ACI Session: Design and Construction of Concrete Streets and Local Roads

Sponsored by ACI Committee 325 – Concrete Pavements

Tue, October 22, 2019 11:00 AM - 1:00 PM, C-Junior Ballroom B

AIA/ICC approved for 2 CEU/PDH credits

- Investigating and Characterizing Soils for Use in Local Road Concrete Pavement Design
- Cement Based Pavement Design Methods and Tools for the Practitioner
- Construction and Jointing of Local Concrete Roads: State of the Practice
- Concrete Overlays for Streets and Roads

ACI Session: Design and Construction of Concrete Streets and Local Roads

Investigating and Characterizing Soils for Use in Local Road Concrete Pavement Design

Brian Killingsworth, P.E.

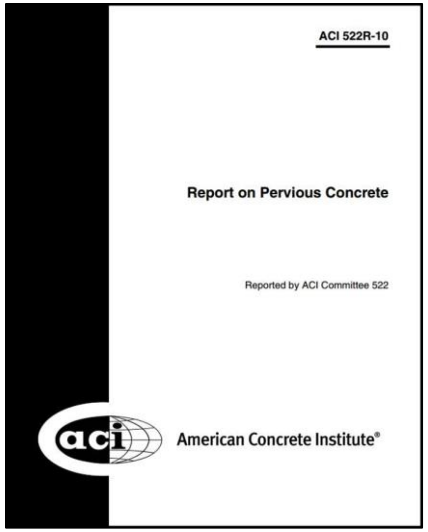
Tuesday, October 22, 2019

ACI Fall Convention

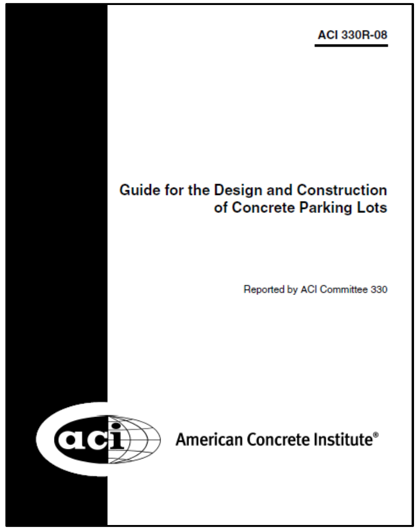
Cincinnati, OH

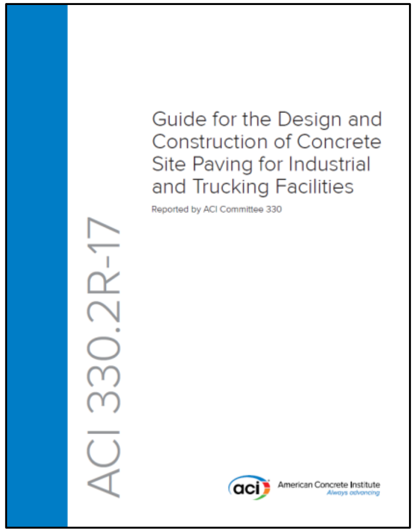
ACI Pavement Design & Construction

- ACI 325.9R-15 Guide for Construction of Concrete Pavements
- ACI 325.11R-19 Accelerated Techniques for Concrete Paving
- ACI 325.12R-02(13) Guide for Design of Jointed Concrete Pavements for Streets and Local Roads
- ACI 325.13R-06: Concrete Overlays for Pavement Rehabilitation
- ACI 325.14R-17 Guide for Design and Proportioning for Concrete Pavements
- ACI 325.YR Report on Precast Concrete Pavements - State of the Practice
- ACI 325.ZR: Design and Construction of Continuously Reinforced Concrete Pavements

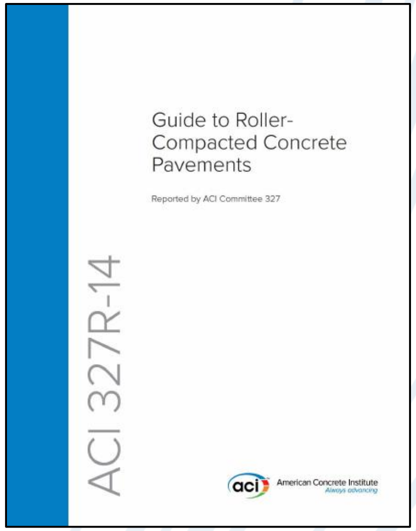


522: Pervious





330: Parking Lot & Industrial



327: Roller Compacted

ACI Pavement Suite of Documents

ACI 325.12R Guide for Design of Jointed Concrete Pavements for Streets and Local Roads

ACI 325.12R-02

Guide for Design of Jointed Concrete Pavements for Streets and Local Roads

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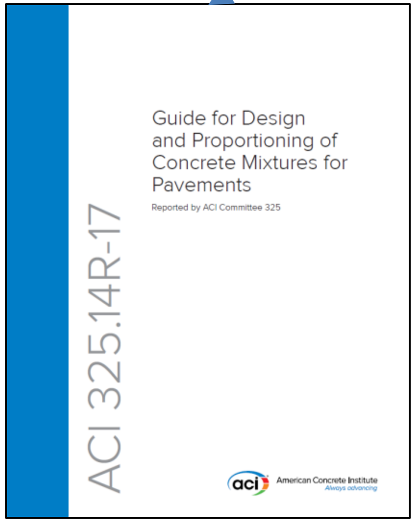
ACI 325.12R


ACI 325.14R-17

Guide for Design and Proportioning of Concrete Mixtures for Pavements

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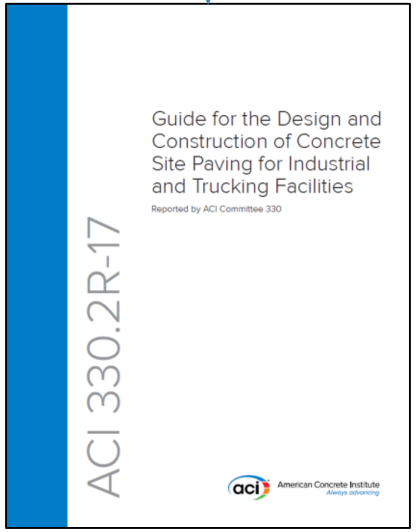
Proportioning


ACI 330.2R-17

Guide for the Design and Construction of Concrete Site Paving for Industrial and Trucking Facilities

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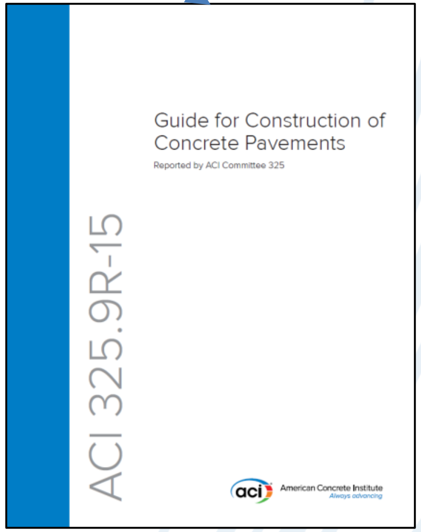
Industrial


ACI 325.9R-15

Guide for Construction of Concrete Pavements

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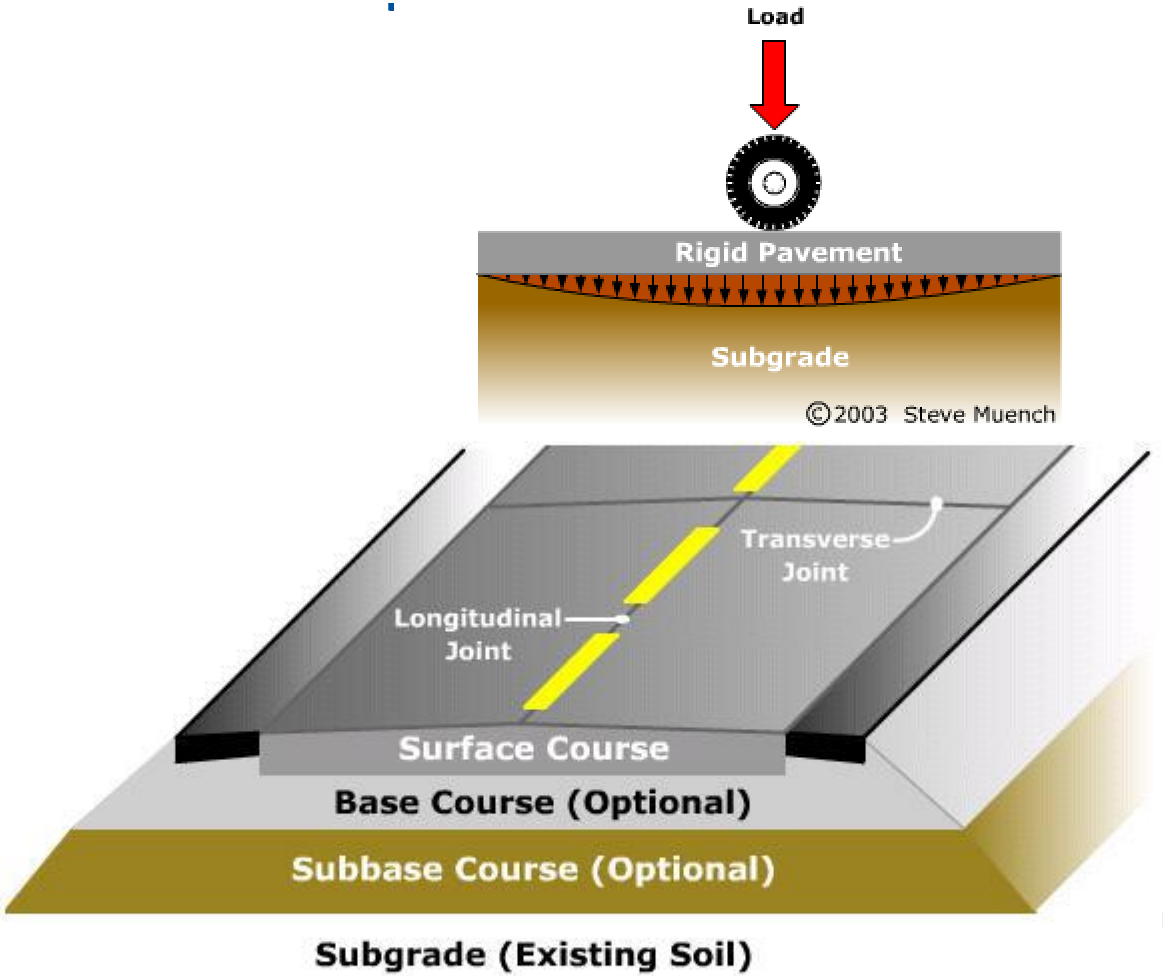
Construction

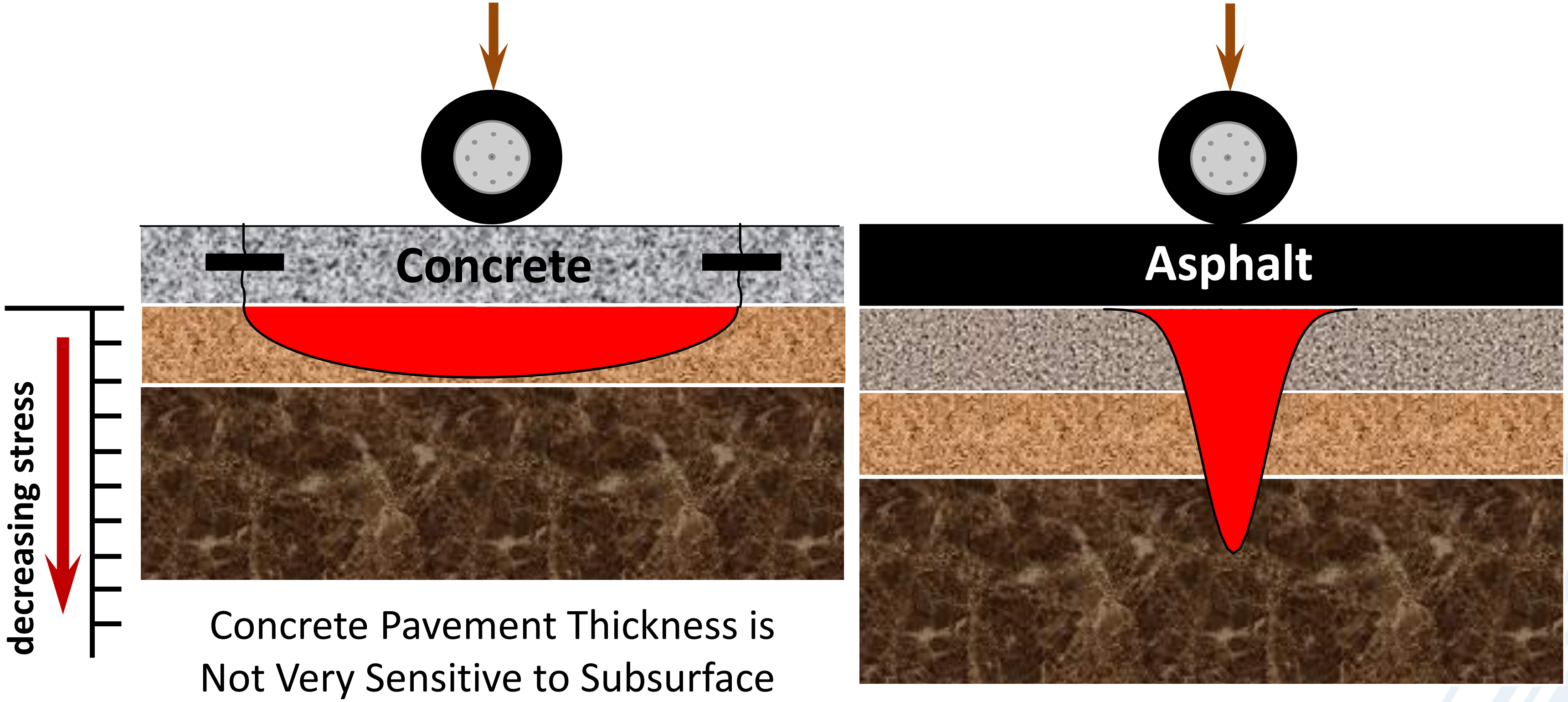
Rigid Pavement Typical Cross Section

- Structure
  - Surface course
  - Base course
  - Subbase course
  - Subgrade



Pavements & Loads – Concrete vs. Asphalt

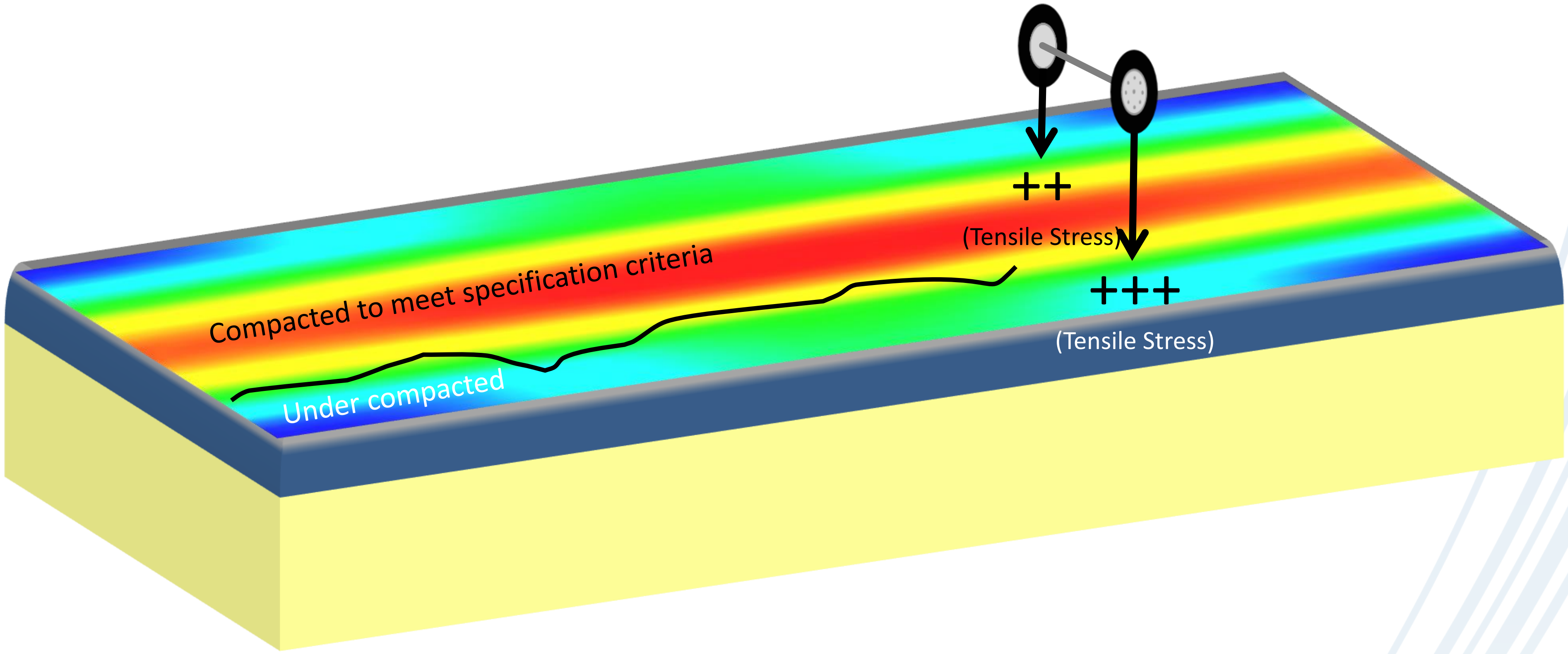
Subgrade stresses differ considerably.



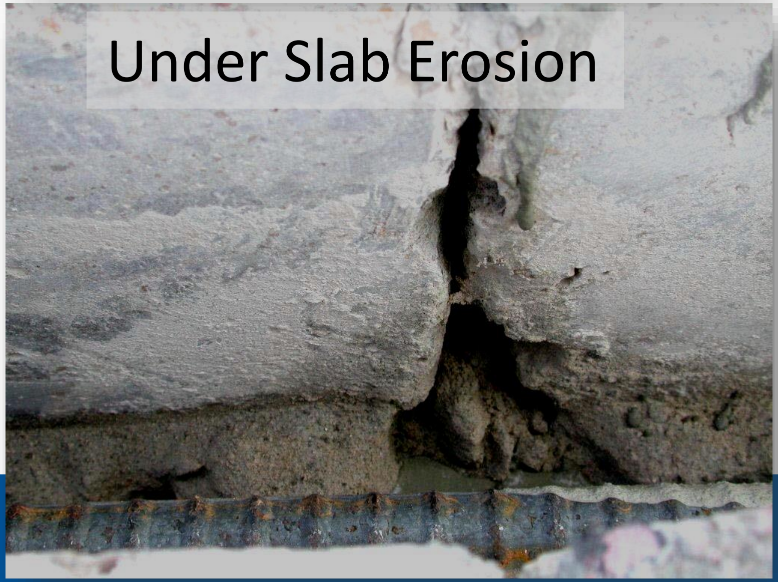
Concrete Pavement Thickness is Not Very Sensitive to Subsurface Strength.

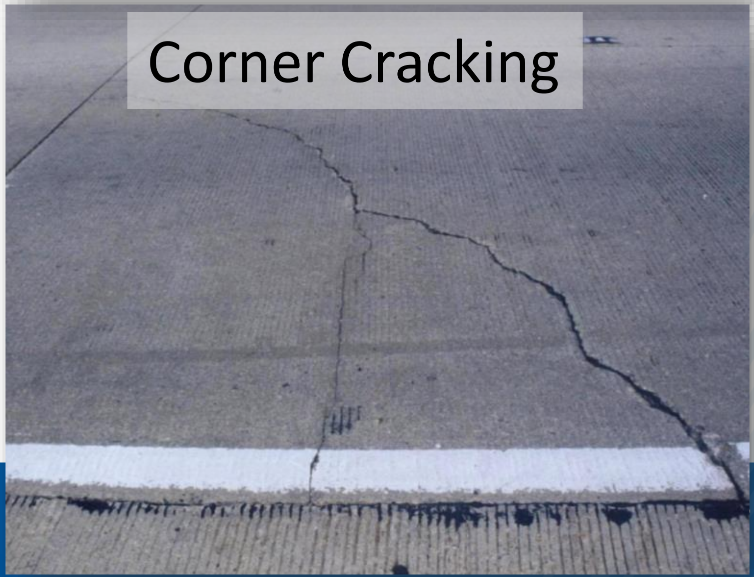
Source: www.pavementinteractive.com

Support Uniformity vs. Strength Under Concrete Pavements

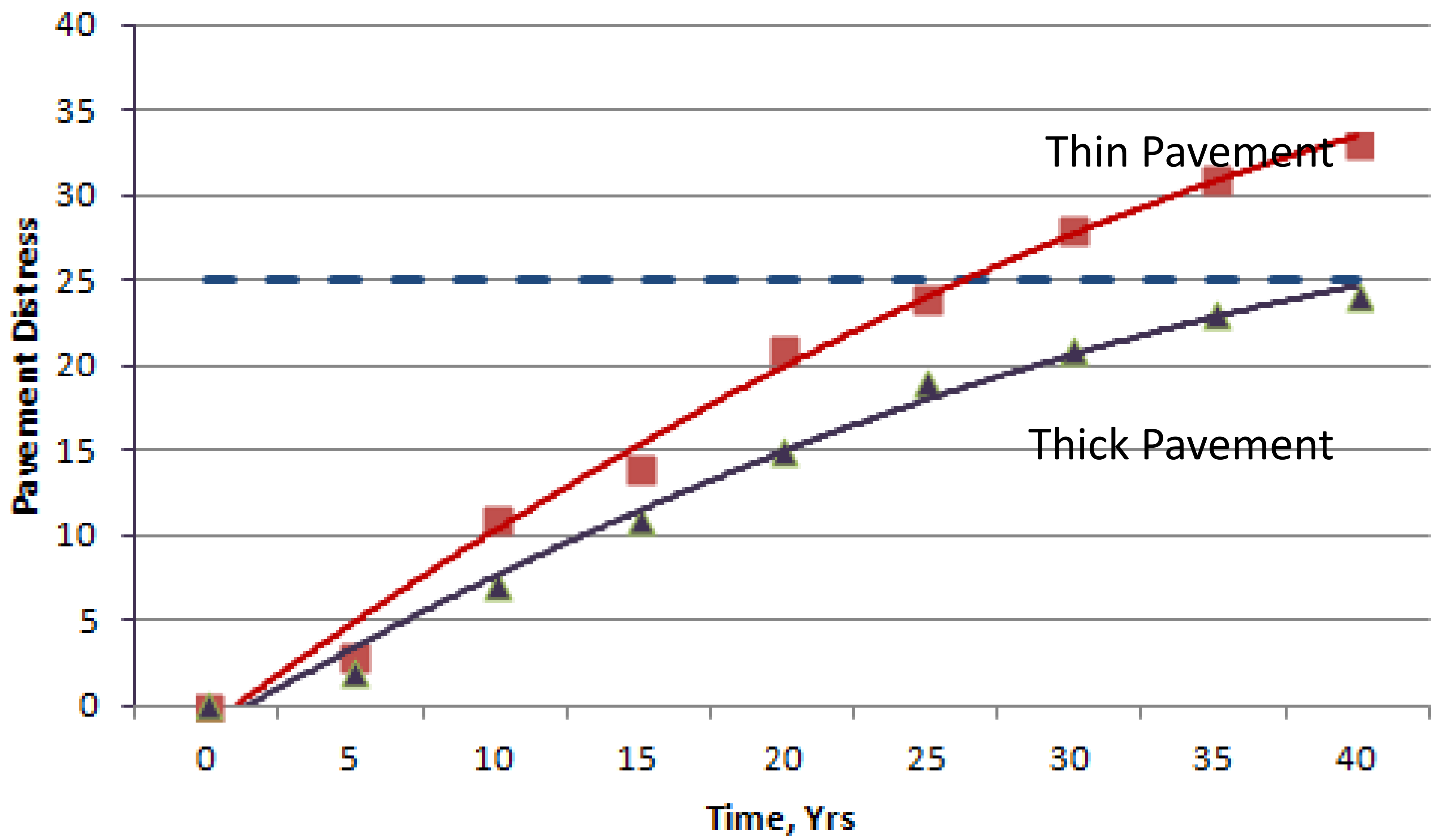


Design to Minimize Key Distresses



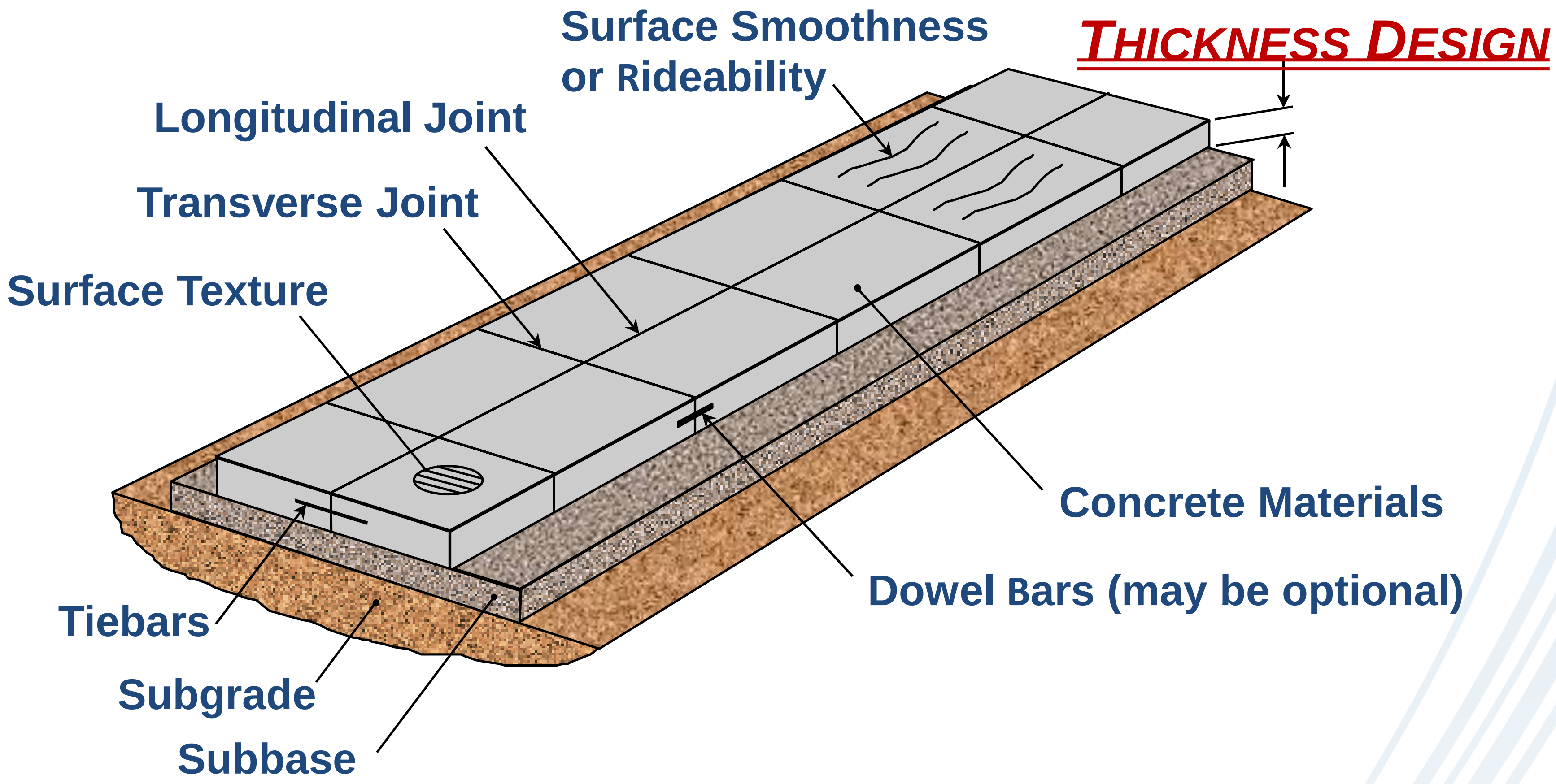


Pavement Distress Development



Convention
Exposition

Pavement Design



Concrete Pavement Design

- Thickness Determination, Based on:
  - Design life
  - Traffic loads & frequencies
  - Concrete strength
  - *Subgrade/subbase support (strength characterization)*

- Jointing & Reinforcement:
  - Load transfer considerations
  - Prevention of uncontrolled cracking

- Other Design Considerations:
  - Grades & drainage
  - Edge support conditions (e.g. curb & gutter, shoulder…)
  - Pavement/subsurface interaction

Suitability of Subgrade Soils

- Classification (Gradation, Atterberg Limits, etc.)
- Depth to Bedrock
- Depth to Water Table
- Potential for Compaction
- Presence of Weak or Soft Layers or Organics
- Susceptibility to Frost Action or Excessive Swell
- Soil Strength Characteristics

Soil/Subbase Strength Characterization

- Soil Support Value (SSV)
- Resistance Value (R-Value)
- California Bearing Ratio (CBR)
- Resilient Modulus (M_r)
- Modulus of Subgrade Reaction (k-value)

Data Collection Activities - Drilling

- Geotechnical Drilling (New Street Pavements)
  - Minimum 5 feet below final top of subgrade elevation**
  - Spacing a function of roadway type and soil conditions
  - High plasticity soils increase drilling depth to 10 to 15 feet
  - Materials for strength testing must be representative of subgrade soil supporting pavement materials
  - May require larger augers at some boring locations

- Geotechnical Drilling (Existing Street Pavements)
  - Obtain existing pavement thicknesses
  - Spacing as stated above
  - Drilling depths as stated above
  - Materials for soil strength as stated above
  - Consider test pits if full depth reclamation is possible

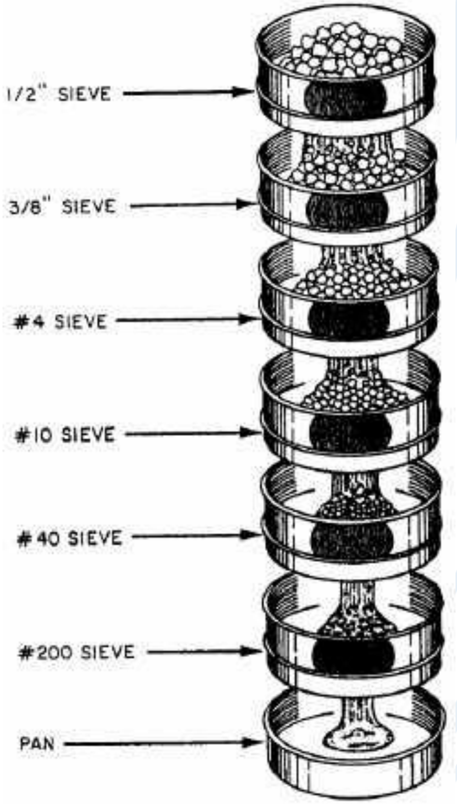
**Airport, Industrial, and Port Facilities may be different!

Subgrade Foundation Soils

- Geotechnical Engineering Report
  - Borings Logs
  - Standard Penetration Test (SPT) blows/ft
  - Material Descriptions
  - Atterberg Limits (LL, PL, PI)
  - Density
  - % Swell (freeze and/or moisture related)
  - Subgrade Strength Characterization

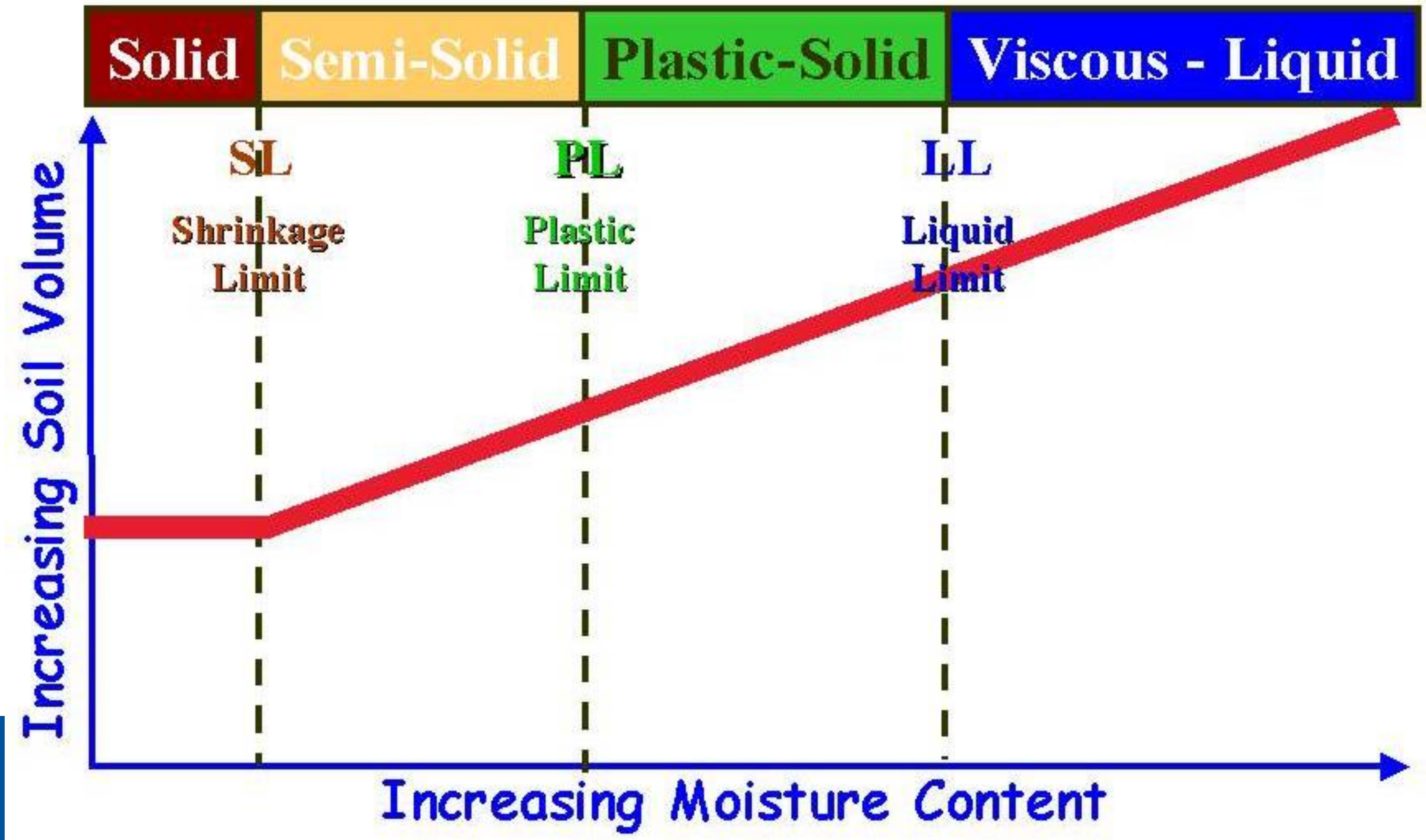
Soil Classification

- Course or Fine Grained
- Typically Classified as:
  - Gravel
  - Sand
  - Silt
  - Clay (Lean or Fat: Based on Plasticity*)
  - Or a combination of any of the above
    - e.g. Sandy Gravel With Clay



*Soil plasticity refers to the manner in which water interacts with the soil particles.

States of Consistency for Cohesive Soils (Soil Passing #40 Sieve)



Atterberg Limits

- Liquid Limit (LL)
- Plastic Limit (PL)
- Plasticity Index (PI)
- PI = LL - PL

PI indicates soils reaction to water content.

Albert Atterberg
1846-1916

Common Classification Systems

- Unified Soil Classification System (USCS)
  - (ASTM D 3282)

- AASHTO Classification System
  - (AASHTO M 145)

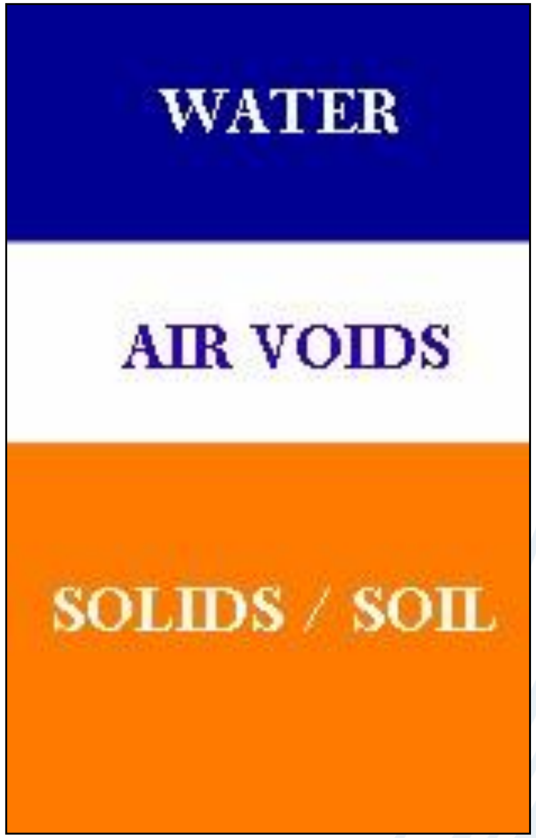
How Do ASTM/AASHTO Compare?

Soil groups in AASHTO system	Comparable soil groups in USCS		
	Most probable	*Possible*	*Possible but improbable*
A-1-a	GW, GP	SW, SP	GM, SM
A-1-b	SW, SP, GM, SM	GP	---------------
A-3	SP	---------------	SW, GP
A-2-4	GM, SM	GC, SC	GW, GP, SW, SP
A-2-5	GM, SM	---------------	GW, GP, SW, SP
A-2-6	GC, SM	GM, SM	GW, GP, SW, SP
A-2-7	GM, GC, SM, SC	---------------	GW, GP, SW, SP
A-4	ML, OL	CL, SM, SC	GM, GC
A-5	OH, MH, ML, OL	---------------	SM, GM
A-6	CL	ML, OL, SC	GC, CM, CM
A-7-5	OH, MH	ML, OL, CH	GM, CM, GC, SC
A-7-6	CH, CL	ML, OL, SC	OH, MH, GC, GC, SM

Source: Liu, 1967

Soil Characteristics

- Three Components:
  - Solids, Water, and Air
- Water Effect
  - Capillary Forces
- Soil Density Test
  - The Proctor Curve



Soil Compaction

- Soil compaction is the process of "artificially" increasing the density (unit weight) of a soil by compaction (by application of rolling, tamping, or vibration).

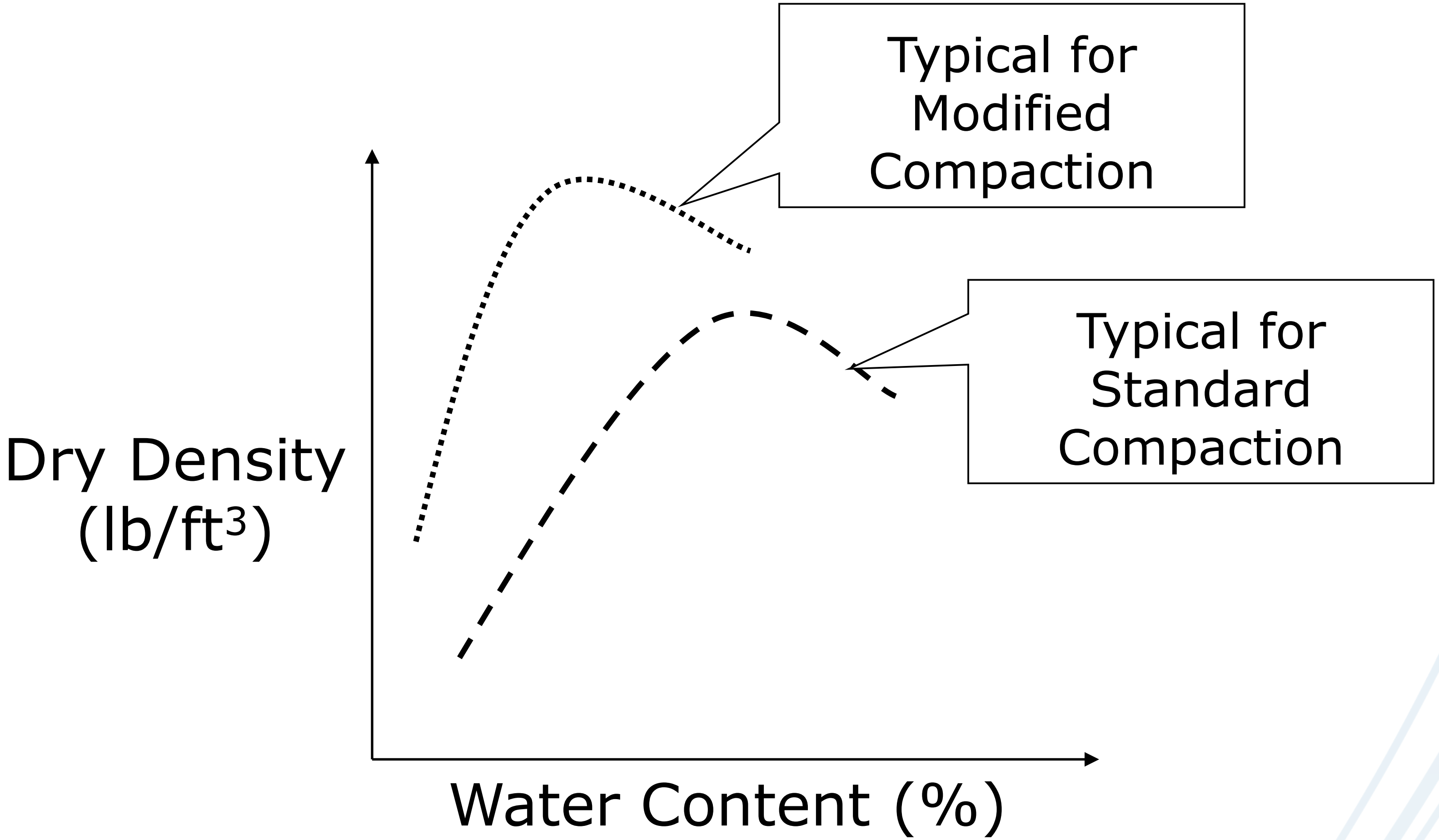
- Moisture-density testing as practiced today was started by R.R. Proctor in 1933. His method became known as the "standard Proctor" test.

Why Compact Soils & Bases?

↑ Density = ↑ Strength

Soil Strength is usually greatest at its maximum dry density.

Typical Compaction Curves



Total Compaction Energy Affects Maximum Dry Density and Optimum Moisture

Why is Soil Compaction Important?

- Compaction Increases Soil Strength
- Adding Water* Can “Pre-Swell” Expansive Soil
- Compaction Achieves Soil Support Uniformity
- Provides Stable Platform for Pavement Layers

*To Optimum or Just Above the Optimum Moisture Content

Soil/Base Strength Characterization

- Not All Design Methods Require the Same Strength Parameter.
- Determining Some Strength Parameters Require Complex & Expensive Machines/Devices
- Some Strength Parameters Cannot Be Easily Determined in the Laboratory.

Soil/Base Strength Characterization

- Soil Support Value (SSV)
- Resistance Value (R-Value)

Limited Use in U.S.

- California Bearing Ratio (CBR)
- Resilient Modulus (M_r)
- Modulus of Subgrade Reaction (k-value)

More Prevalent Use in U.S.

Materials Testing for Subgrade Strength

– California Bearing Ratio (CBR)
  - Measures shearing resistance
  - Units: percent
  - Typical values: 0 to 20

– Resilient Modulus (M_R)
  - Measures stress-strain relationship
  - Units: psi or MPa
  - Typical values: 3,000 to 40,000 psi

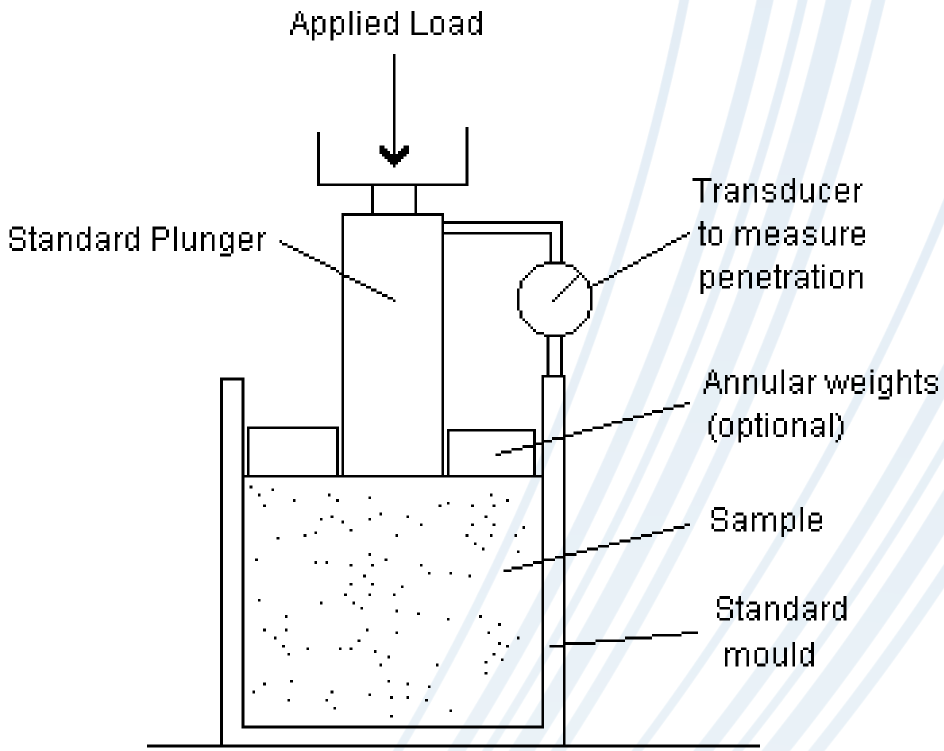
– *K-value (k)*
  - *Measures resistance to deflection*
  - *Units: psi/in*
  - *Typical Values: 75- 200 psi/in*

Source: FHWA

Laboratory California Bearing Ratio (CBR)

Source: www.matest.com

ASTM D1883-Standard Test Method for CBR (California Bearing Ratio) of Laboratory-Compacted Soils

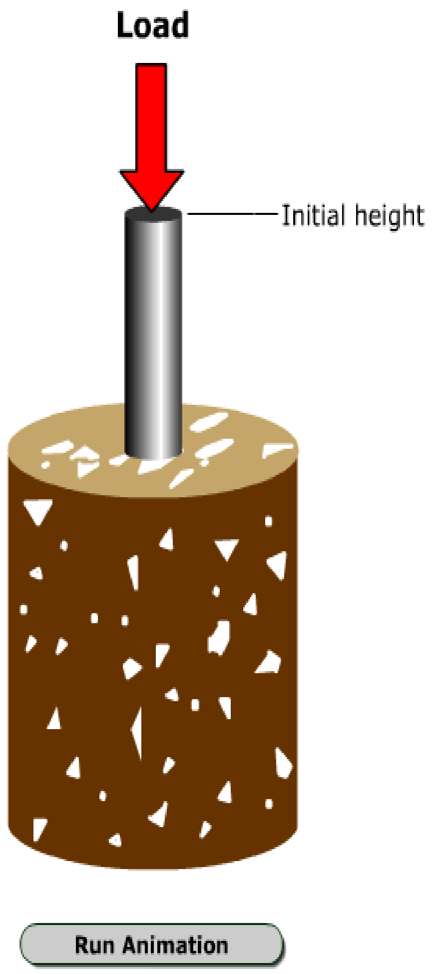


Source: www.dur.ac.uk/

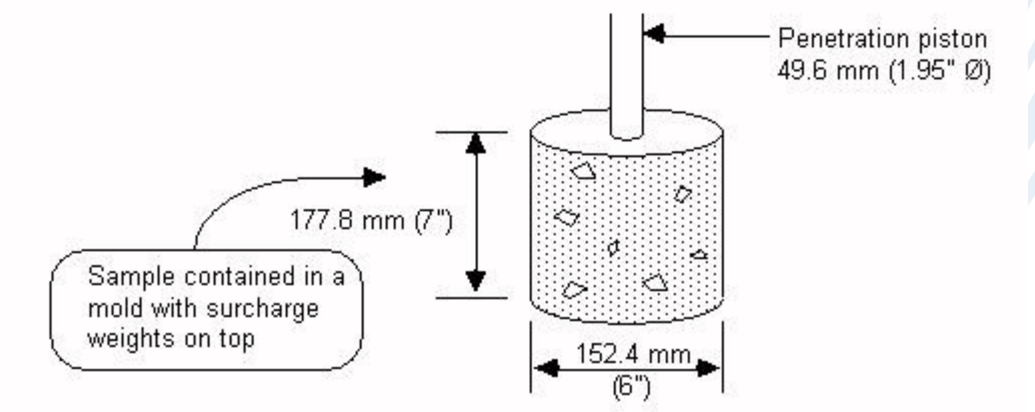
California Bearing Ratio (CBR)

- Developed by The California State Highways Department in 1930.
- Resistance of the material to uniaxial penetration.
- Measure of soil shear strength relative to standard crushed stone material.
- Field and laboratory test.

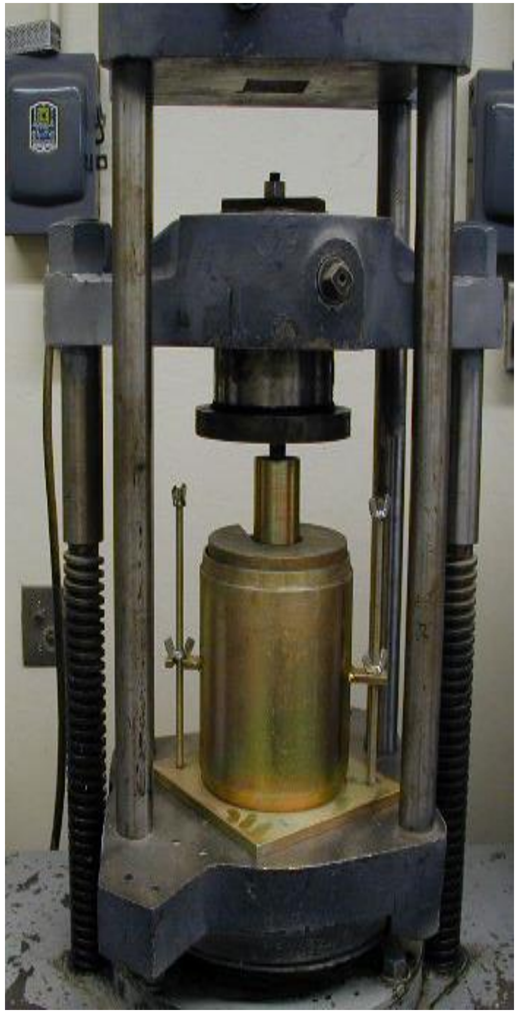
California Bearing Ratio (CBR)



- Load a piston (area = 3 in^2) at a constant rate (0.05 in/min)
- Record Load every 0.1 in penetration
- Total penetration not to exceed 0.5 in.
- Draw Load-Penetration Curve.



CBR Test Equipment



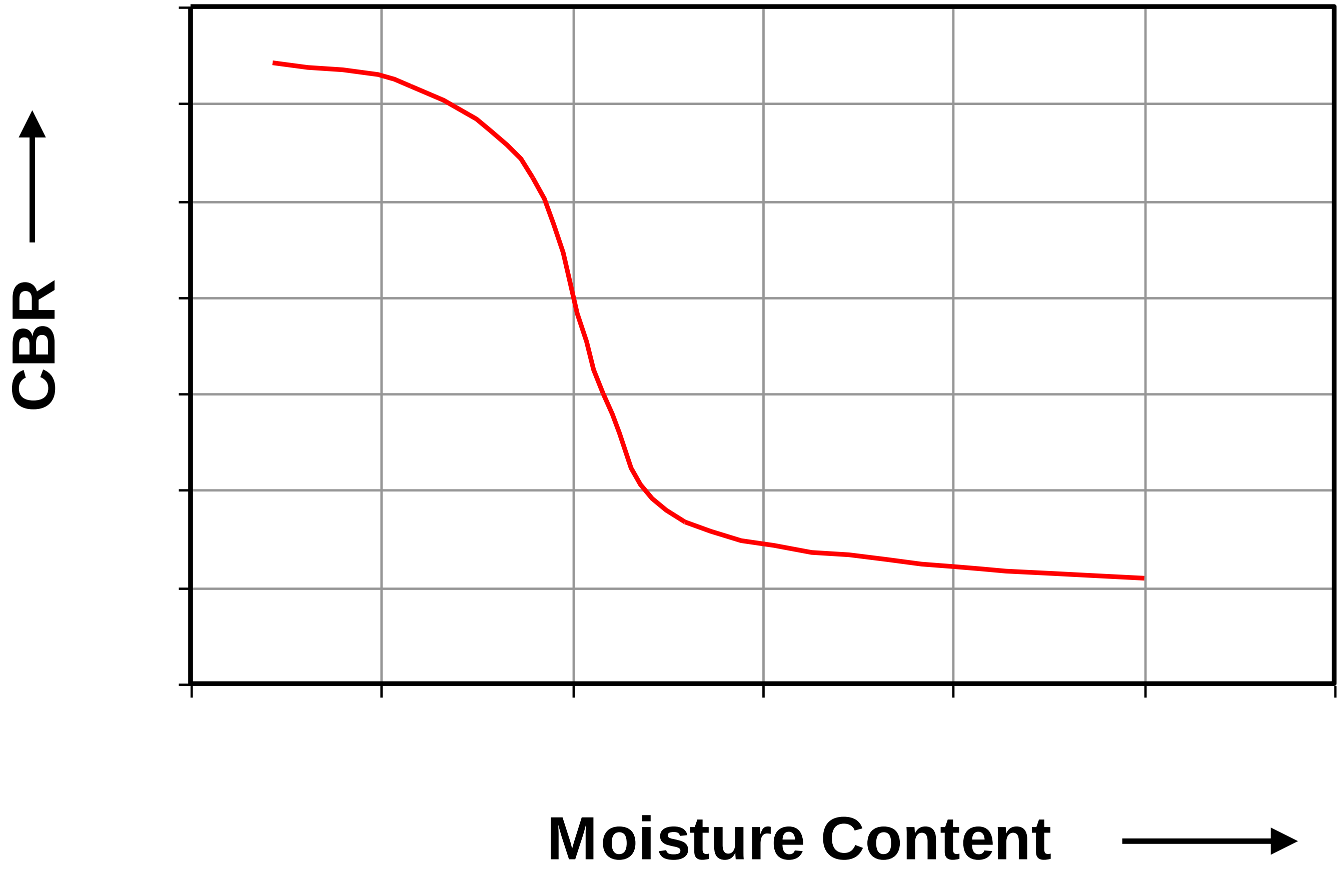
Typical Testing Machine

- Surcharge weights are added during testing and soaking to:
  - Simulate the weight of pavement.
  - Prevent heaving up around the piston.

Surcharge Weights

Soaking Samples for 4 days measure swelling and CBR

Influence Of Moisture On CBR



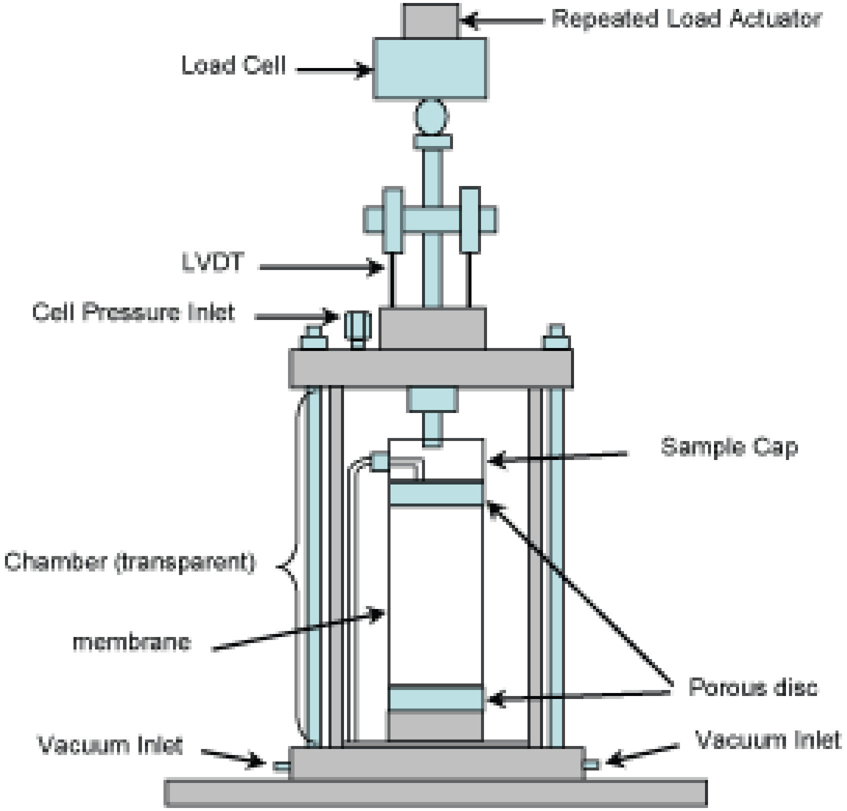
Use relevant value of moisture content when assessing soils under laboratory conditions.

Resilient Modulus of Soils/Subbase

AASHTO T307-Standard Method of Test for Determining the Resilient Modulus of Soils and Aggregate Materials

Most Soils Are Stress Sensitive

- More Confinement = More Strength
- Higher the Vertical Load = Less Strength



Modulus of Subgrade Reaction (k-value)

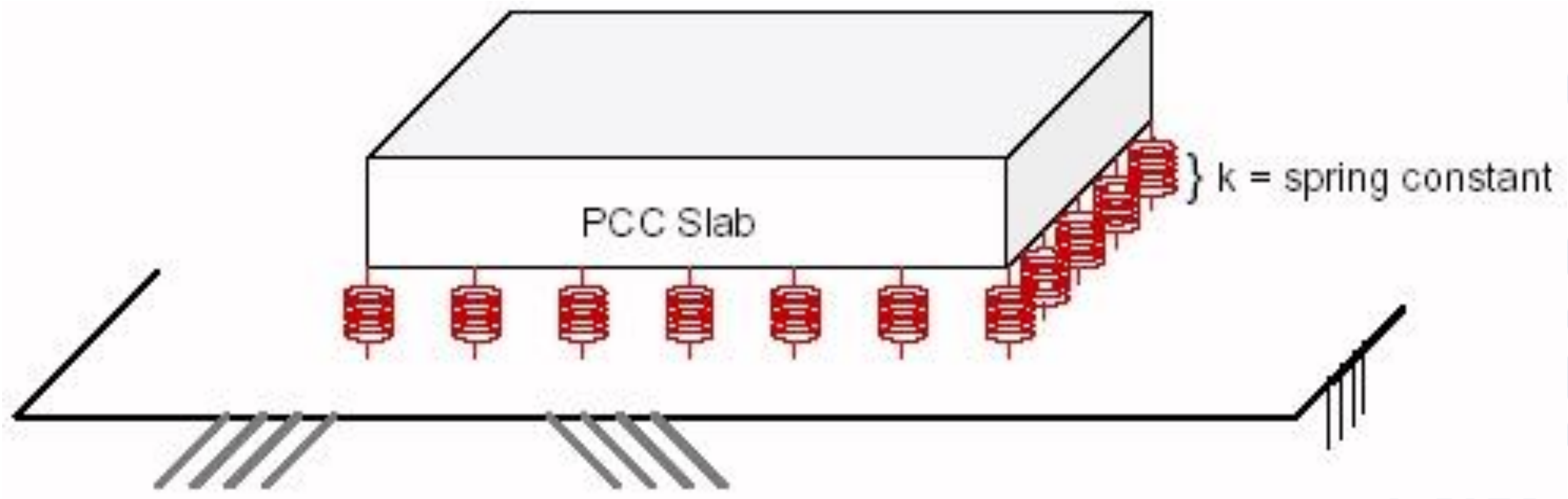
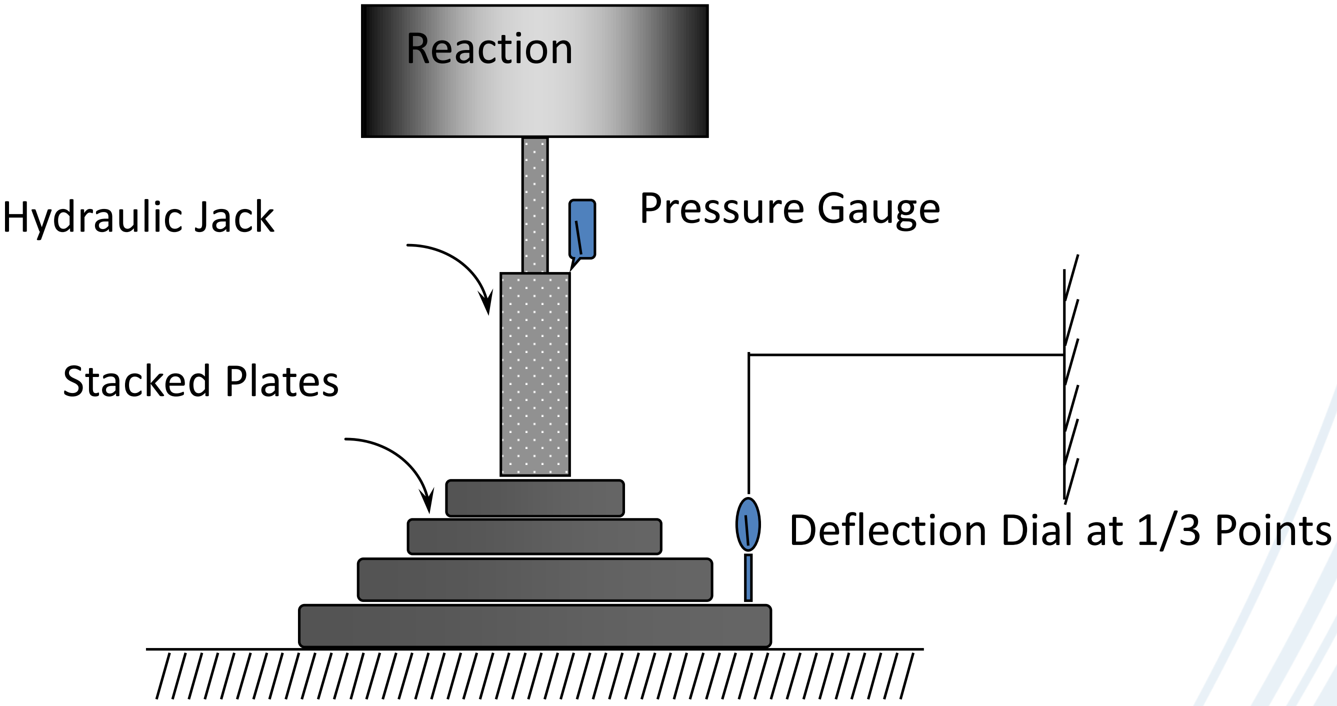


Plate Load Bearing Test (k-value)



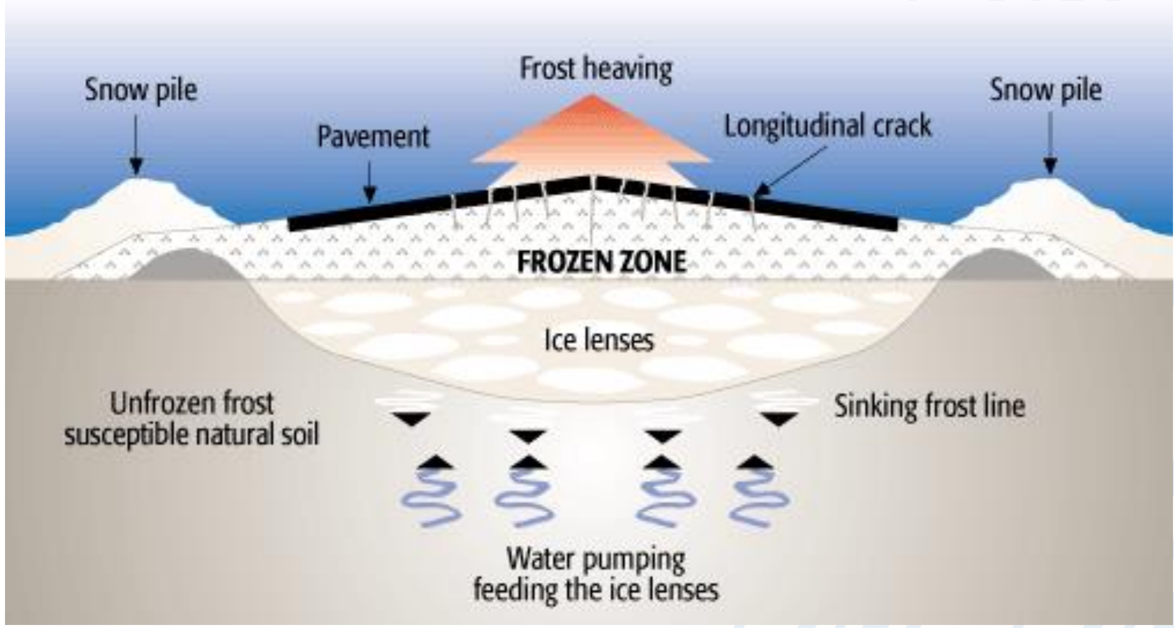
k (psi/in) = unit load on plate / plate deflection

Soil/Base Strength Summary

Soil Strength	Units	Practical Range
CBR	%	2 - 80
Resilient Modulus	psi	1,500 – 45,000
k-Value	psi/in	50 - 300

Encountering Special Circumstances…

- Expansive Soils:
  - Frost Heave
  - High Plasticity Soils



Pavements On Expansive Soils – Mitigation Techniques

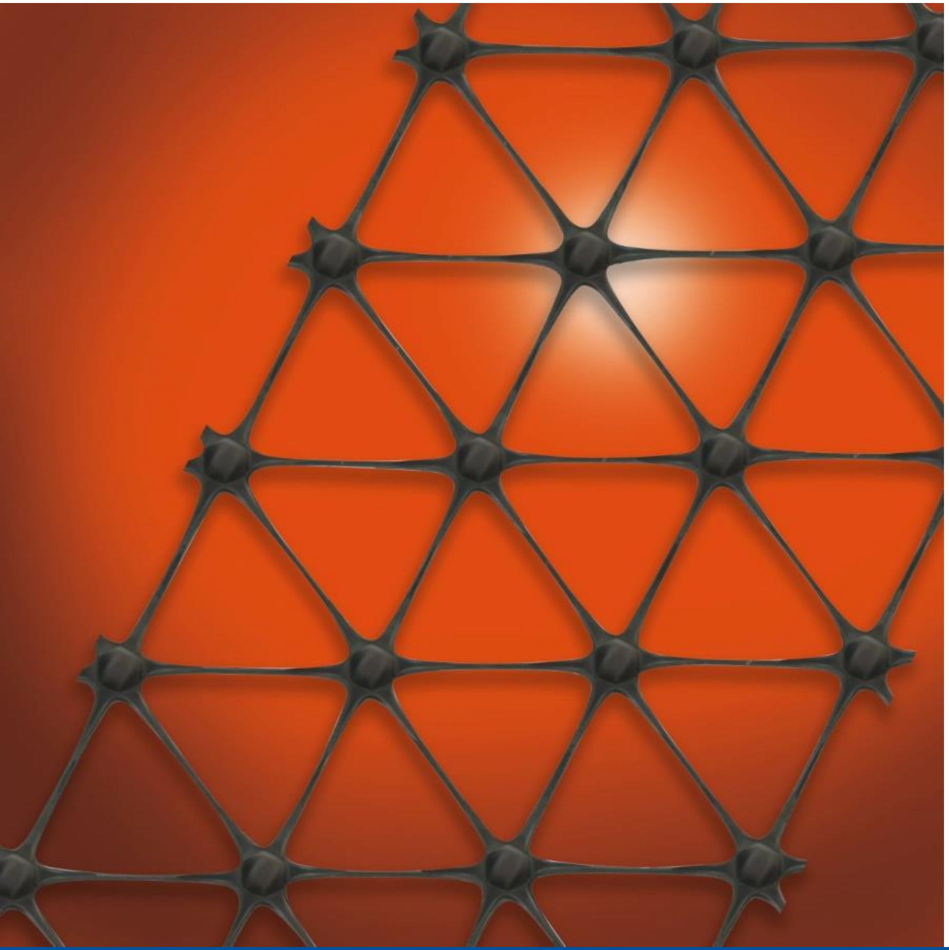
- Soil Treatment with Cement, Lime, or Fly Ash
- Geosynthetics: Geotextiles or Geogrids
- Removal and Replacement of High PI Soils
- Drains or Barriers to Collect or Inhibit Moisture Infiltration
- Chemical Injection of Soil
- Moisture Treatment
- Soil Mixing

Selecting the *Right* Treatment

- Soils and Environment Dependent
- Presence of Sulfates
- Material Availability and Cost
- Local Contractor Experience
- Project Schedule and Complexity
- Meet Owner Guidelines

Deep Soil Stabilization

Triaxial Geogrid



Source: www.tensar.com

Geogrids or Geosynthetics

Source: www.tensar.com

Soil Mixing (Low PI Added to High PI)

Full Depth Reclamation

Thank You!