New Approach for Determining Permeability of Hot Mix Asphalt

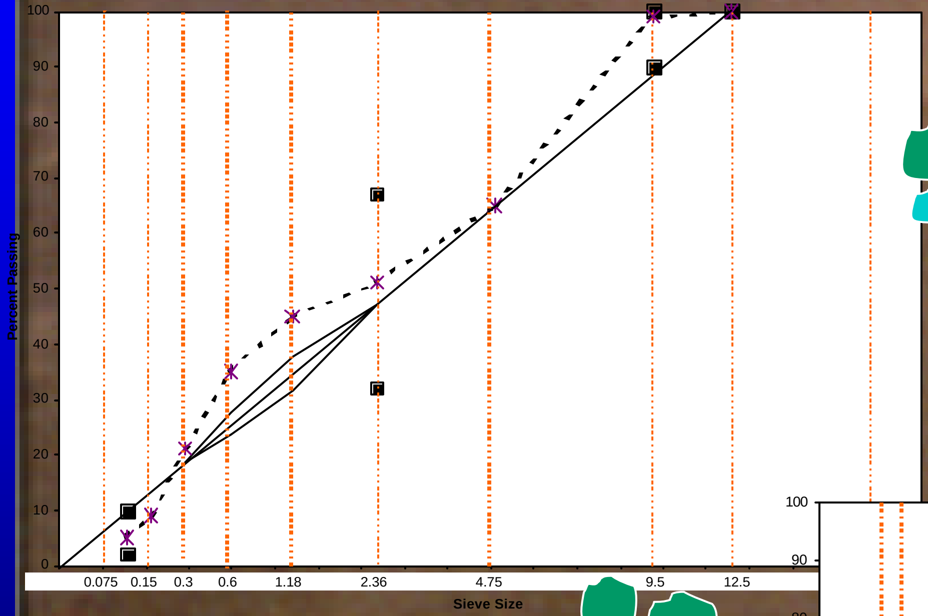
Worcester Polytechnic Institute (WPI)

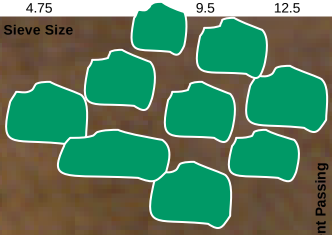
University of Massachusetts at Dartmouth

Topics

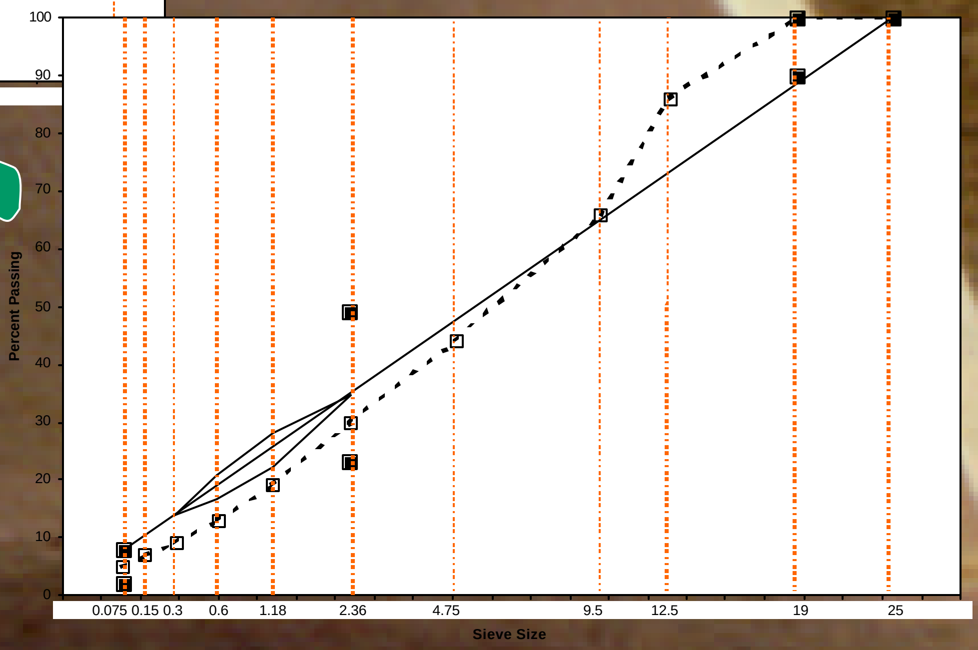
- ☞ Laboratory permeability
- ☞ Use of a different approach
- ☞ Field permeameter
- ☞ Recommendations

Why the concern?





More interconnected voids in coarse graded mixes



Objective

- Determine a test procedure for evaluation of permeability of HMA

Use of Laboratory Permeability Test

- Falling Head Permeameter used

- Samples saturated before testing

- Coefficient of permeability is determined, assuming Darcy's law is valid

Main Objectives of Mix Design

- What do we actually want to know?
  - Is the pavement going to let in too much water?
- At the construction air voids, is the pavement going to let in too much water?
- For the gradation I have, what is the desirable construction air voids such that the pavement does not let in too much water?

Approach

- Determine the amount of interconnected air voids present in the mix
- Interconnected air voids are actually water accessible air voids
- Determine the amount of water accessible air voids in an accelerated fashion.

Concept of Porosity

- Porosity is defined as
- the % air void in the compacted sample that is accessible to water.
- A sample is vacuum sealed inside a bag and a density, ρ_1 is calculated by using the method outlined in ASTM T130-01.
- The same sample while under water is opened and a second density, ρ_2 is determined.

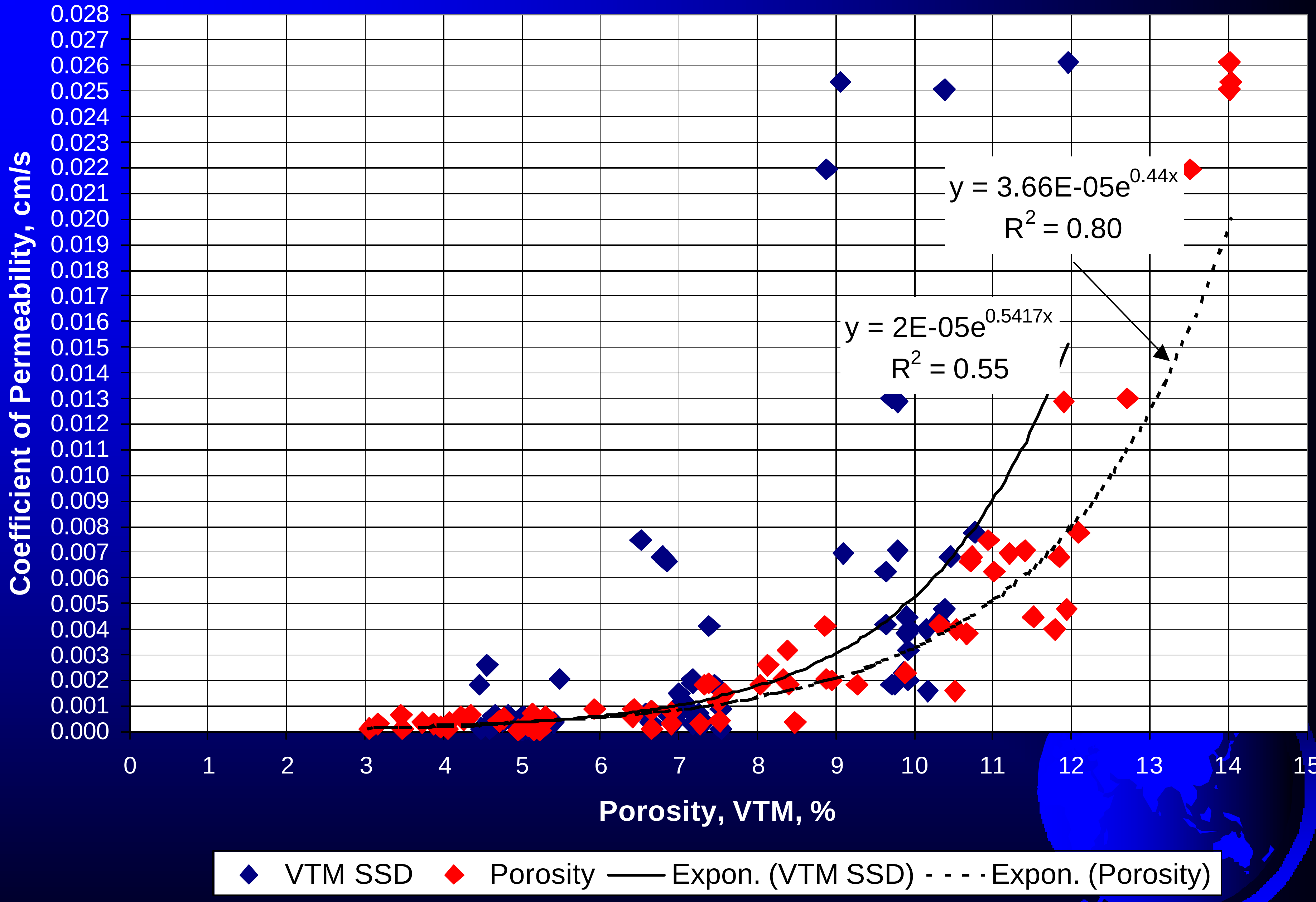
Concept of Porosity

- % Porosity = $\%P = \left(\frac{?2-?1}{?2}\right)X100$

- ρ_1= the vacuum sealed density of compacted sample
- ρ_2= density of the vacuum sealed sample after opening under water

Permeability and Porosity

- Water flows through accessible voids or pore spaces in a pavement.
- Hence, the rate of flow must be related to the amount of water accessible voids, or porosity, in some way.
- Therefore, the permeability or coefficient of permeability must be a function of porosity.



9.5 mm and 12.5 mm NMAS

Interpretation of data

- The critical porosity corresponding to a critical permeability can be determined.

- As recommended by Florida DOT researchers, considering a critical permeability of 10^{-3} cm/second,
  - a critical porosity of 7 percent is determined.

Interpretation of Data

- Therefore, mix design samples can be checked for permeability potential
- by conducting porosity tests on samples compacted to construction voids (as determined by SSD method),
- and a maximum allowable porosity value of 7 percent can be used.

Can we get an indication of porosity before we start?

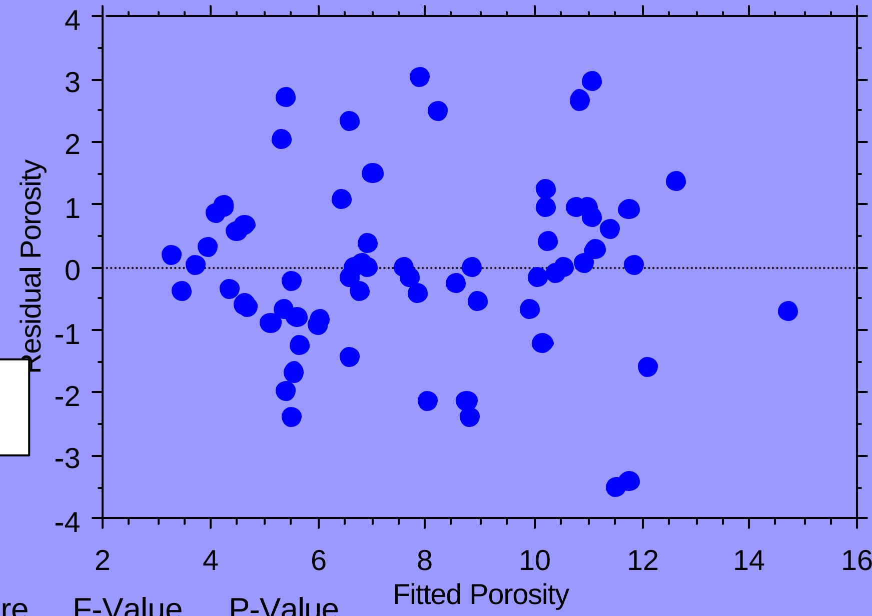
- Porosity has been defined as total amount of water accessible voids in a mix.
- How can one estimate the porosity from knowledge of mix gradation and air voids?
- Multiple regression analysis conducted with porosity, air voids and aggregate gradation data.

Regression Summary
Porosity vs. 2 Independents
Row exclusion: perm #1_12.5_9.5.svd

Count	68
Num. Missing	3
|R|	.897
R Squared	.804
Adjusted R Squared	.798
RMS Residual	1.406

Porosity = 3.47 + 12.6 * VTM – 0.127 * PP 2.36

Residuals vs. Fitted
Row exclusion: perm #1_12.5_9.5.svd

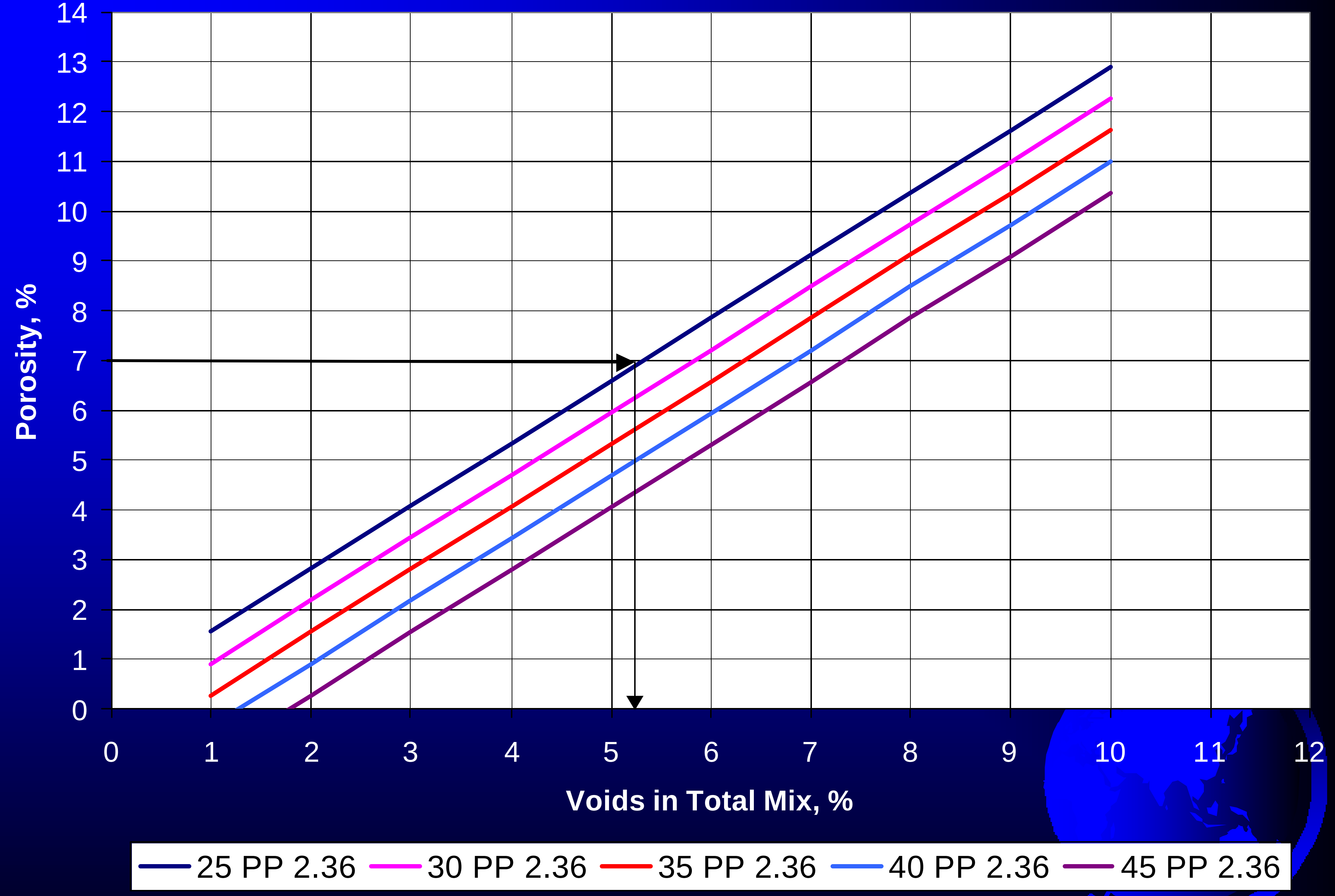


ANOVA Table
Porosity vs. 2 Independents
Row exclusion: perm #1_12.5_9.5.svd

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	2	526.694	263.347	133.281	<.0001
Residual	65	128.432	1.976		
Total	67	655.126			

Regression Coefficients
Porosity vs. 2 Independents
Row exclusion: perm #1_12.5_9.5.svd

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	3.472	1.225	3.472	2.834	.0061
Air Voids, SSD	1.260	.080	.861	15.686	<.0001
PP2.36	-.127	.028	-.251	-4.575	<.0001



14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Porosity, %
0
1
2
3
4
5
6
7
8
9
10
11
12
Voids in Total Mix, %
25 PP 2.36
30 PP 2.36
35 PP 2.36
40 PP 2.36
45 PP 2.36

Critial air voids for mixes with different gradations

Percent passing the 2.36 mm sieve	Critical Air Voids
25	5
30	6
35	6.5
40	7
45	7.5

Note

– For a mix with approximately 45 percent passing the 2.36 mm sieve

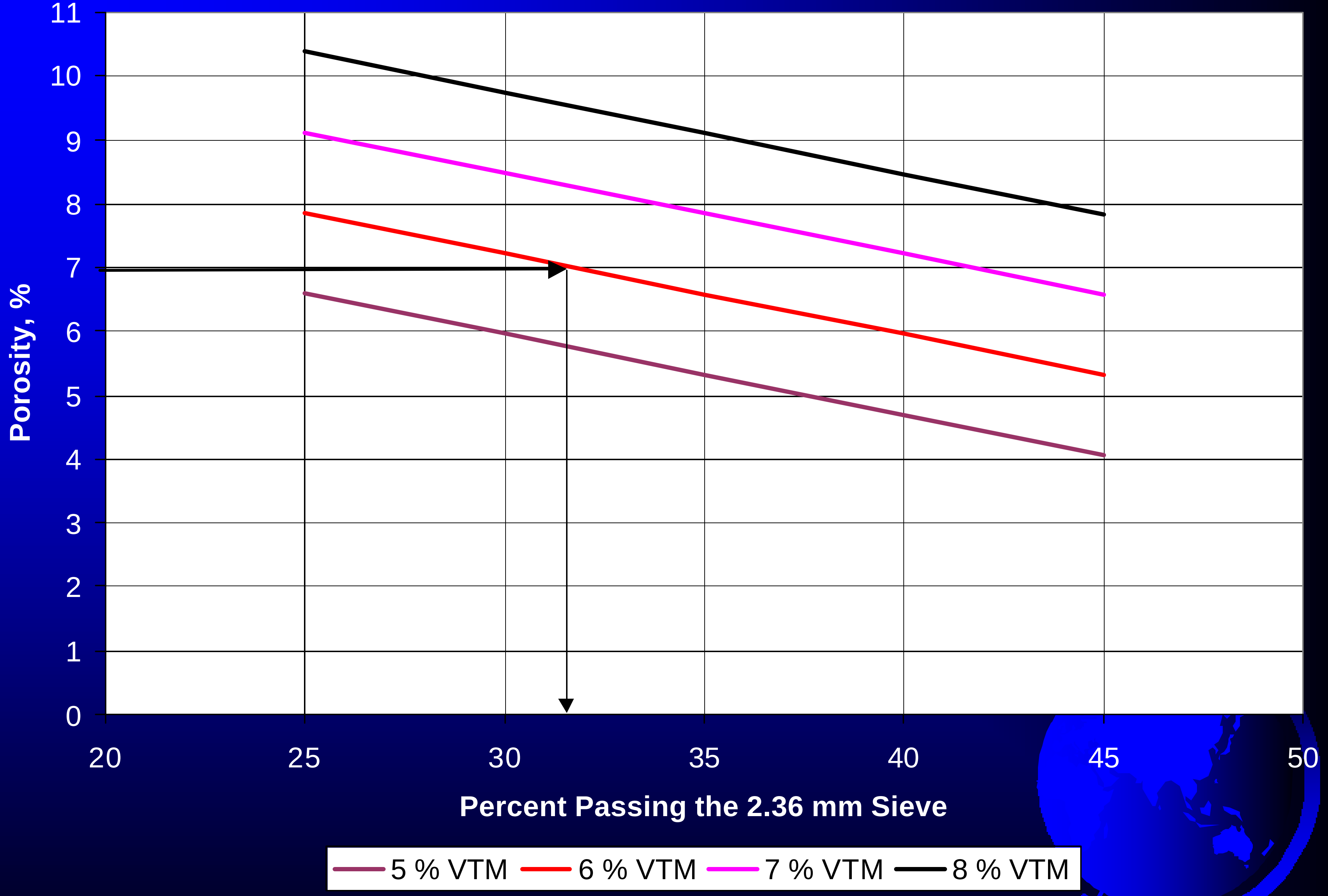
– A porosity of 7 percent corresponds to VTM of 7 percent

– Most of experiences from the past (in the pre-Superpave era) has been with mixes with 40-45 percent passing the 2.36 mm sieve

Note

– A density of 93 percent of TMD or VTM of 7 percent has often been recommended and used, without any significant permeability problem.

– Therefore, the selection of 7 percent porosity as a critical porosity seems to be justified.



11
10
9
8
7
6
5
4
3
2
1
0
Porosity, %
20
25
30
35
40
45
50
Percent Passing the 2.36 mm Sieve
5 % VTM
6 % VTM
7 % VTM
8 % VTM

List of critical percent passing the 2.36 mm sieve for specific air voids

Air Voids	Allowable percent passing the 2.36 mm sieve
5	> 25
6	> 31
7	> 41
8	> 45

Permeability or Porosity?

- Which parameter should be used during mix design to prevent mixes from being excessively permeable –
- Is it permeability test or is it porosity test?
- Measuring permeability is a more direct approach.
- Porosity shows a very good relationship with permeability

Permeability or Porosity?

- Porosity is a good mix design parameter candidate
- Argument becomes stronger when one considers the coefficient of variation of the permeability and the porosity tests.
- The average CV for permeability testing is about three times the average CV of porosity.

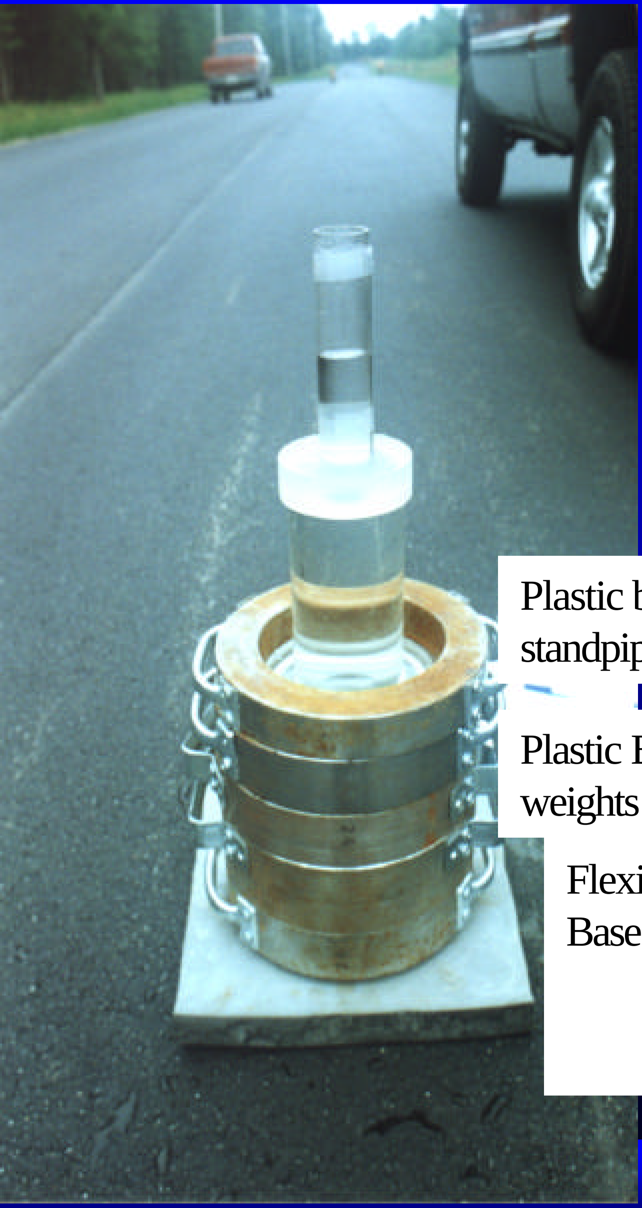
Permeability or Porosity?

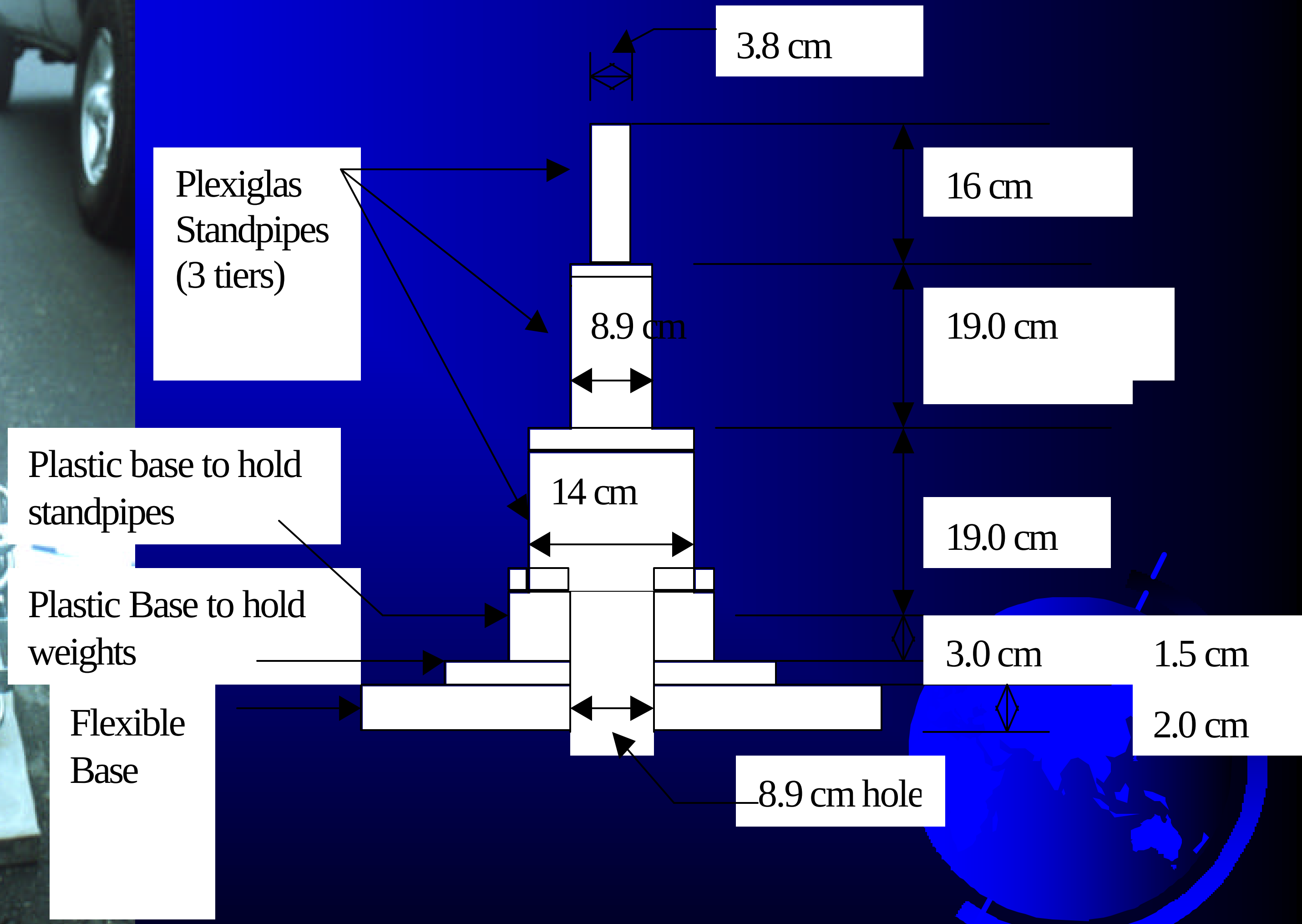
- Hence, as a regular test procedure, because of better repeatability,
- Porosity seems to be more appropriate than permeability.

What about field permeability?

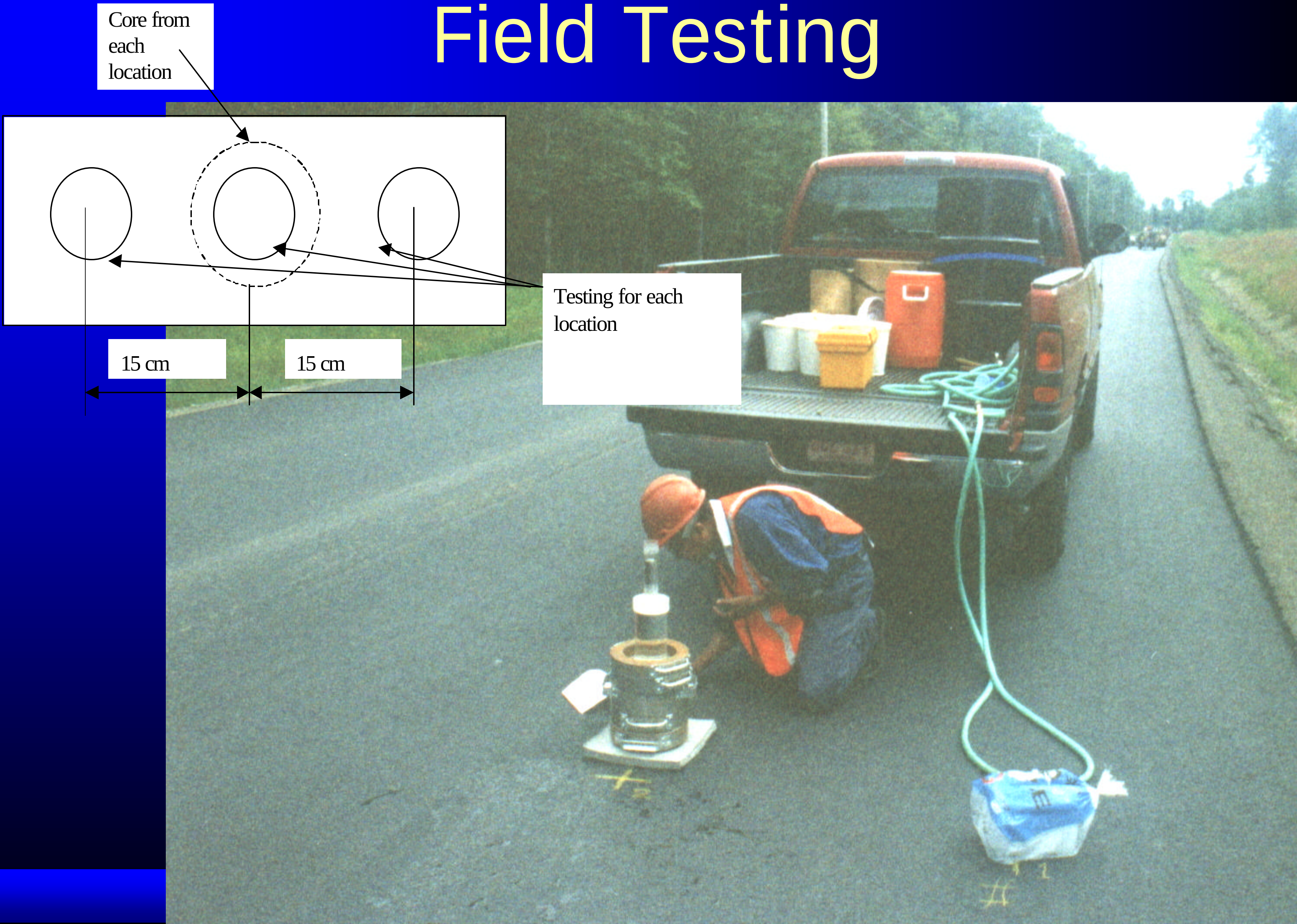
- Can we use it as a quality control tool?
- Can we use it for getting a true picture of flow through porous media?
- Can we use it to determine permeability in different directions?

Field Permeameter

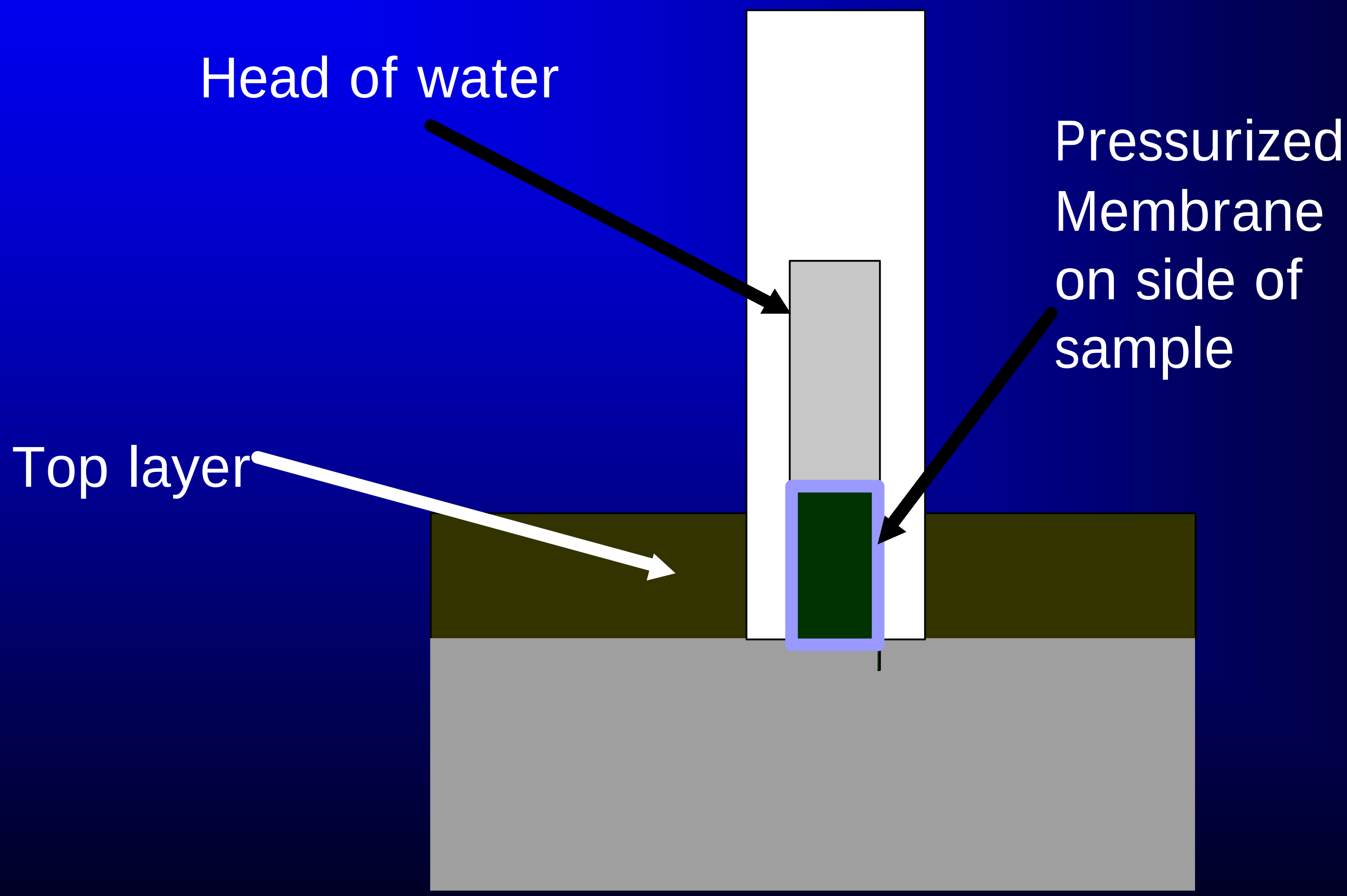




Field Testing



New Field Permeameter



New Permeameter

- ☞ Same equipment for lab and field test
- ☞ Basically falling head or constant head test
- ☞ Cuts down variability of results from using different equipment in lab and field

PROTOTYPE

Mobile Cart

- Laptop
- On-board water pressure tank (20 gal, 30 psi precharge)
- Core rig
- Valve assembly
- Permeameter in foreground

NEW PERMEAMETER

General

- Laptop PCMCIA data acquisition
- Differential/gauge pressure for head pressure, LVDT for volume change

Field

- 4” ID, 5” OD ring cored 3” Deep (100mm x 63.5mm)

Lab

- 6” diameter by 4” tall specimen (150mm x 100mm)

PROPOSED PROCEDURE (Field)

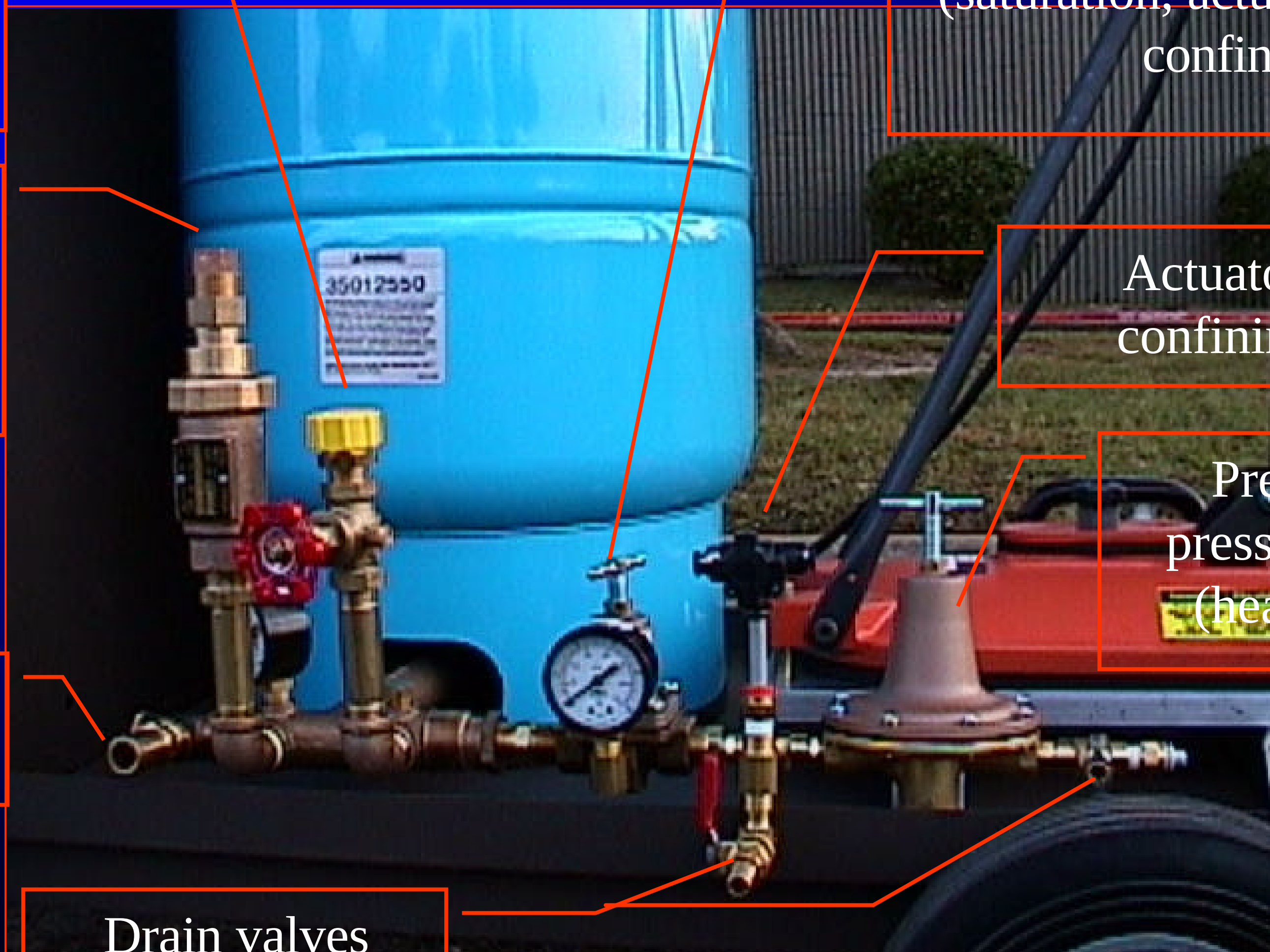
- Core & remove a ½” ring 3” deep
- Set permeameter in groove
- Saturate, charge actuator, & apply confining pressure equal to or higher than max head pressure to be applied
- Start data acquisition
- Open valve to apply head pressure
- Stop data acquisition when actuator is full down
- Bleed pressures, remove permeameter & patch “moat”

PROPOSED PROCEDURE (Lab)

- Same as field except without the coring and patching
- Test will need to be done over a floor or sink drain
- Confining cell for lab is interchangeable with smaller field cell via quick disconnects

4” CORE BARREL INSIDE 5” CORE BARREL

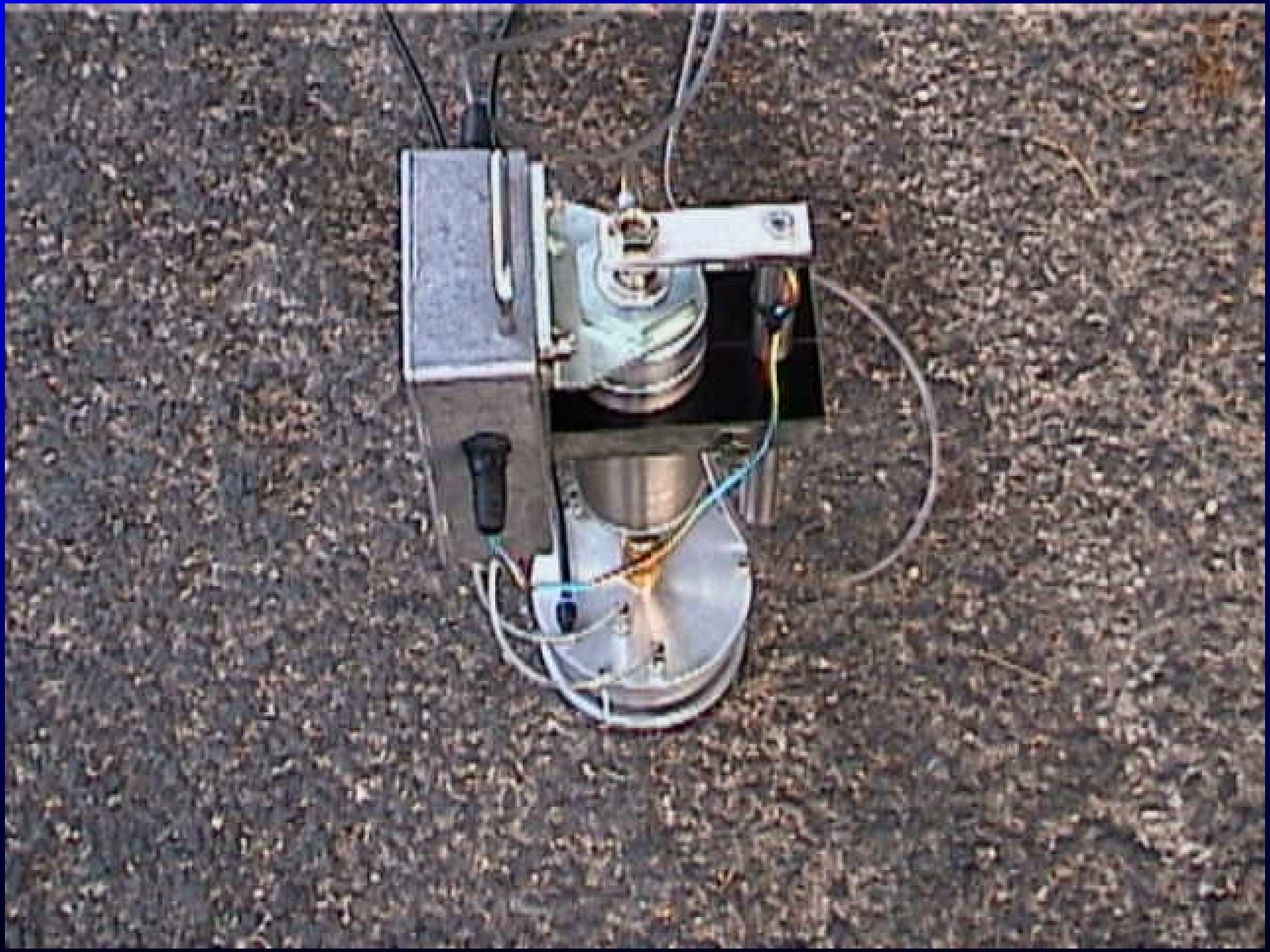
VALVE ASSEMBLY



PERMEAMETER ASSEMBLY

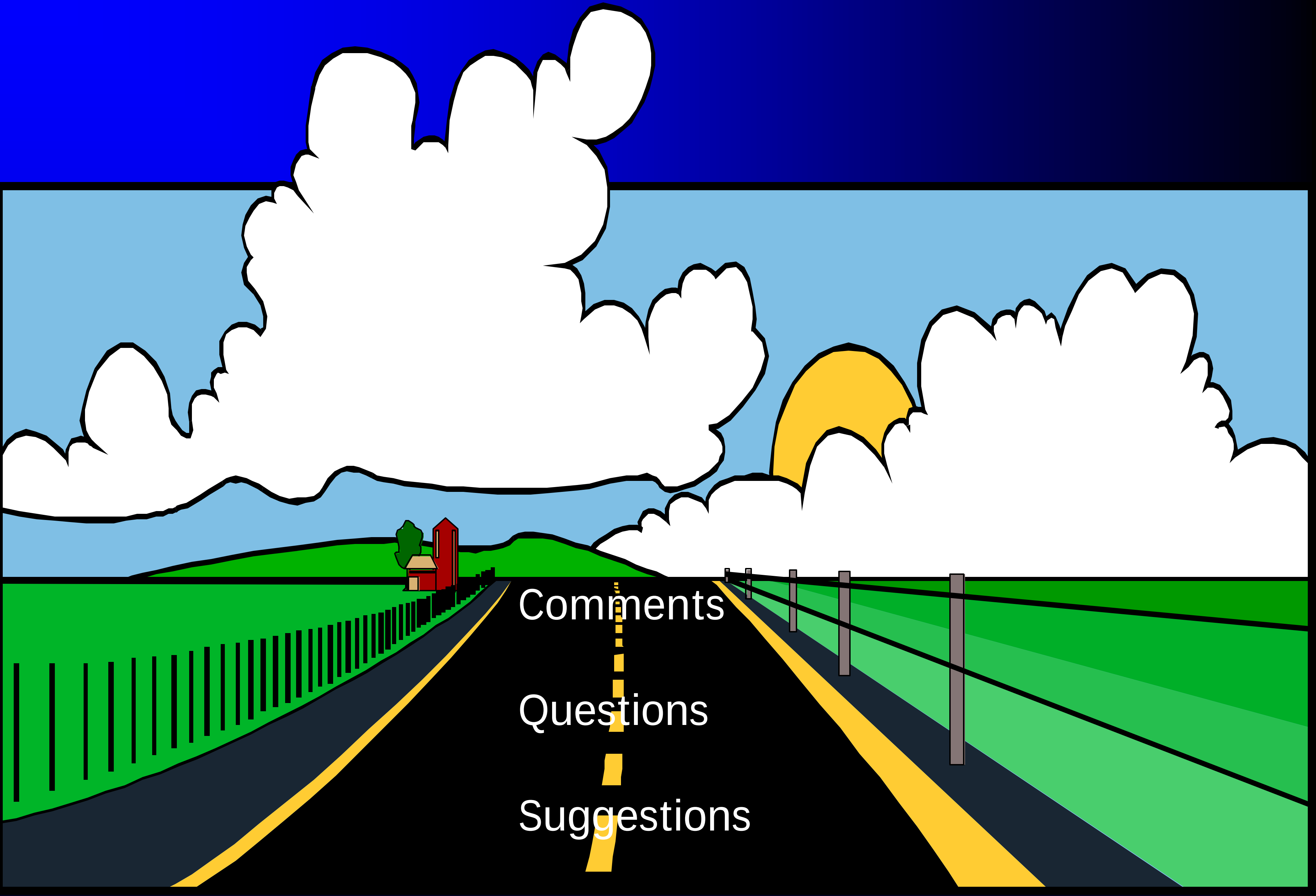
- Upper box assembly has electronics, actuator, and LVDT
- Lower permeameter cell

TOP VIEW OF PERMEAMETER ASSEMBLY



Recommendations

- Use porosity as an indicator of mix permeability
- Estimate porosity and use estimated porosity to select gradation or desirable construction air voids
- Conduct porosity test on mix design samples at construction air voids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Questions
Suggestions