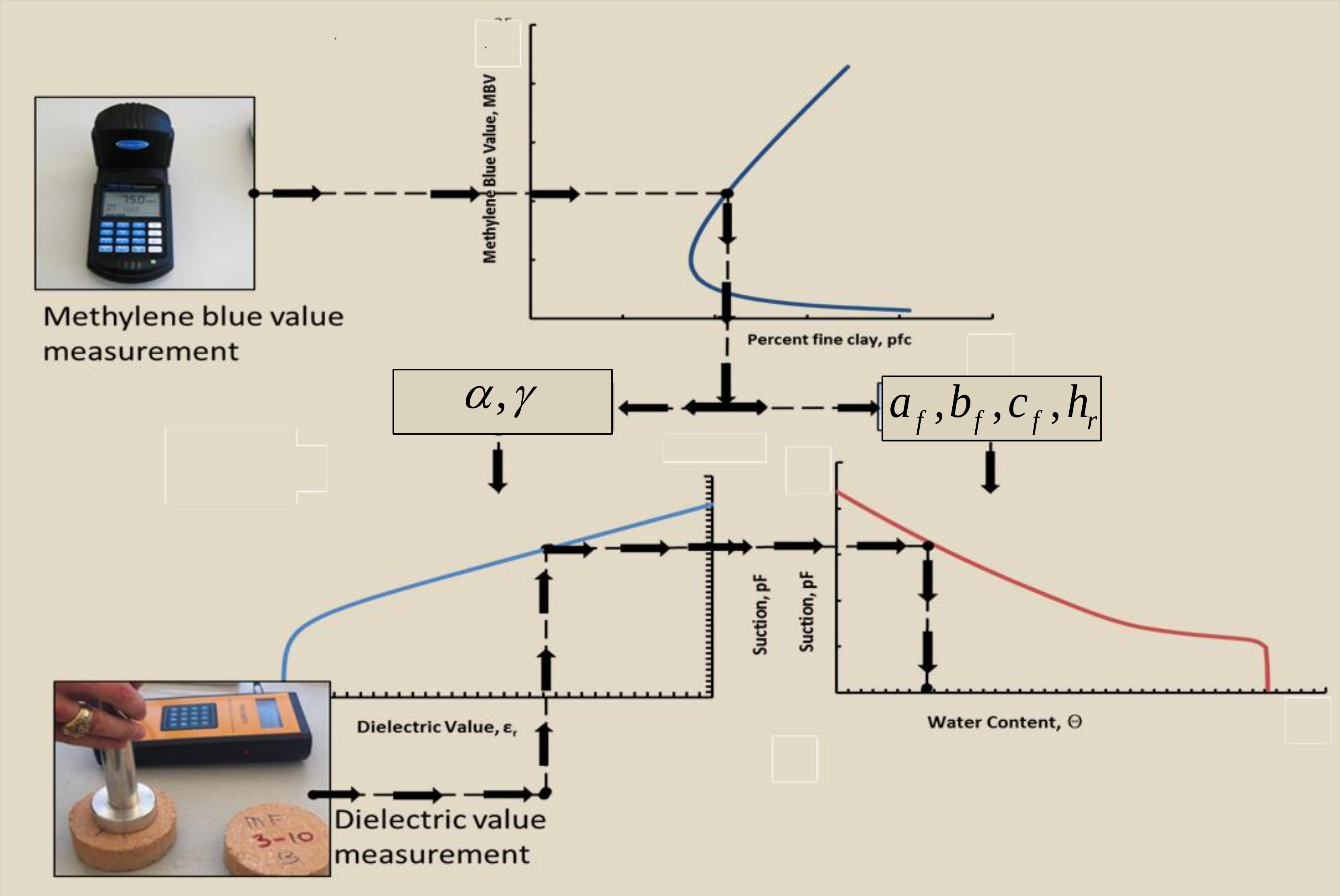


$$\varepsilon_{sat} = 0.0334\left(MBV^2\right) - 0.1086\left(MBV\right) + 12.569$$

A Family of Generated SDCCs



Matric Suction and Water Content Measurements



Soil Water Characteristics Curve (SWCC)

Soil Water Characteristics Curve (SWCC)

Fredlund and Xing Equation (1994)

Saturated volumetric water content

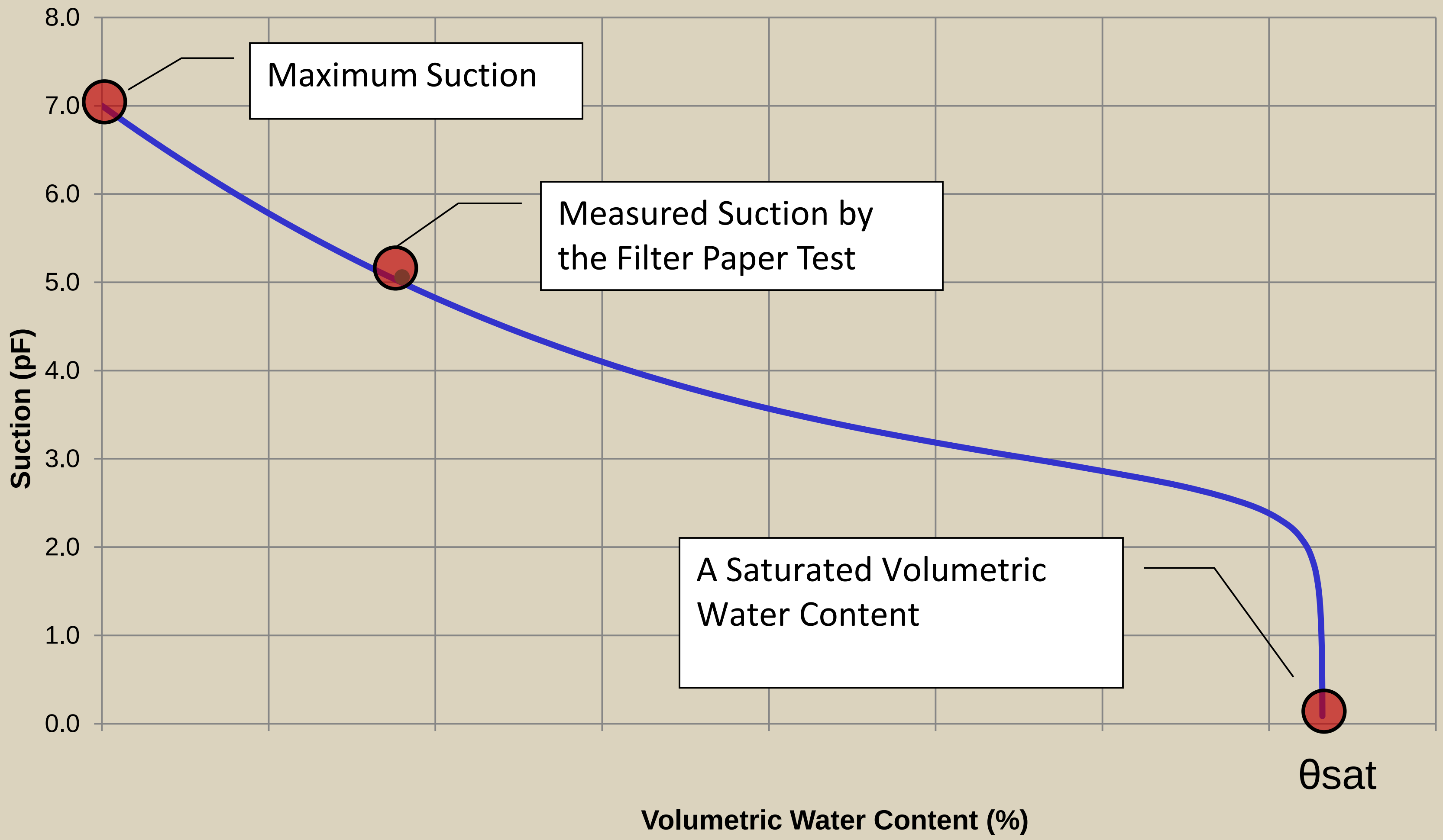
$$\theta_w = C(h) \times \left[\frac{\theta_s}{\left[\ln\left[\exp(1) + \left(\frac{h}{a} \right)^{b} \right] \right]^{c}} \right]$$

Volumetric water content

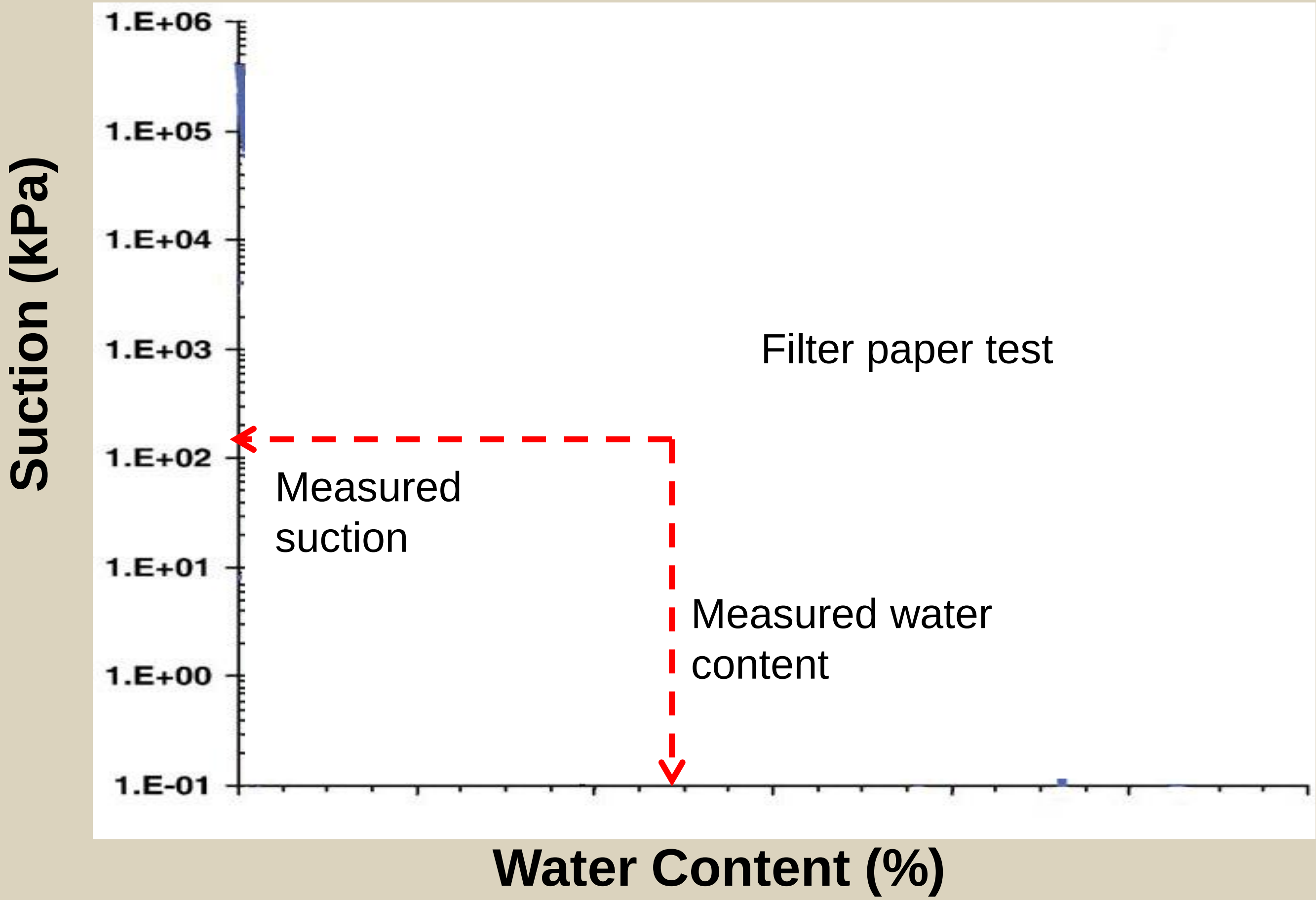
Four soil parameters

$$C(h) = \left[1 - \frac{\ln\left(1 + \frac{h}{h_r} \right)}{\ln\left(1 + \frac{10^6}{h_r} \right)} \right]$$

Typical Soil Water Characteristic Curve (SWCC)

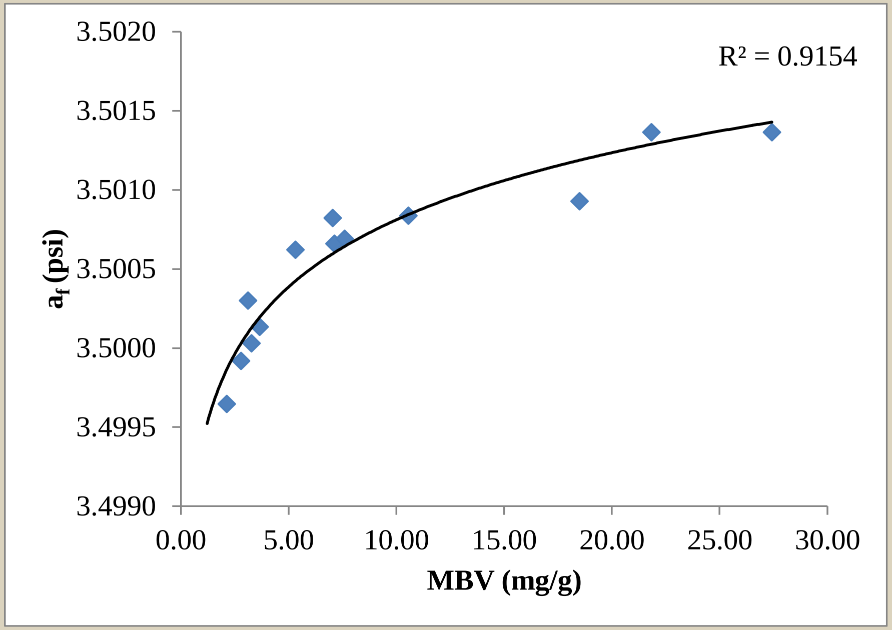


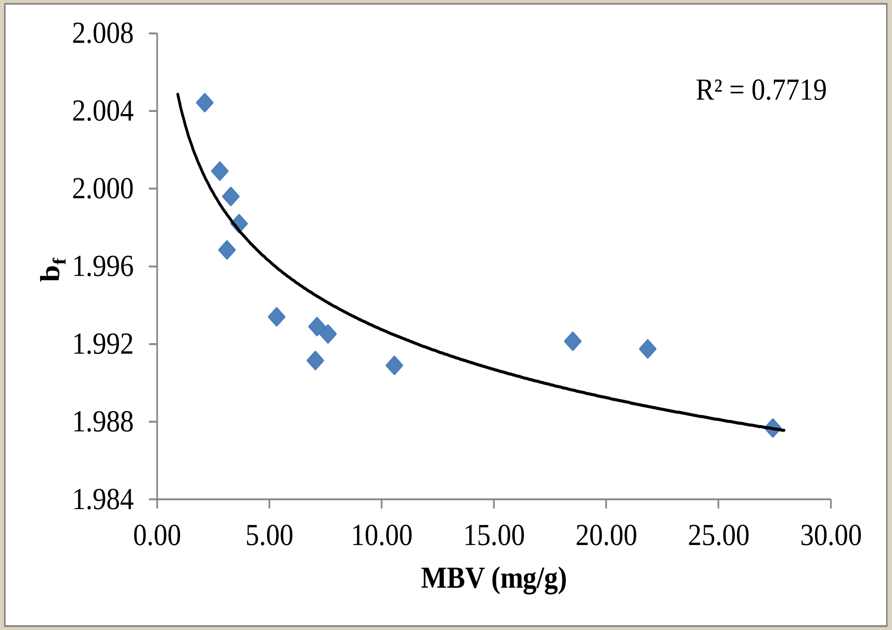
Generate a Soil Water Characteristic Curve (SWCC)



Four Parameters

Correlations for parameters a_f and b_f :



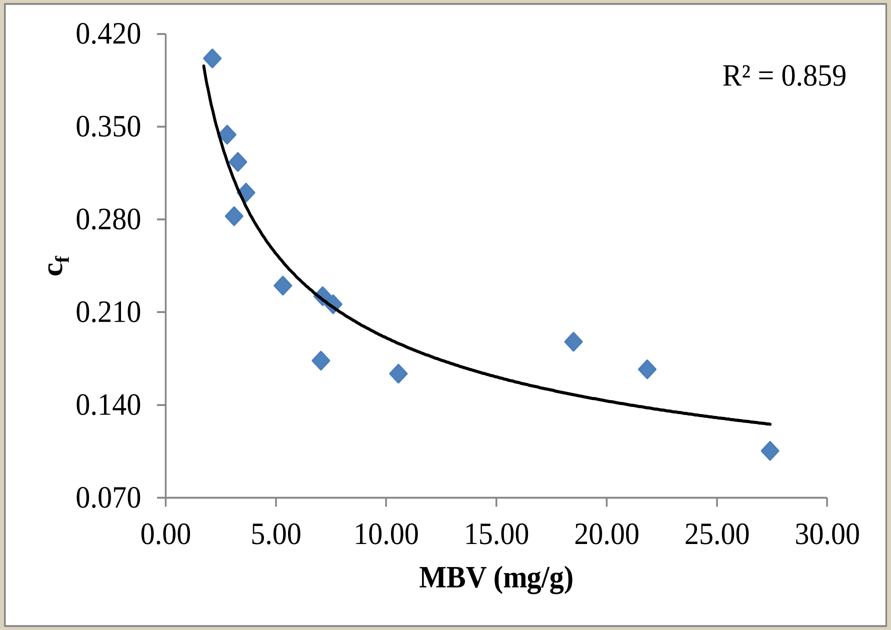


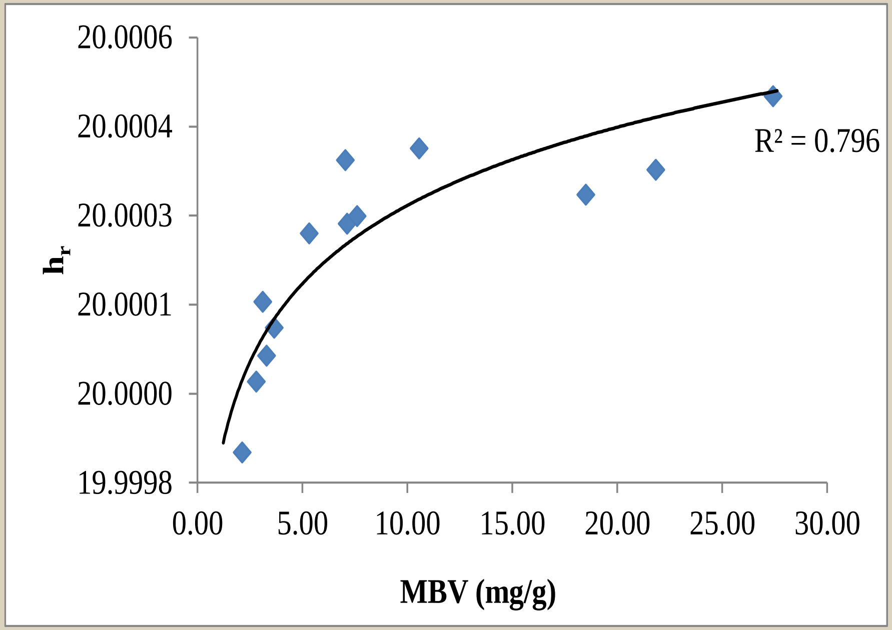
$$a_f = 3.4994 MBV^{0.0002}$$

$$b_f = 2.0044 MBV^{-0.003}$$

Four Parameters

Correlations for parameters c_f and h_r:



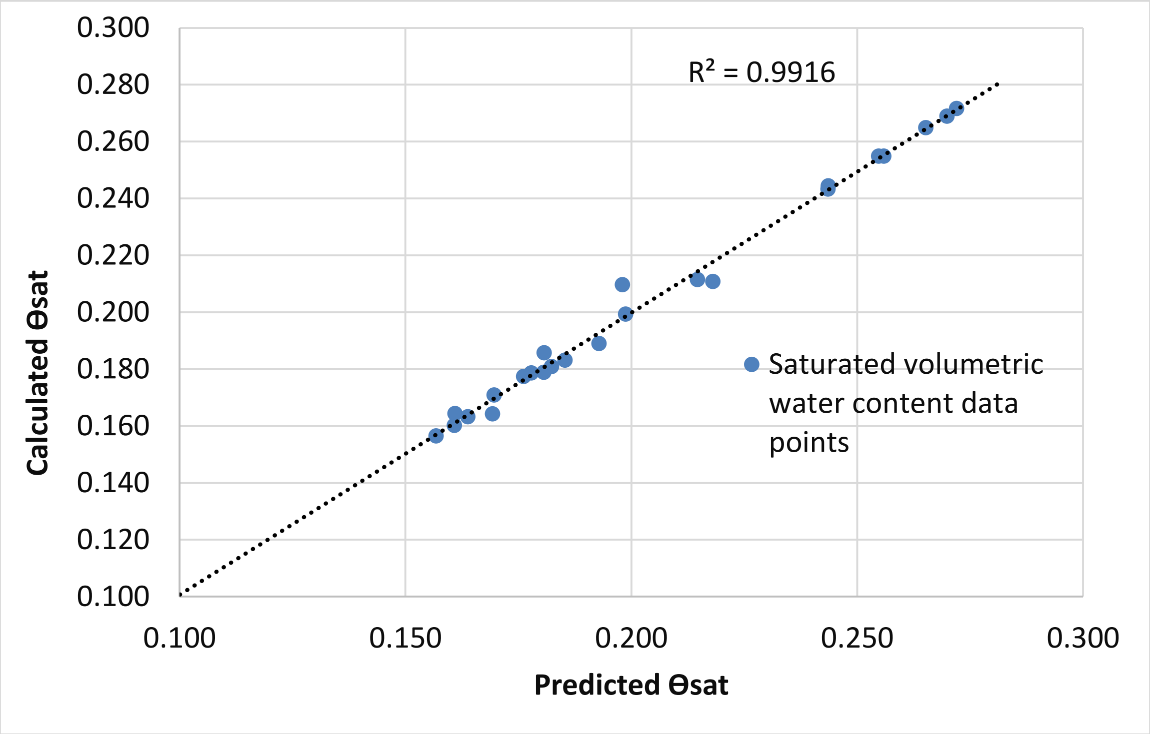


$$c_f = 0.4956 MBV^{-0.415}$$

$$h_r = 20.00 x MBV^{9.5E-06}$$

Saturated Volumetric Water Content

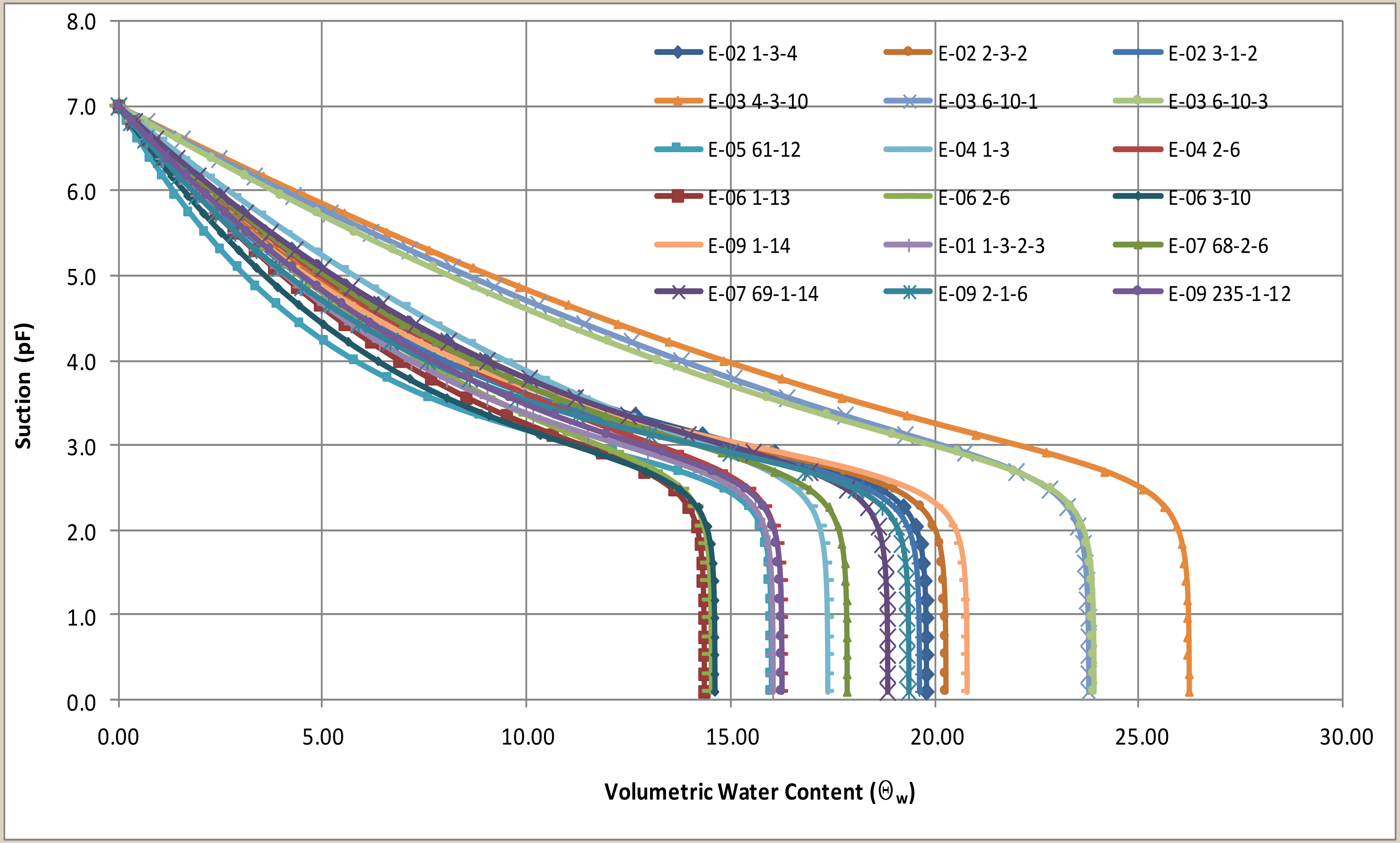
Predicted and calculated saturated volumetric water contents:



$$\theta_{sat} = 0.214926485 H_{1\theta_{sat}} + 0.27640261 H_{2\theta_{sat}} - 0.12511932 H_{3\theta_{sat}} + 0.30045553$$

$$H_{1\theta_{sat}}, H_{2\theta_{sat}}, \text{and } H_{3\theta_{sat}} = f(MBV \text{ and } pfc)$$

A Family of Generated SWCCs



Optimum Moisture Content and Compaction Curves

Automatic Compaction Device

- Followed Test procedure
  - Tex-113 E
- Base course sample
  - 6 in diameter
  - 8 in height
  - 4 layers
- Compaction
  - 750 ft-lbs per layer

Compaction Curve Equation

Three fitting parameters change with soil type

Dry unit weight

$$\left(\frac{\gamma_d}{\gamma_w}\right) = a_d\left[\operatorname{csch}\left(\frac{\theta_w \theta_{sat}}{G_s\left(\theta_{sat}-\theta_w\right)}\right)\right]^{n_d} - b_d\left[\operatorname{csch}\left(\frac{\theta_w \theta_{sat}}{G_s\left(\theta_{sat}-\theta_w\right)}\right)\right]$$

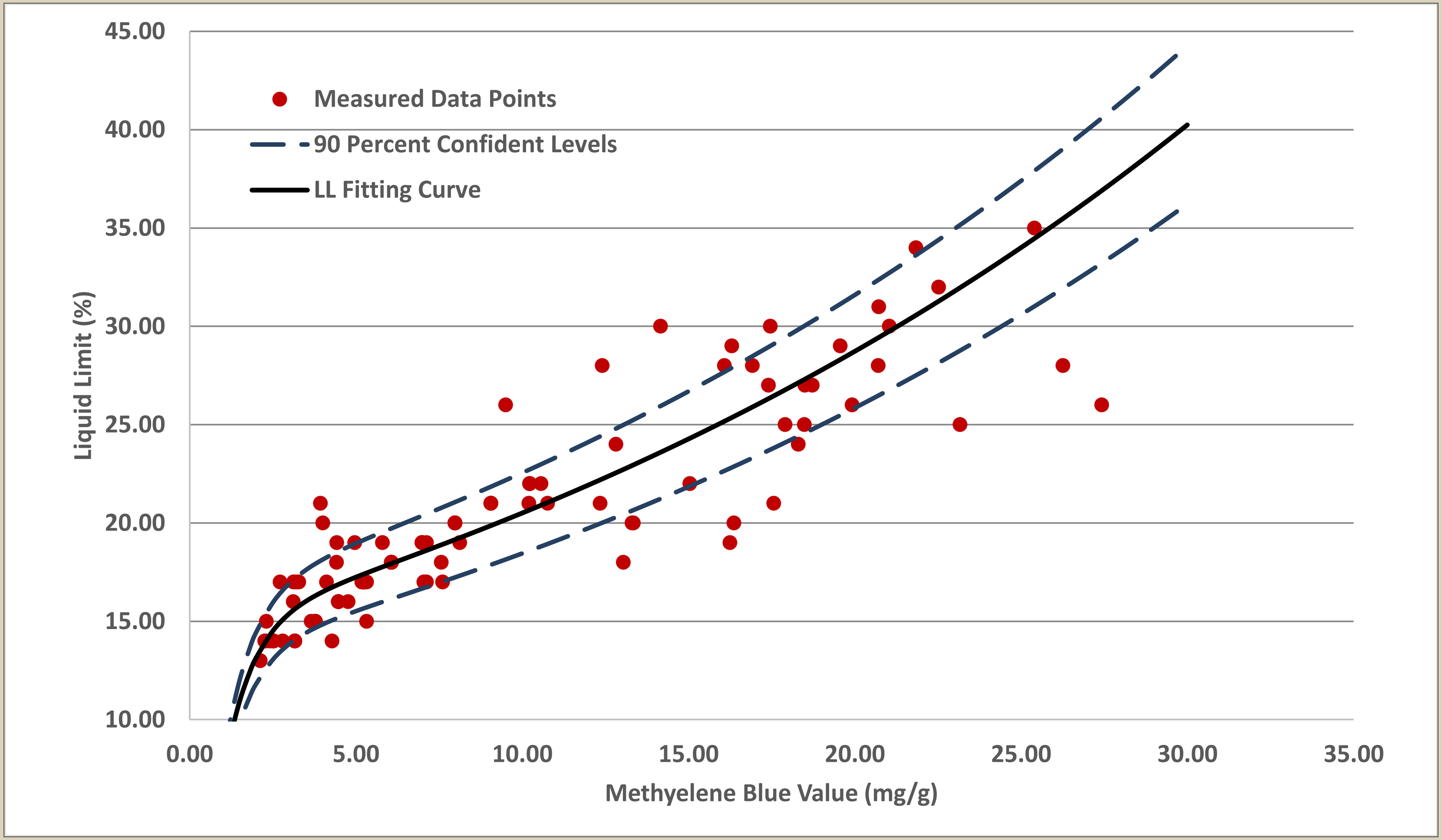
Unit weight of water

Specific gravity

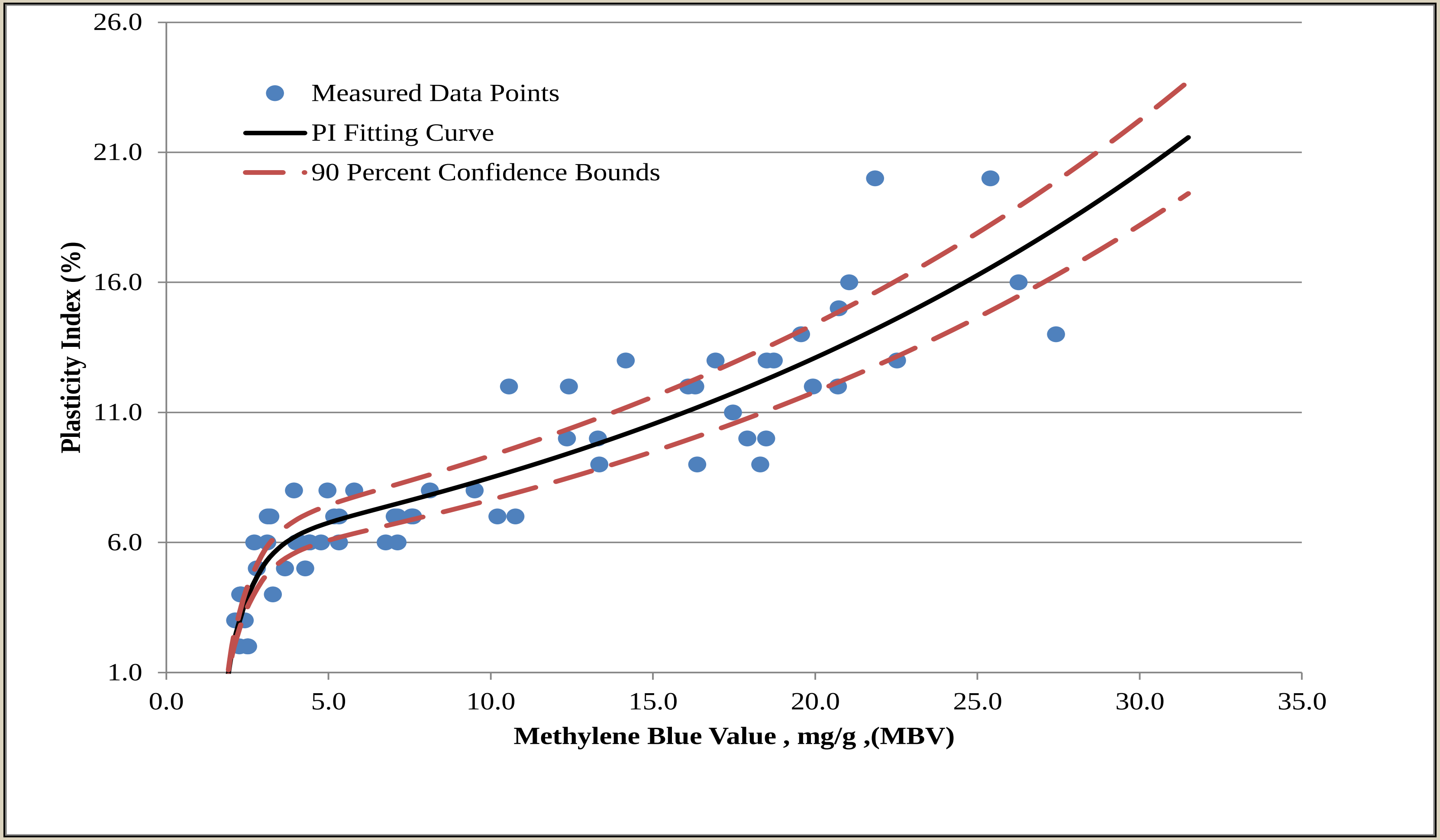
Volumetric water content

Saturated volumetric water content

Liquid Limit



Plasticity Index



Specific Gravity

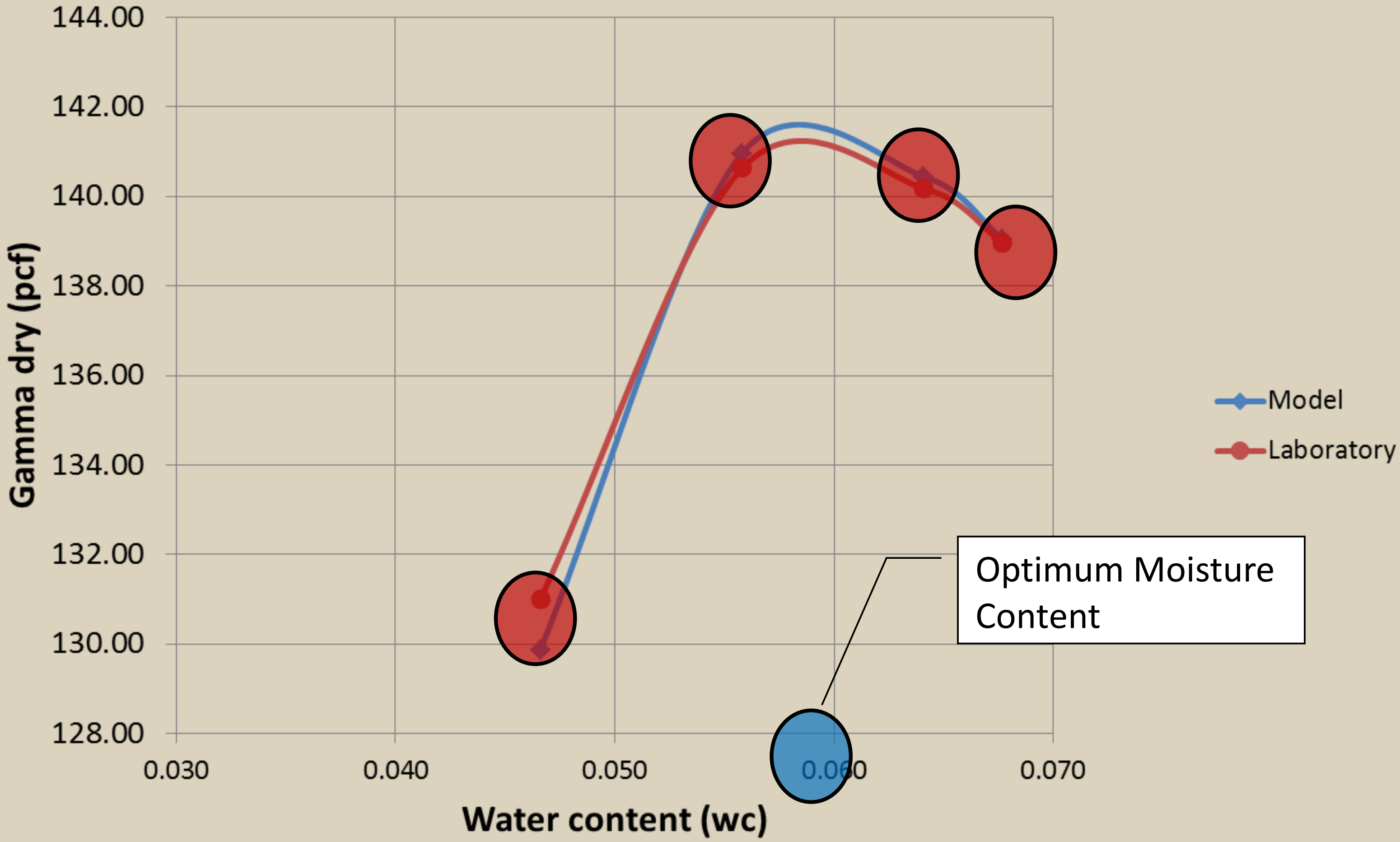
Liquid Limit

$$G_s = \frac{2.55 + 2.91(2.43)\left(\frac{PI-1}{22-PI}\right)^{0.3076}\left(\frac{LL-1}{40-LL}\right)^{-0.3525}}{1+(2.43)\left(\frac{PI-1}{22-PI}\right)^{0.3076}\left(\frac{LL-1}{40-LL}\right)^{-0.3525}}$$

Specific Gravity

Plasticity Index

Typical Compaction Curve as Tested in the Laboratory and as Modeled



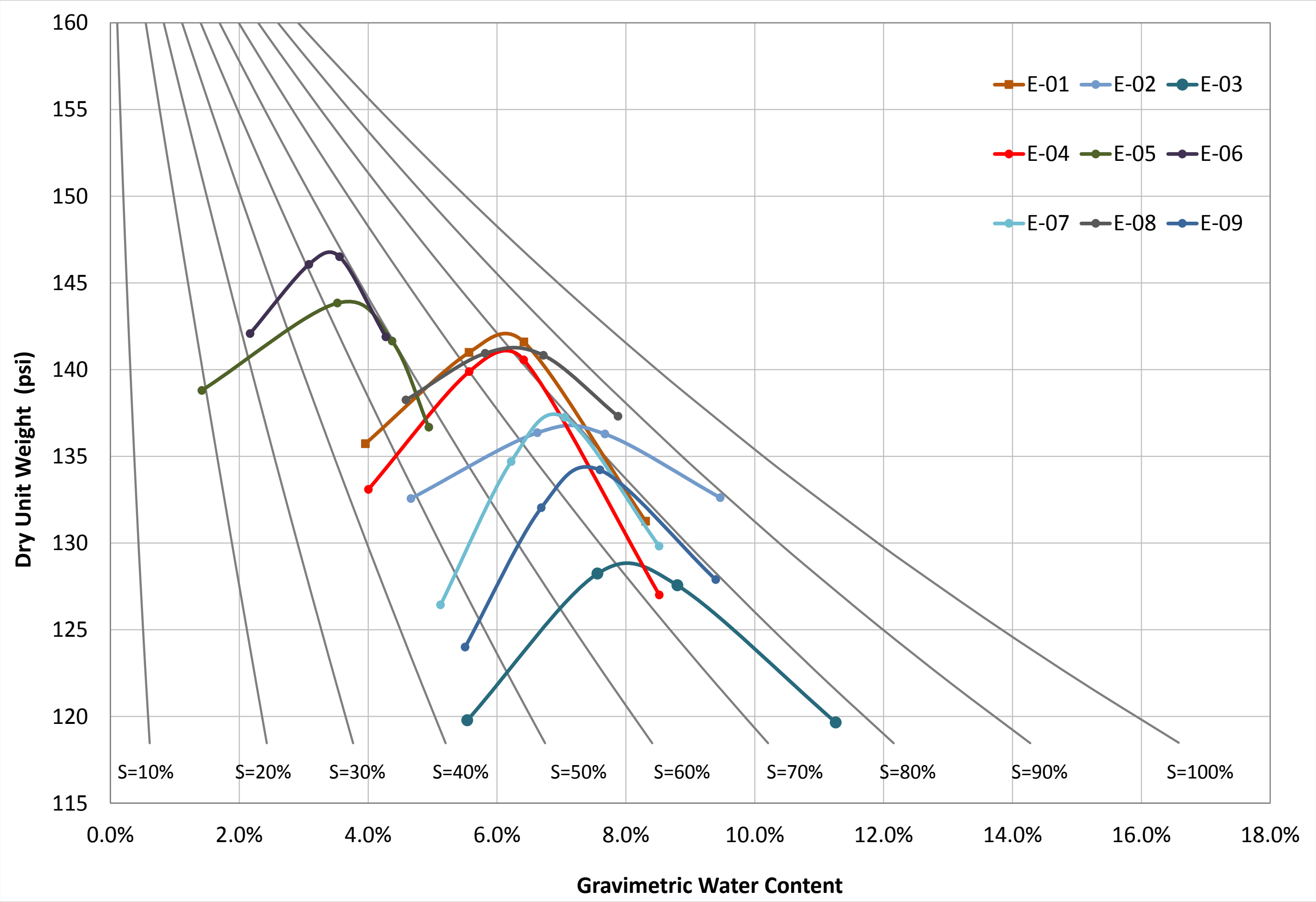
Optimum Moisture Content

$$\theta_{opt} = \left(\frac{G_s \theta_{sat} \ln\left[\frac{1}{2}\left(1 + \sqrt{1 + 4\left(\frac{2^{1-n_d} b_d}{a_d n_d} \right)^{\frac{2}{-1+n_d}}} \right) \left(\frac{2^{1-n} b_d}{a_d n_d} \right)^{-\frac{1}{-1+n_d}} \right]}{\theta_{sat} + G_s \ln\left[\frac{1}{2}\left(1 + \sqrt{1 + 4\left(\frac{2^{1-n} b_d}{a_d n_d} \right)^{\frac{2}{-1+n_d}}} \right) \left(\frac{2^{1-n} b_d}{a_d n_d} \right)^{-\frac{1}{-1+n_d}} \right]} \right)$$

↑ Optimum Moisture Content

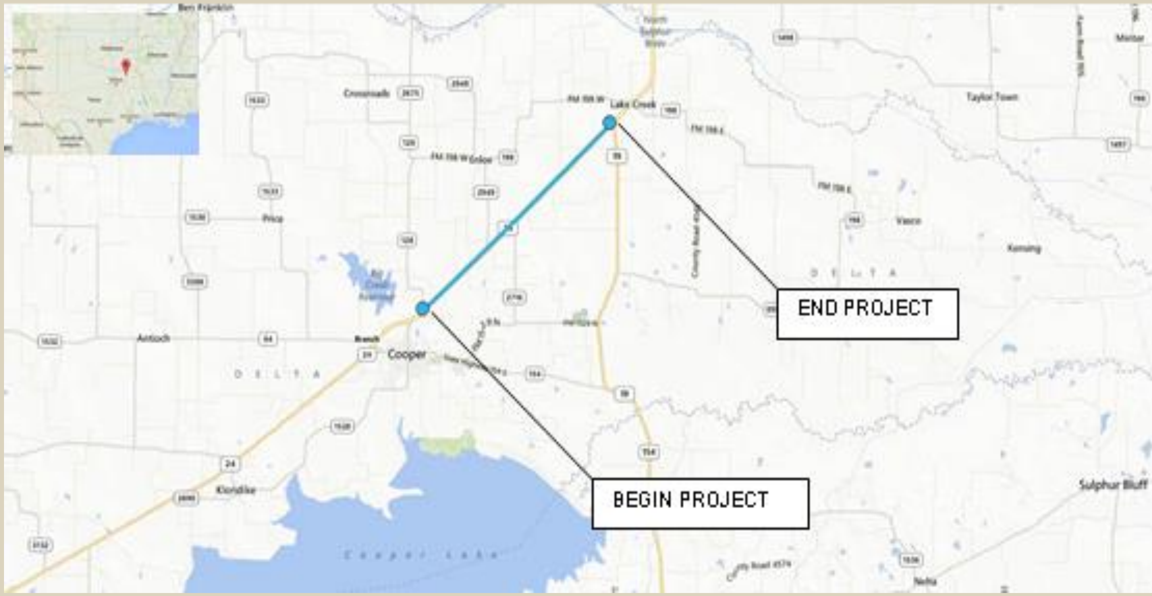
A Family of Compaction Curves

Generated compaction density-moisture curves



A Case Study: Verification GPR and FWD

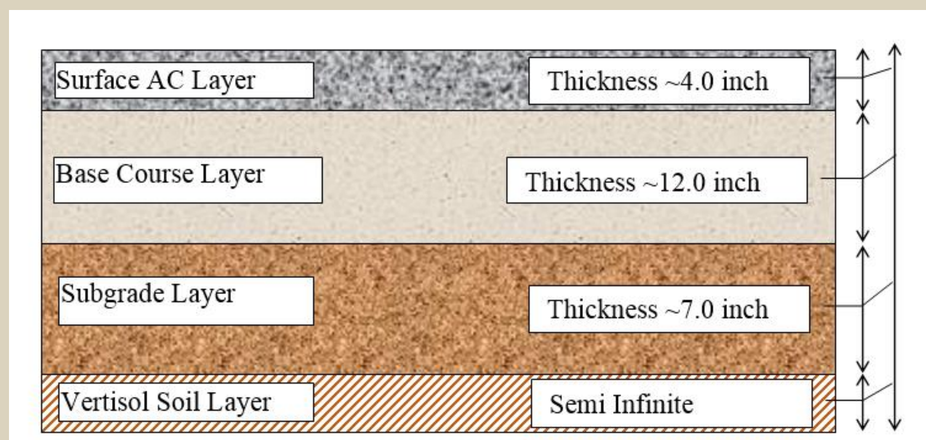
Test Location



Site:
Delta County, Texas

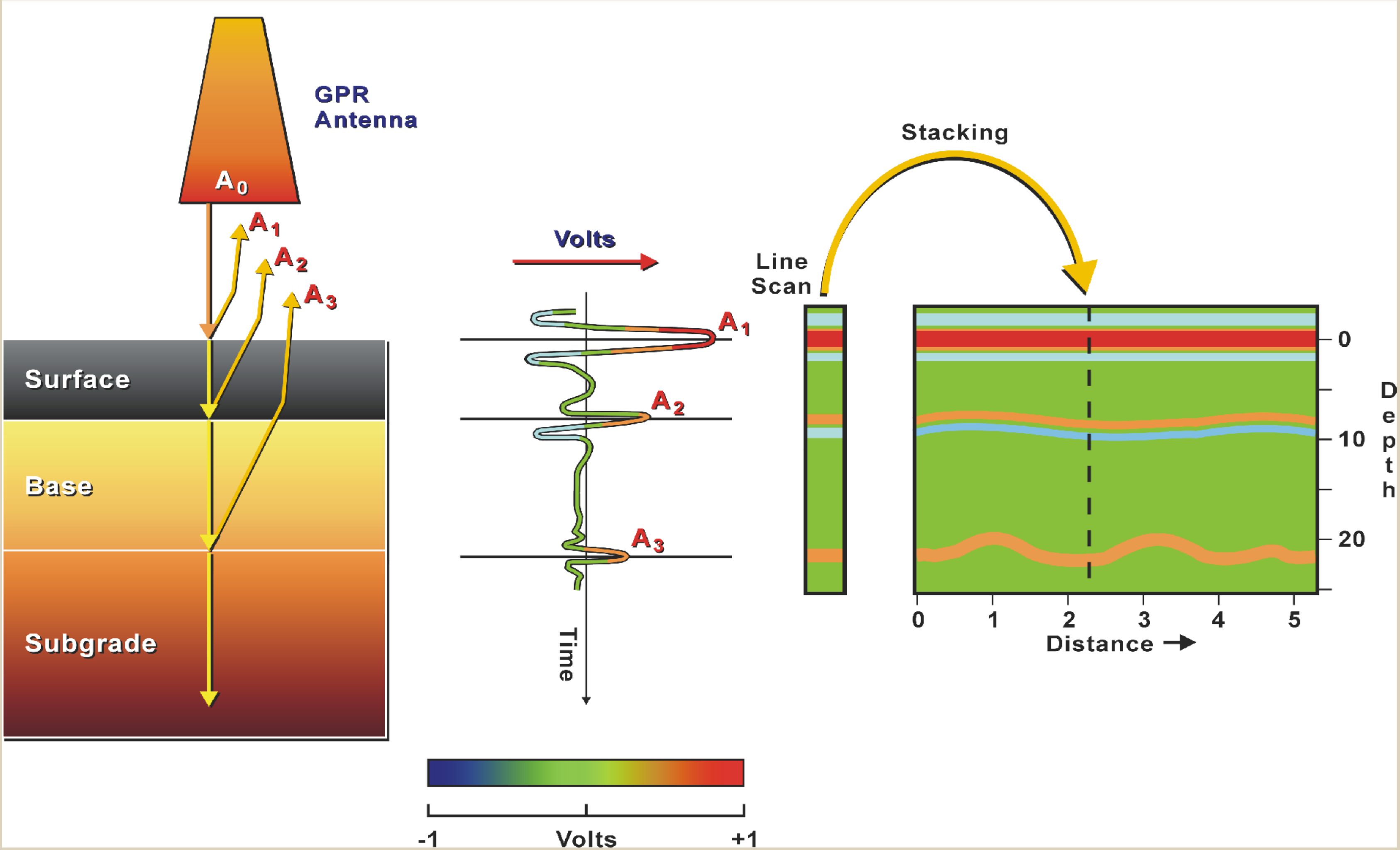
Total length:
4.5 miles (~24000 ft)

Base Course Pit:
Martin Marietta Material
Oklahoma

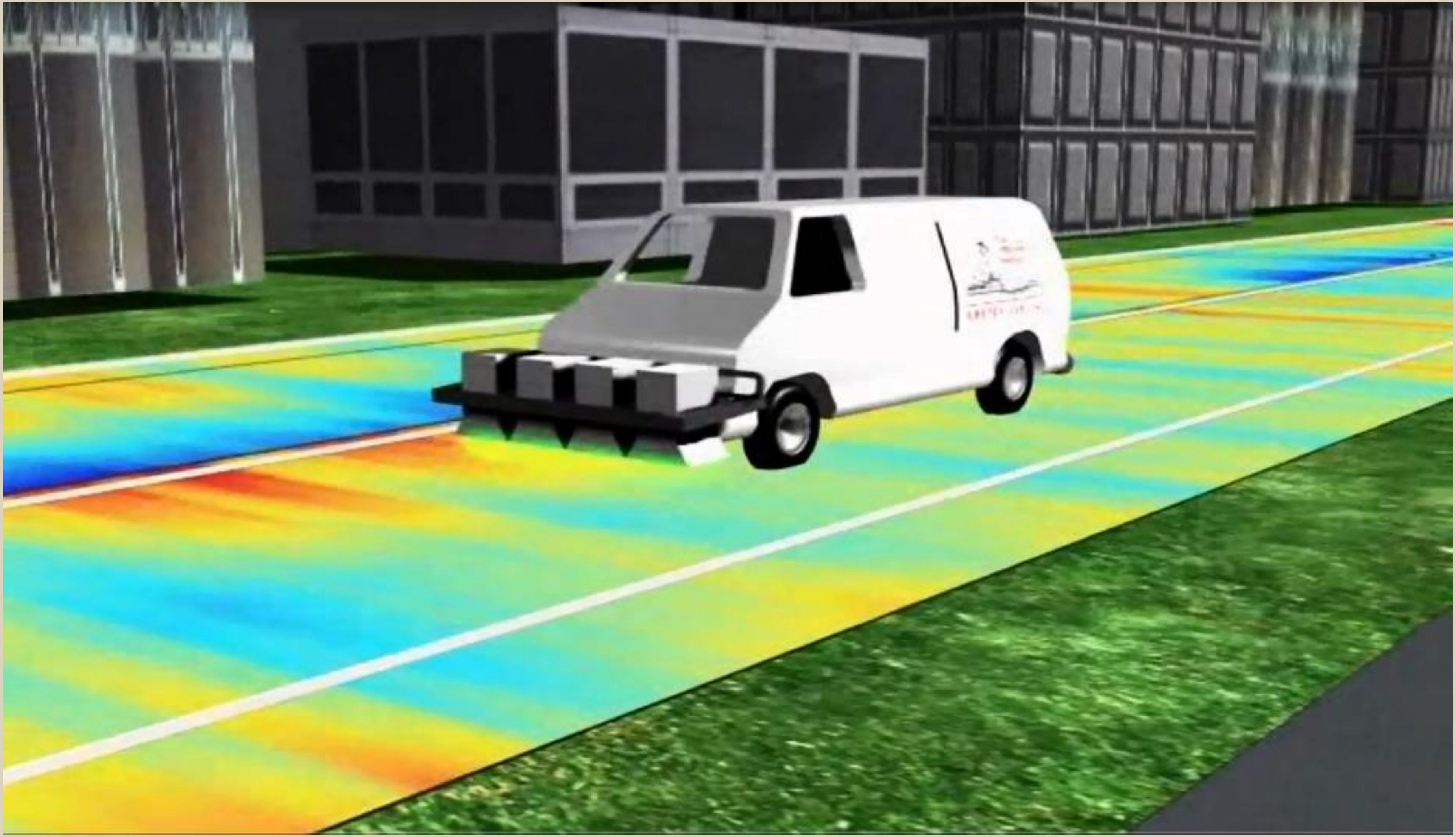


Ground Penetrating Radar Van

Return Reflection at Interfaces

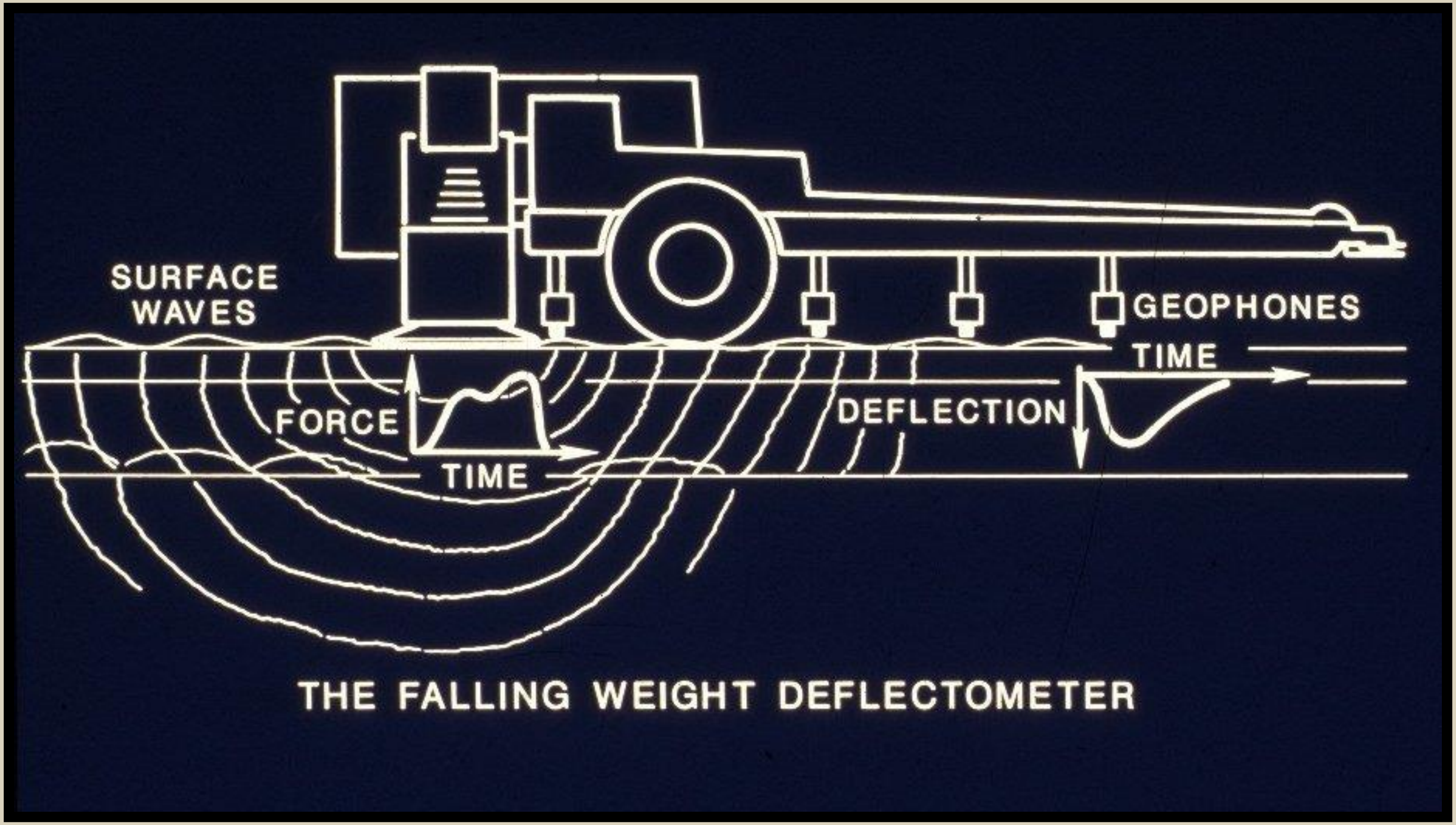


Radar Hyper Optics Animation Video

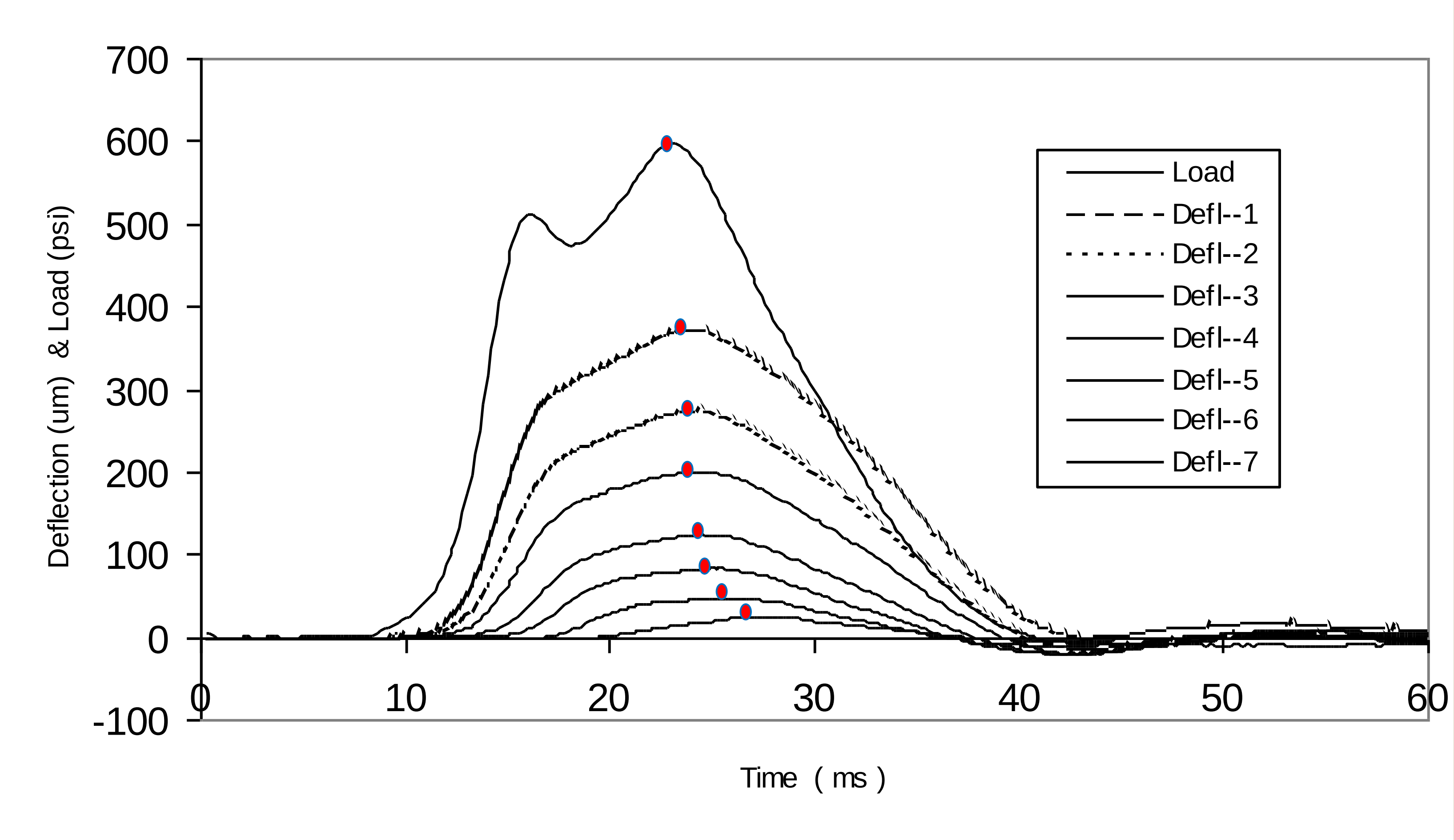


Falling Weight Deflectometer (FWD)

Falling Weight Deflectometer (FWD)

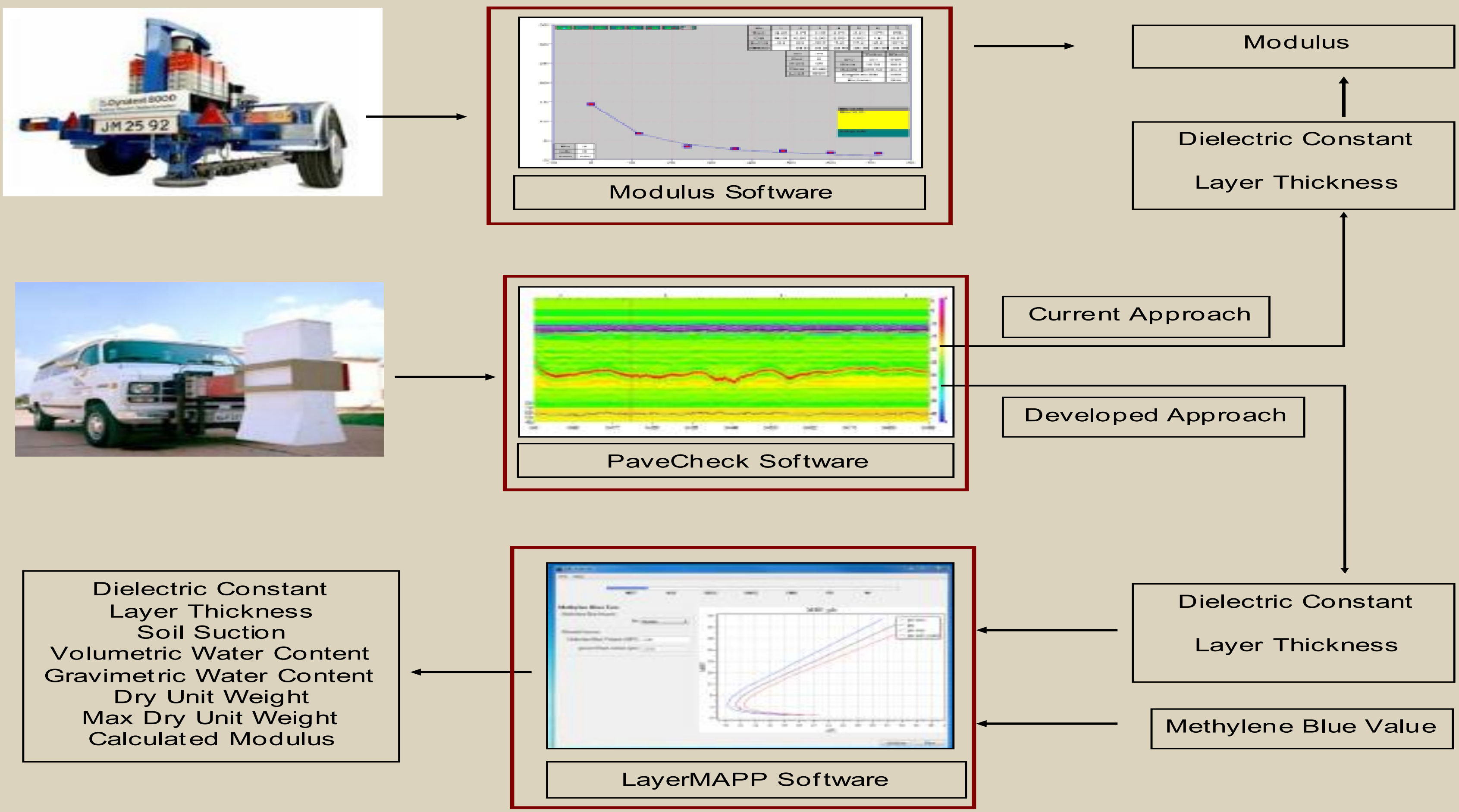


Falling Weight Deflectometer (FWD)



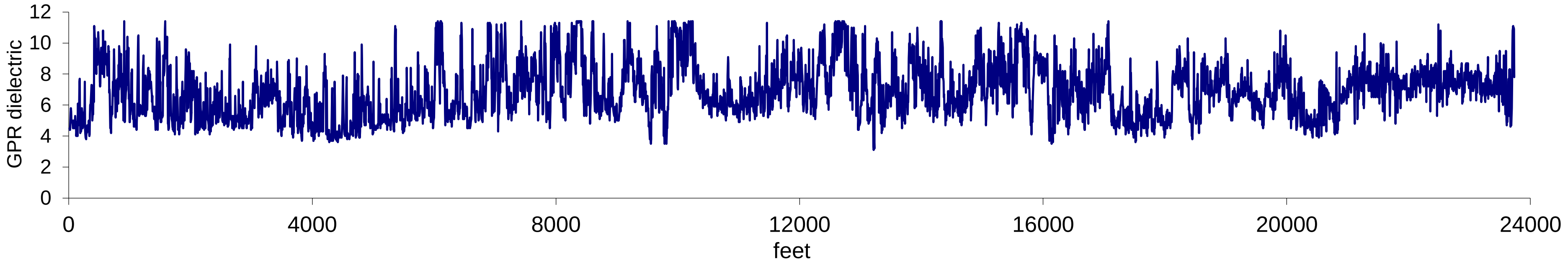
FWD Test Performing Animation Video

Field Measurements

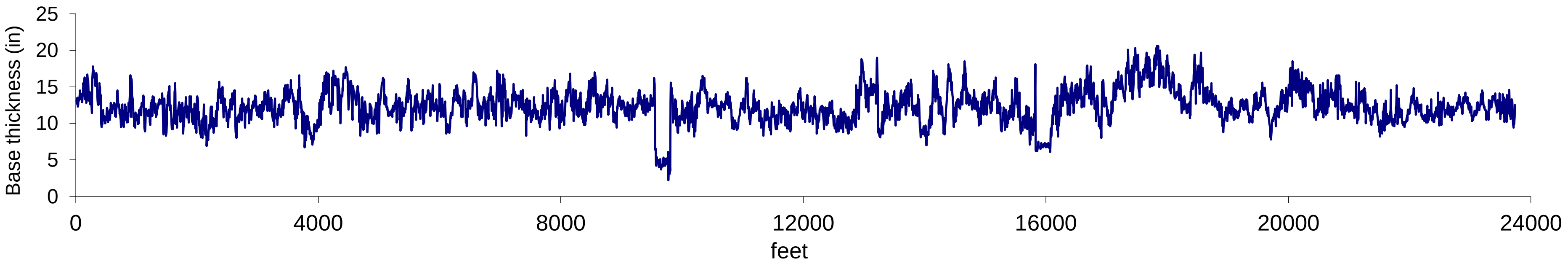


Information from GRP

Dielectric constant

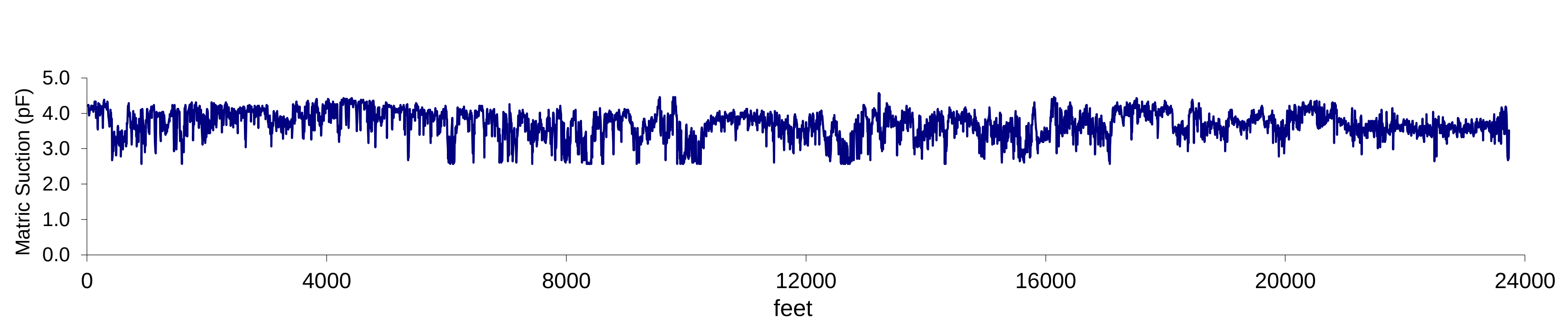


Base course thickness

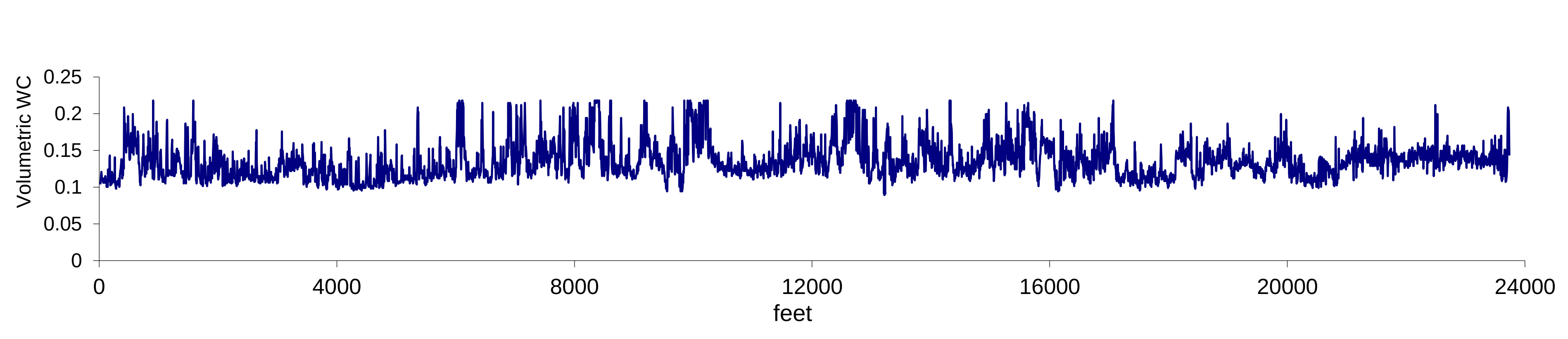


Information from GRP

Matric Suction

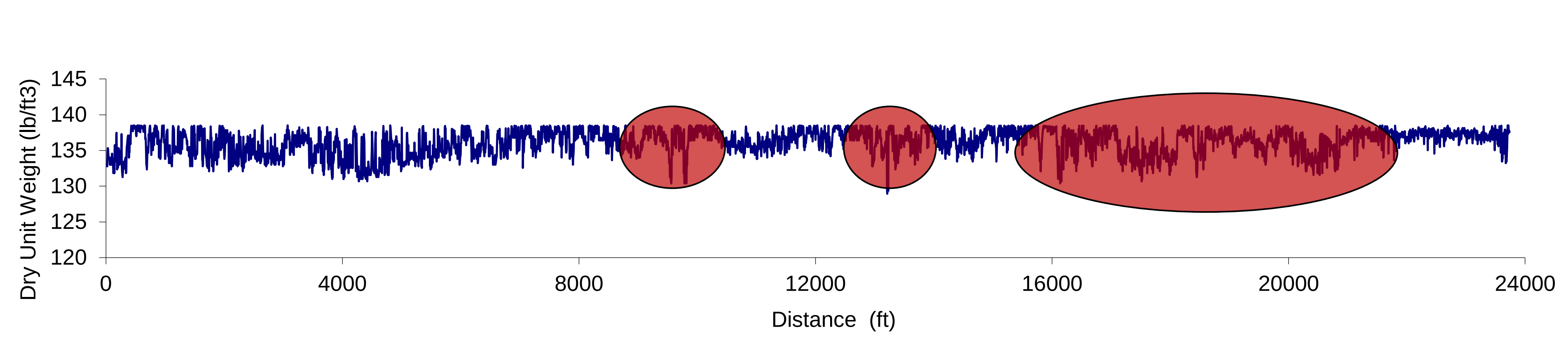


Volumetric Water Content

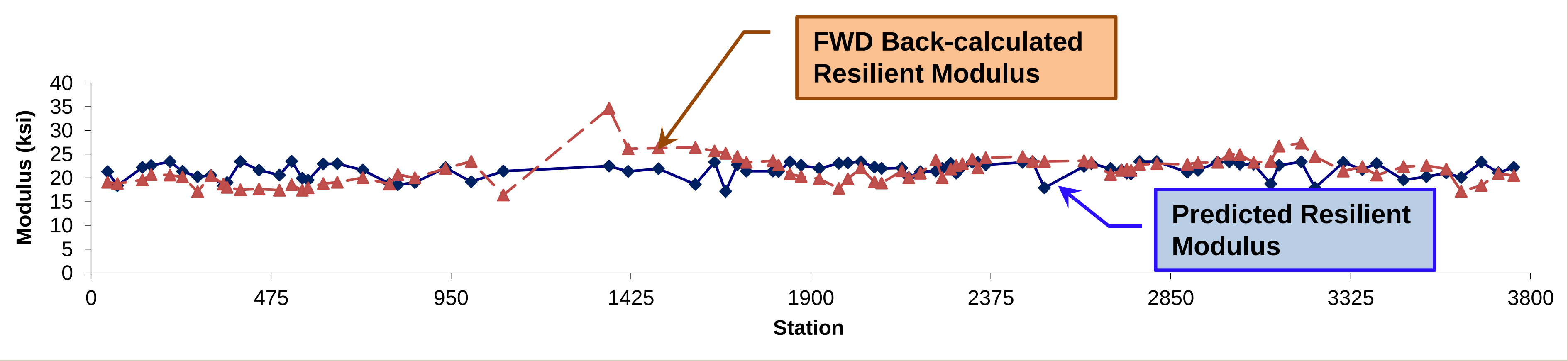


Information from GRP

Dry Density



Resilient Modulus

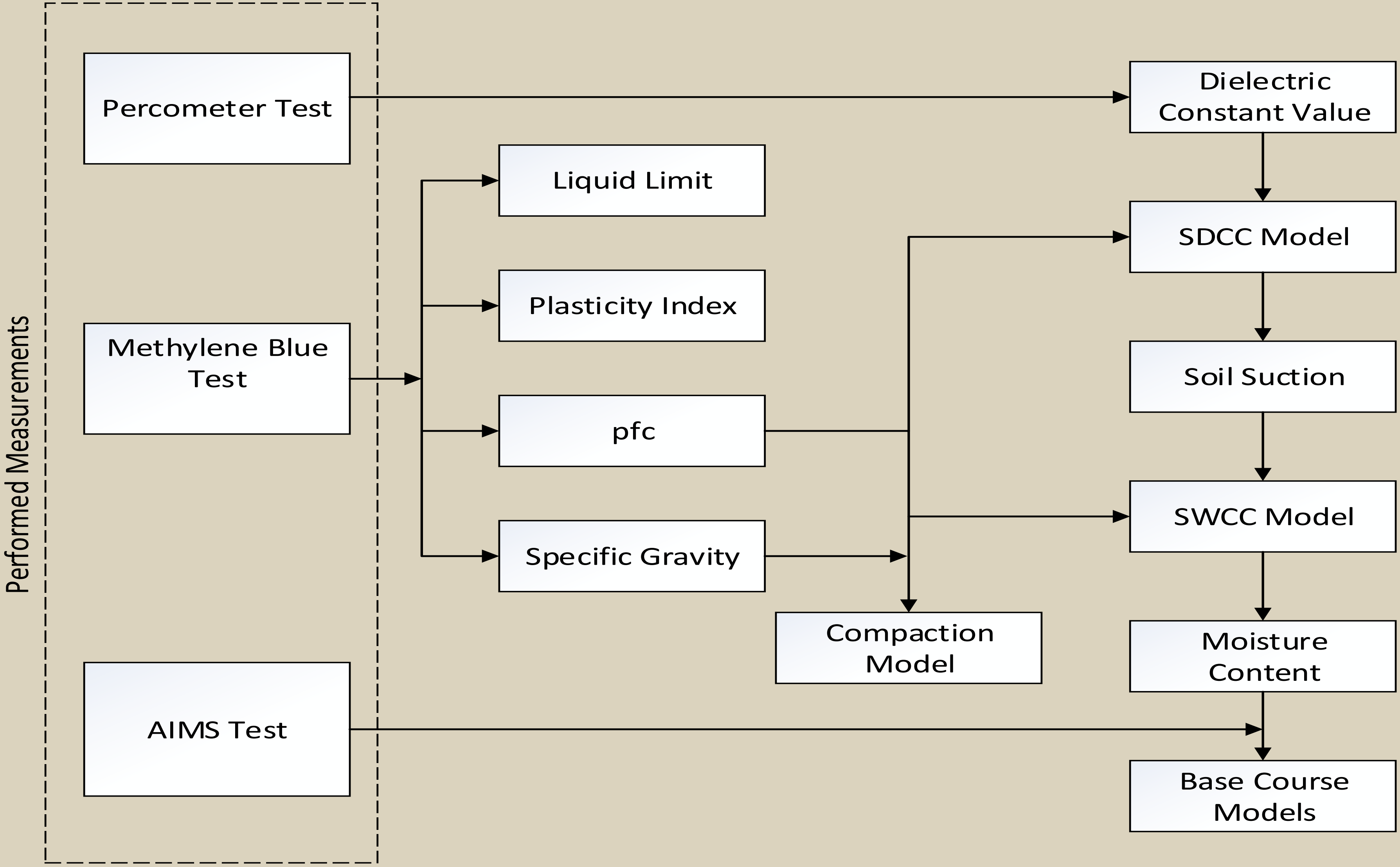


Develop a Software Program: LayerMAPP

What is LayerMAPP?

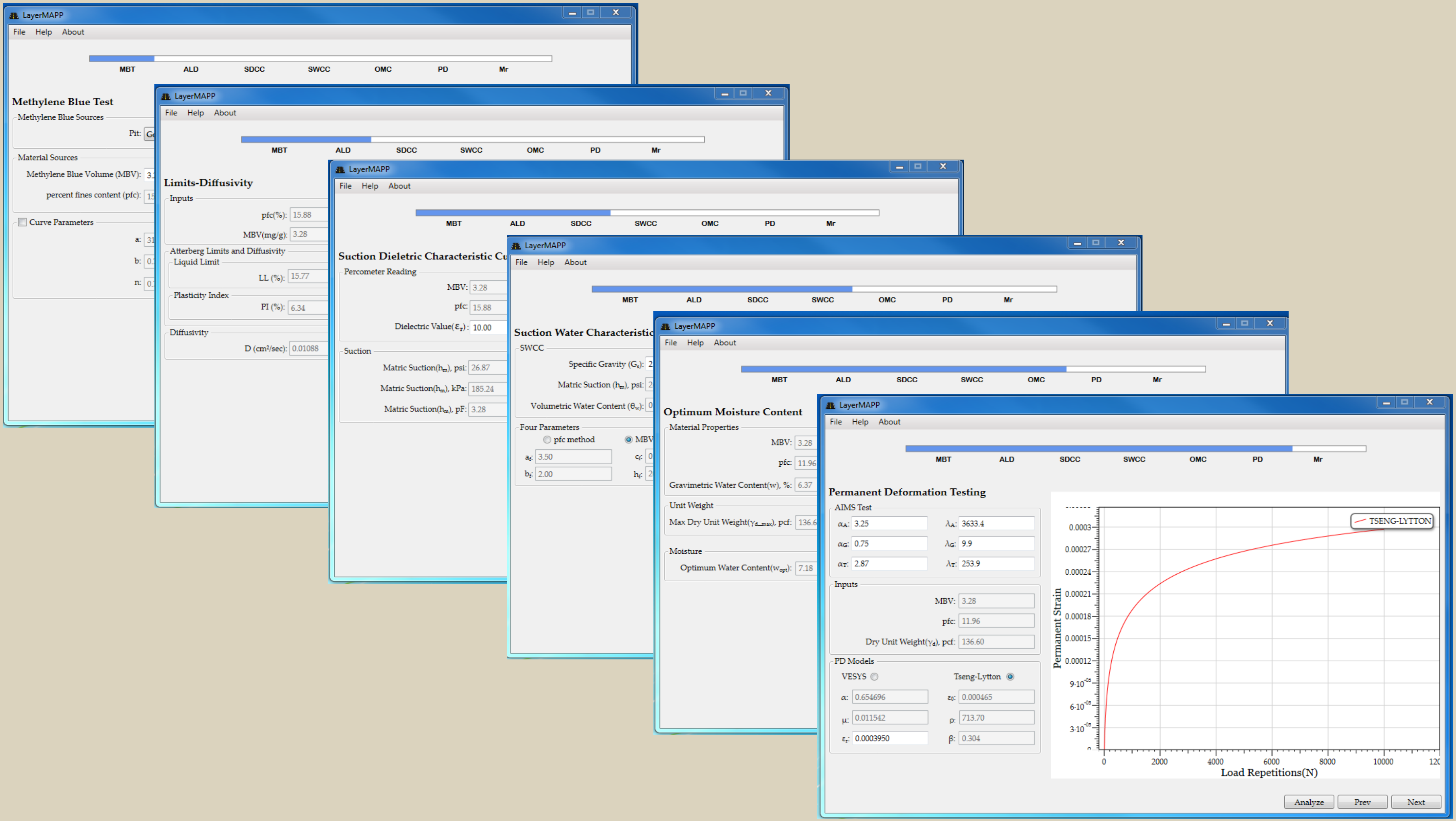
- Layer Measurement and Analysis of Performance Properties (MAPP)
- Methylene blue test, AIMS test and Percometer
- Quality control and quality assurance supporting layer analysis tool

Structures of LayerMAPP



TEXAS A&M ENGINEERING

Layer MAPP



Tests to be RUN In the FIELD

- MBT- Methylene Blue Value
- Percometer-Dielectric Constant Value

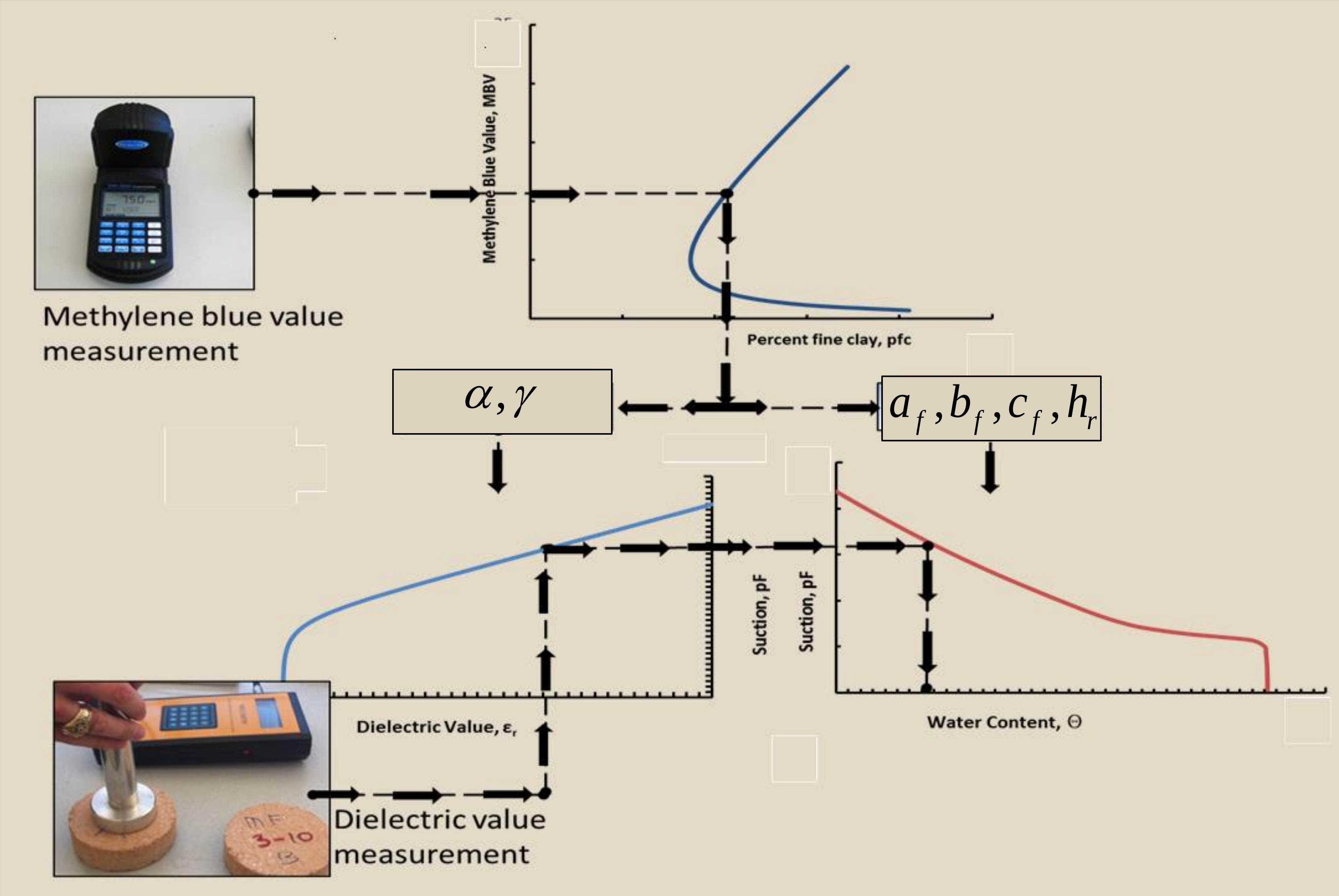
What Can be Measured in the Field?

- Percent Fines Content
- Gravimetric Water Content
- Volumetric Water Content
- Suction
- Dry Density
- Resilient Modulus
- Permanent Deformation

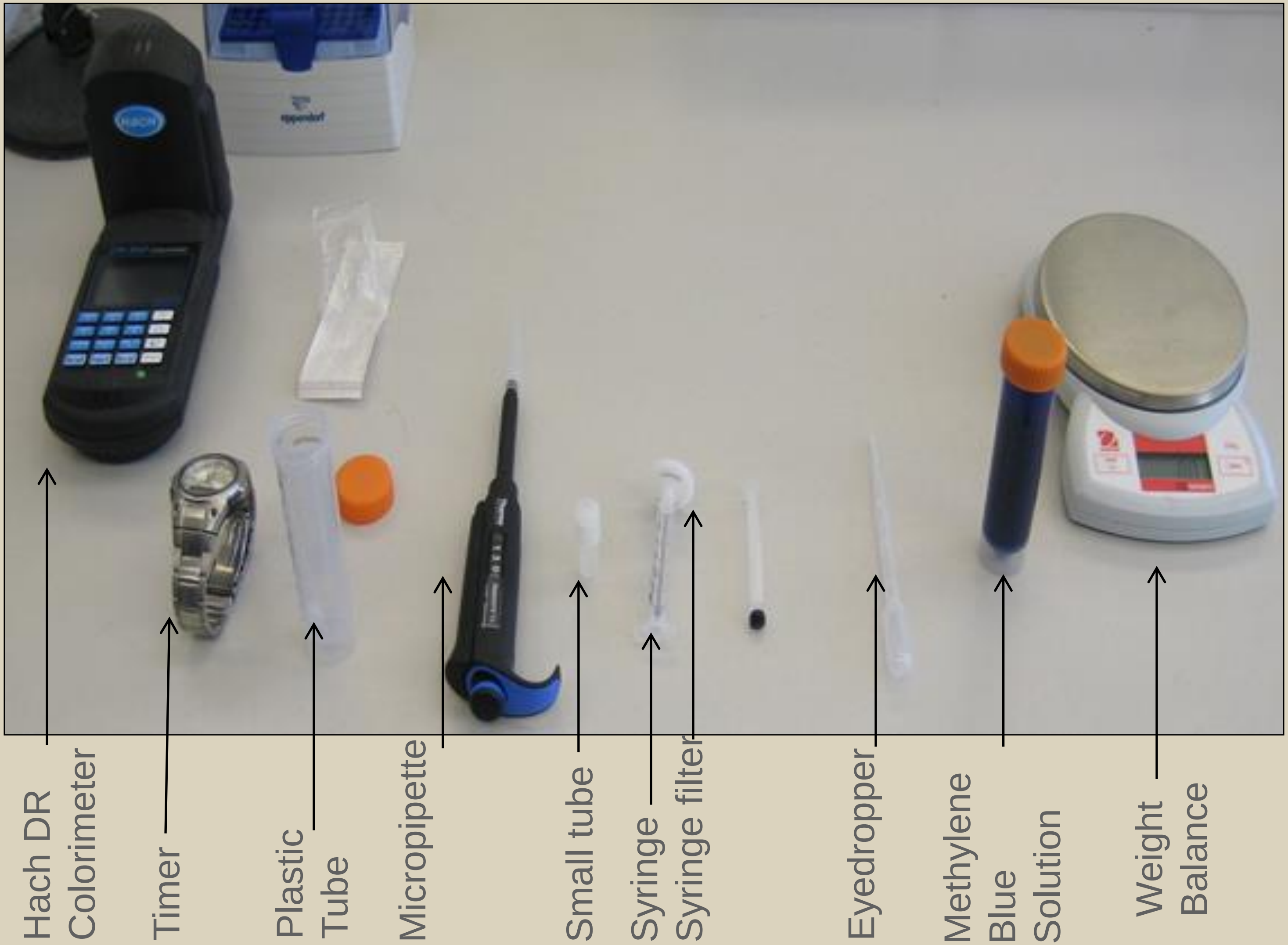
Test to Run in the LABORATORY PRIOR TO Construction

1. MBV and pfc on samples of base course
2. Suction vs Dielectric constant (matric suction with filter paper)
3. Suction vs Water volumetric content (matric suction)
4. Compaction curve (dry density vs gravimetric water content)
5. Specific gravity of solids, Gs
6. Gradation Weilbull scale and shape coefficients
7. Aggregate Imaging System: Weibull Scale and Shape coefficients for
   - Form
   - Angularity
   - Texture
8. Base course diffusivity

Matric Suction and Water Content Measurements



Methylene Blue Equipment



Dielectric Constant Measurements Process with a Percometer

Material	Dielectric Constant
Air	1.0
Water	81.0
Asphalt	4.0-6.0
Concrete	8.0-12.0
Clay	4.0-40.0

Methylene Blue Test of Soil Properties:

A Rapid and Accurate Field Test

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