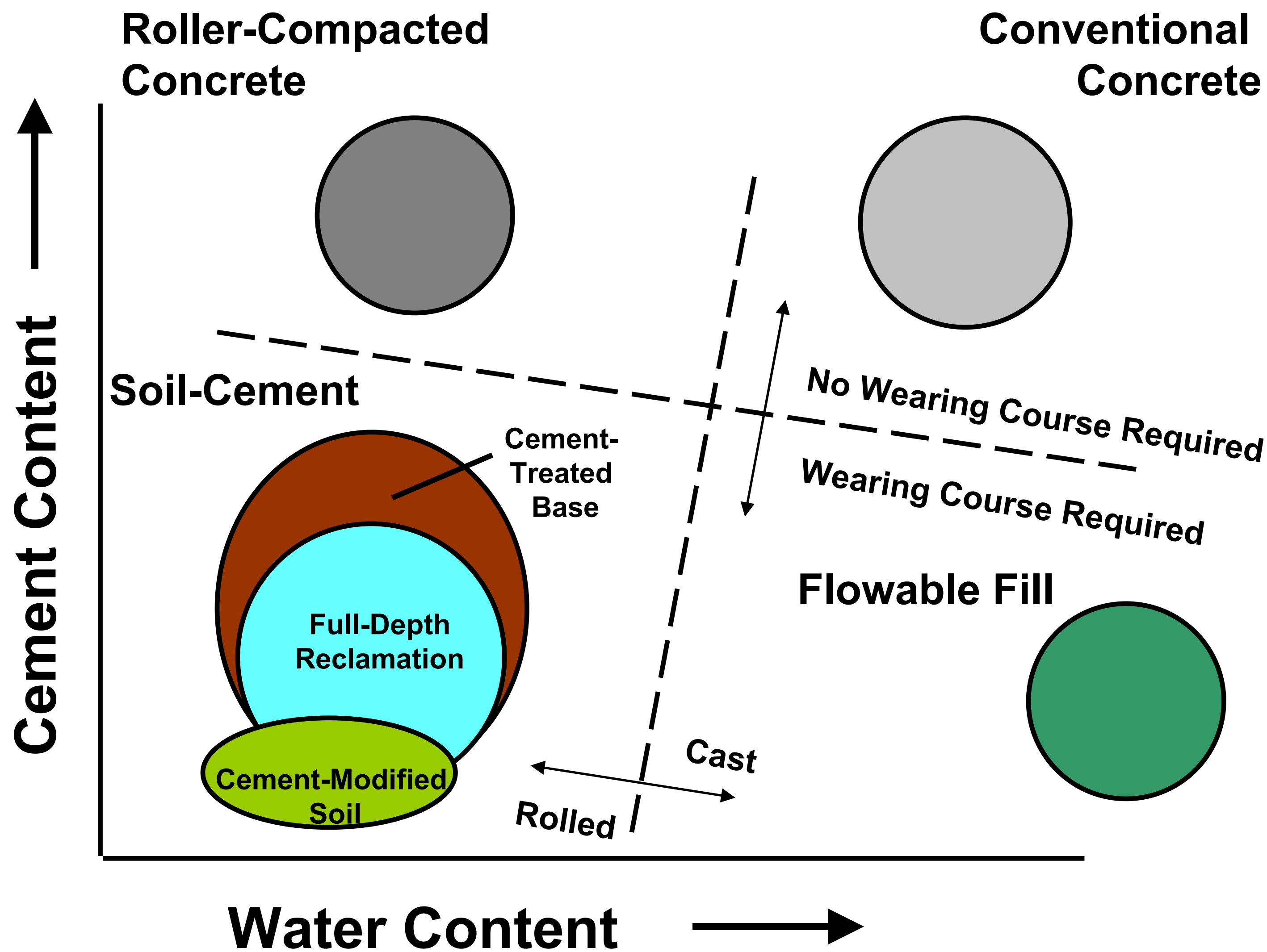
Cement Council of Texas

Cement Stabilization of Soils

Matthew W. Singel, P.E.
Program Manager
Soil Cement/Roller-Compacted Concrete

FOUNDATION PERFORMANCE ASSOCIATION

Cement-Based Pavement Materials



Concrete Soil-Cement

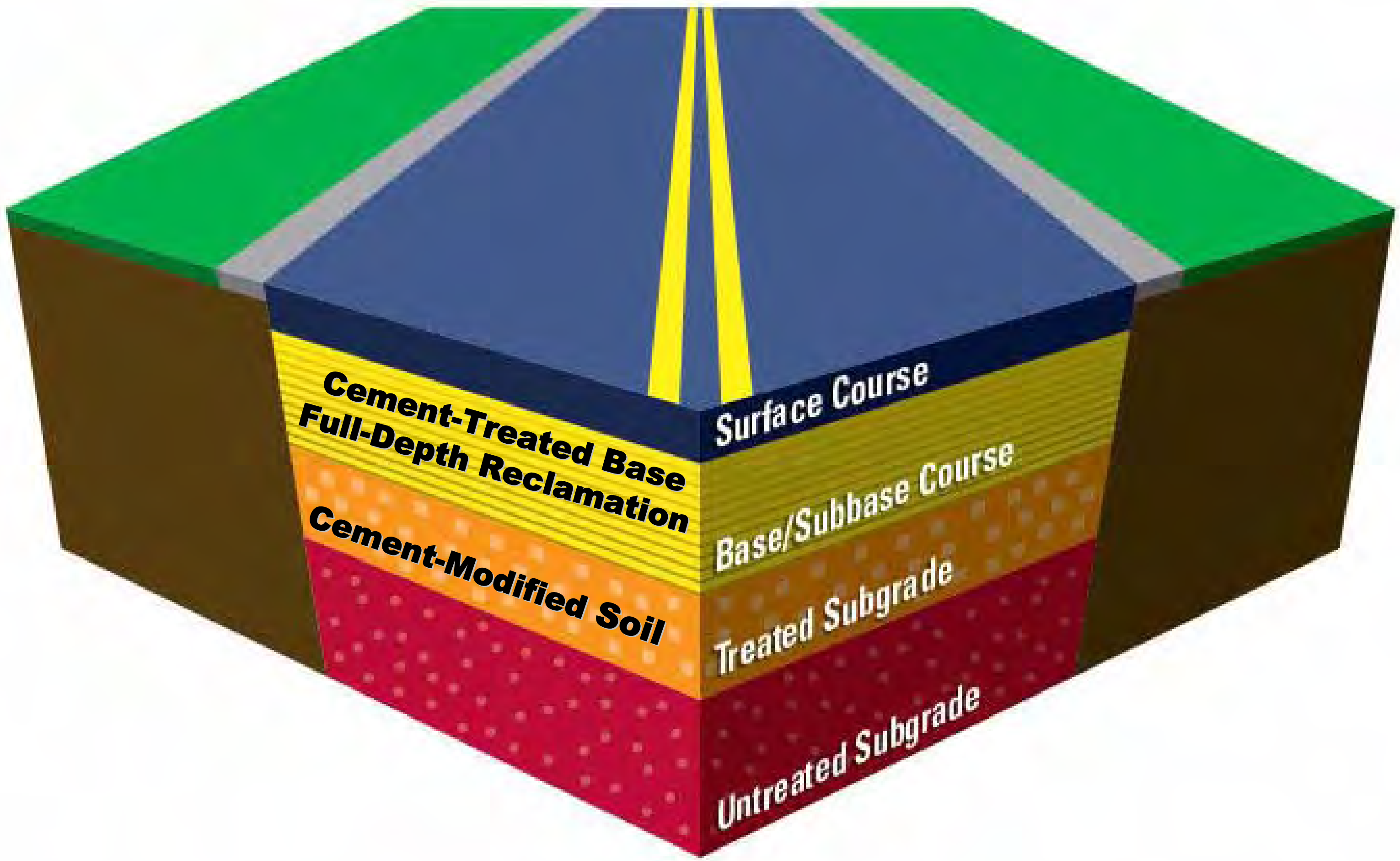
Cementitious Gel or Paste

- coats all particles
- fills voids

Hydration Products

- all particles not coated
- voids not filled
- linkages bind soil agglomerations together

Soil-Cement Materials in a Pavement Section



APPLICATIONS

Reasons to Modify

- **Improve the properties of the subgrade soil**
  - Reduce volume change caused by moisture
  - Improve wet strength
  - Improve compactibility
- **Expedite construction by improving subgrade support in wet weather**
  - Eliminate muddy construction sites
  - Create an all-weather work platform

It is important to remember that soil *modification* is different than soil *stabilization*

Construction Problems with Silts or Sandy Soils

- Fine-grained and difficult to compact
- Poor gradation
- Low bearing capacity
- Low cohesiveness and shear strength
- Unstable under construction equipment

Construction Problems with Clay Soils

- High plasticity and cohesiveness
- Fine-grained and poorly graded
- High shrink and swell potential
- Expansive when wet
- Low bearing strength when moist and deform under load
- Difficult to dry out
- Difficult to compact

Solutions for poor subgrade soils

- Excavate/replace with select fill
  - ✓ ***Aggregate***
  - ✓ ***Soil***
- Increase the base/pavement thickness
- Contain using fabrics or other geotextiles
- Modify soils with a calcium-based additive such as portland cement


BENEFITS
1/2 Mile

Benefits of Cement-Modified Soil

- Small addition of cement to soils to change properties
- Eliminates need for removal/replacement of inferior soils
- Low cost soil improvement
- Improves pavement support
- Forms weather-resistant work platform
- Provides permanent non-leaching modification

By treating the soil with cement, the detrimental properties of clay can be improved through the following three processes:

1. Particle Restructuring
2. Cement Hydration
3. Pozzolanic Reaction

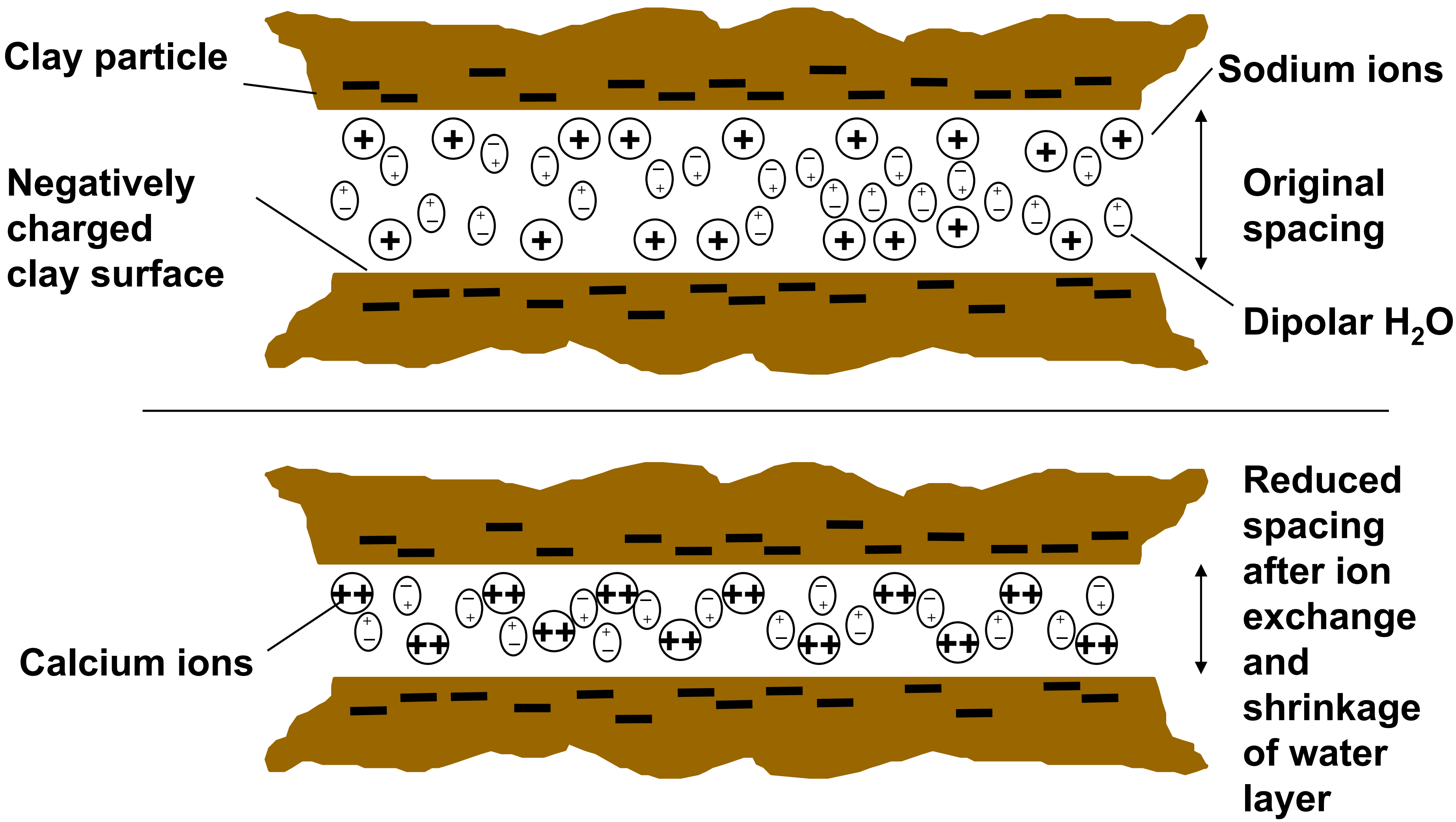
Cement Reactions with Clay

- **Primary**
  - Ion exchange between calcium in cement and clay which occurs immediately
- **Secondary**
  - Normal cement hydration contributes to strength gain

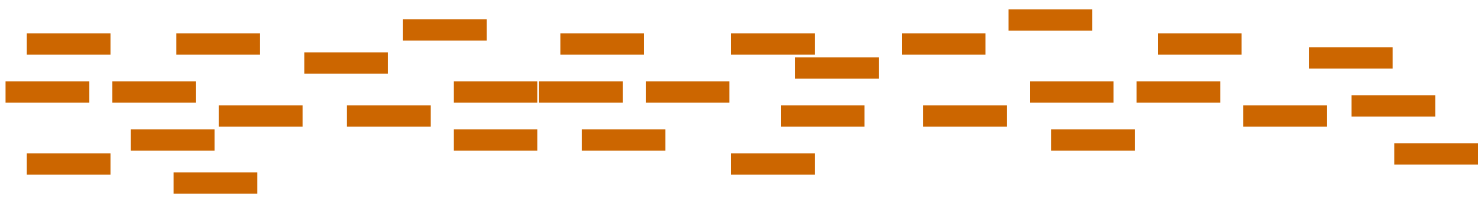
Primary Reaction

- Cation exchange reactions occur
- Intensifies the grouping of the clay particles by neutralizing the negative surface charges
- Produces Calcium Hydroxide – $Ca(OH)_2$ – (hydrated lime)

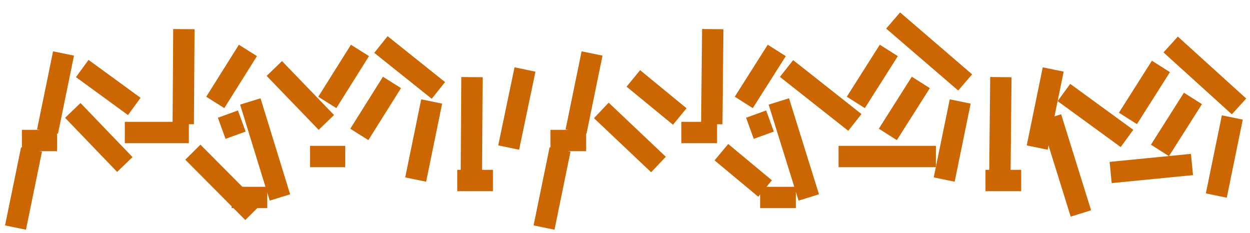
Cation Exchange



Particle Restructuring



Unmodified clay particles



Clay particles after flocculation / agglomeration

Secondary Reaction

- Clay participates in the secondary process
- Clay is converted to calcium form
- Calcium ions combine with dissolved silica and alumina in the clay to create additional cementitious materials
- Strength gain occurs

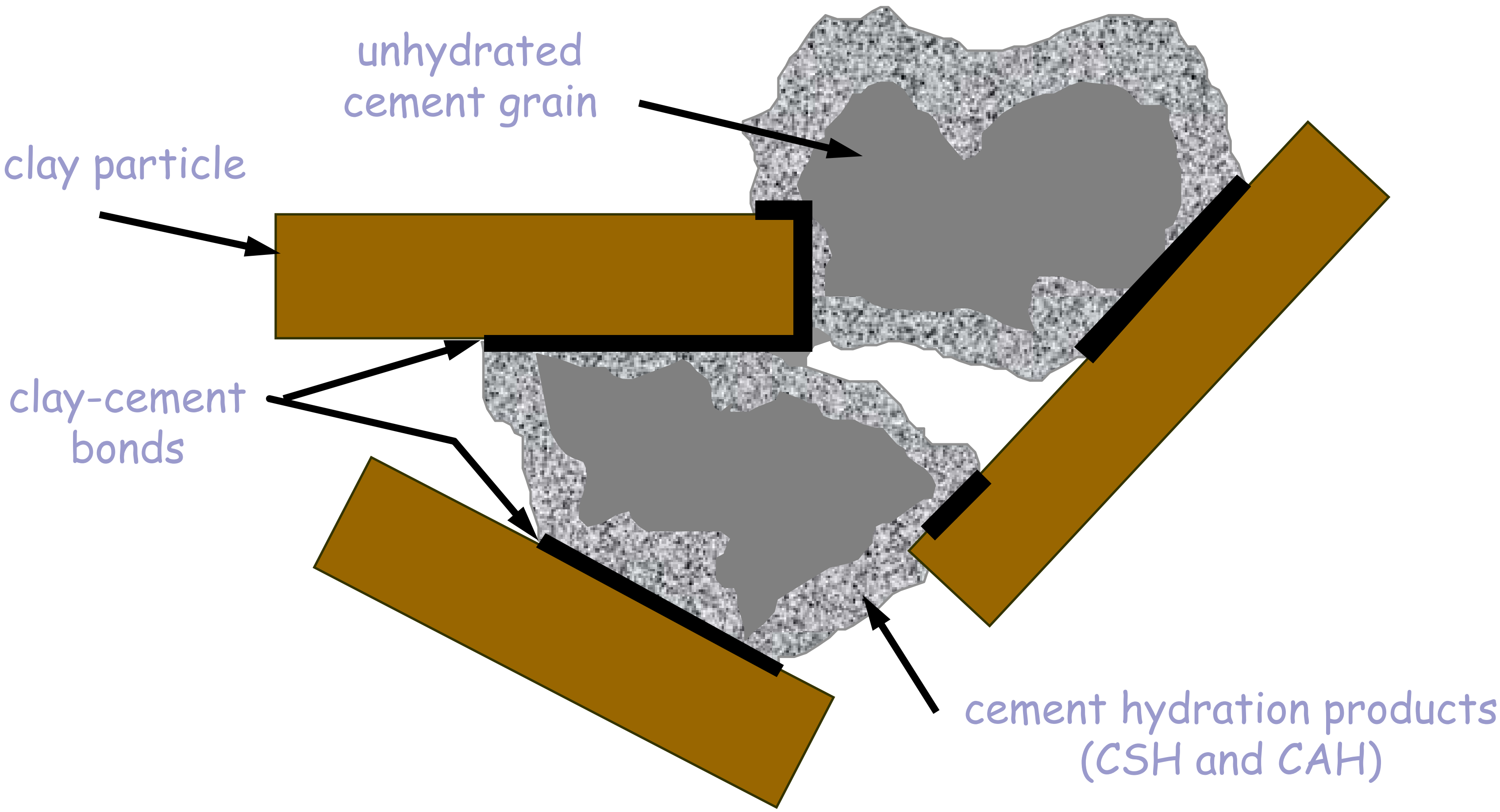
Cement Hydration

Cement + Water = Calcium Silicate Hydrate
(Cementitious Gel)

- plus -

Calcium Hydroxide
(Hydrated Lime)

Hydration



unhydrated
cement grain
clay particle
clay-cement
bonds
cement hydration products
(CSH and CAH)

Pozzolanic Reaction

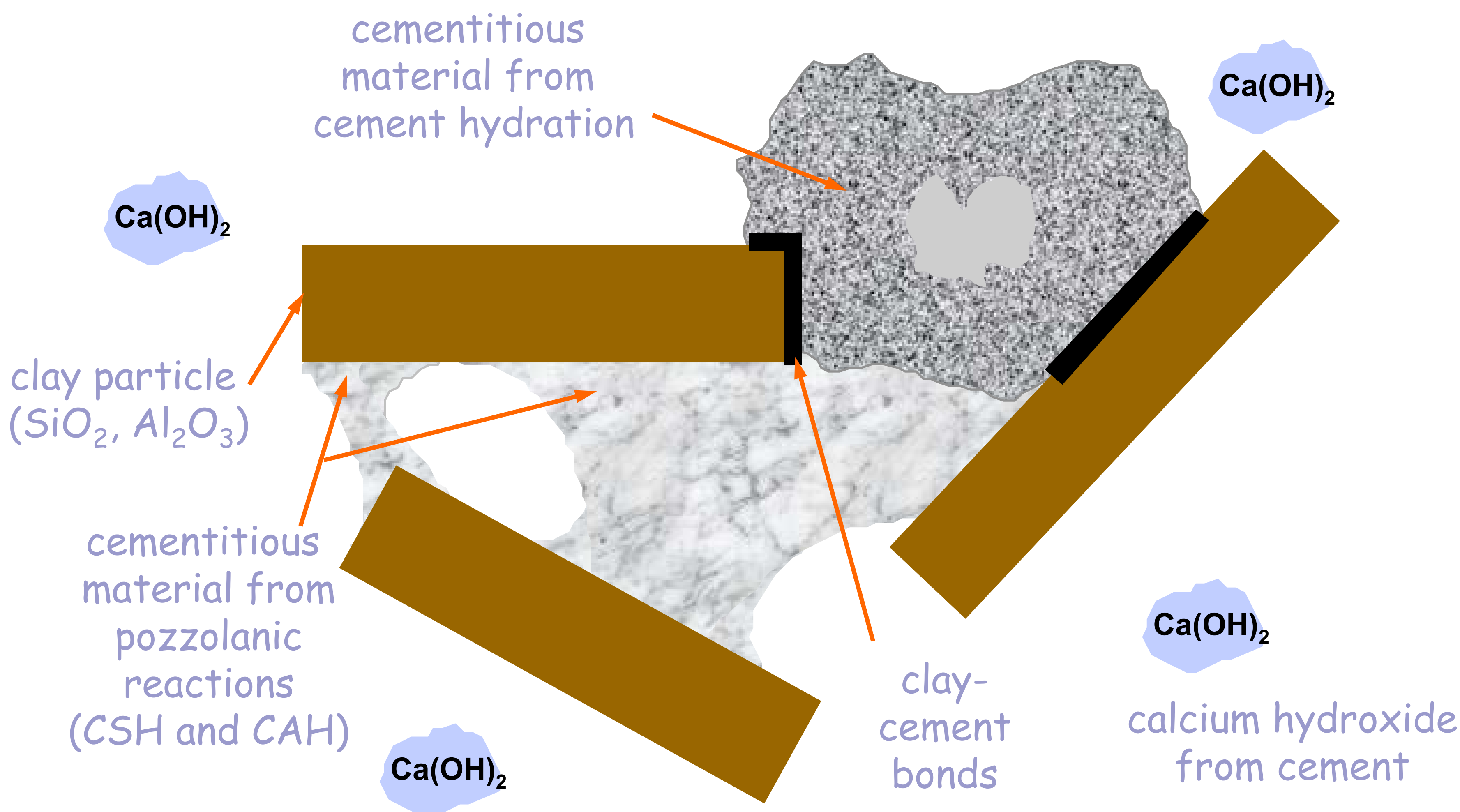
Hydrated Lime + Silica = Calcium Silicate Hydrate

Hydrated Lime + Alumina = Calcium Aluminate Hydrate

Supplied by Cement Hydration	Clay Minerals	Cementitious Gel

Note: Without silica or alumina-based clay minerals, this process does not occur (e.g. sandy or silty soils).

Pozzolanic Reaction



Time of Modification Processes

1. Particle Restructuring → Immediate to a few hours
2. Cement Hydration → Largest strength gain between 1 day and 1 month
3. Pozzolanic Reaction → Slowly, over months and years

DESIGN

Laboratory Tests

- Sieve Analysis (ASTM C136)
- Atterberg Limits (ASTM D4318)
- Moisture-Density (ASTM D558)
- Durability Tests
  - Wet-Dry (ASTM D559)
  - Freeze-Thaw (ASTM D560)
- Soluble Sulfates (ASTM D516)
- Compressive Strength (ASTM D1633)

ASTM C136

Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates

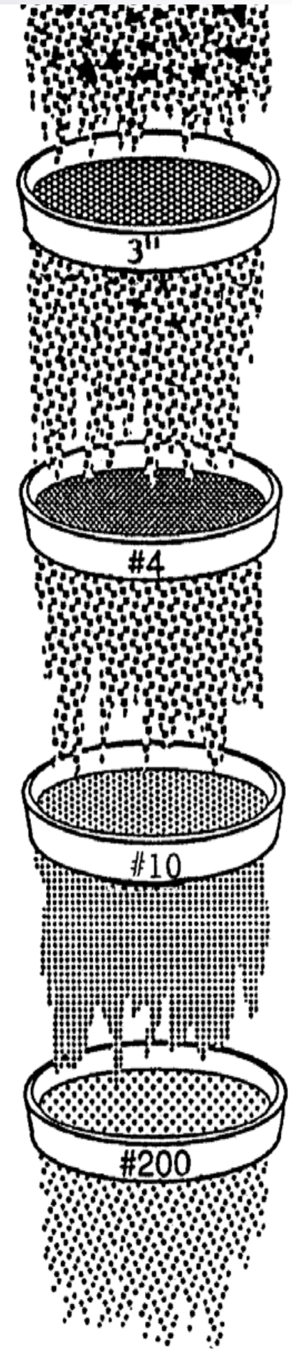
Particle Size Distribution

Gravel

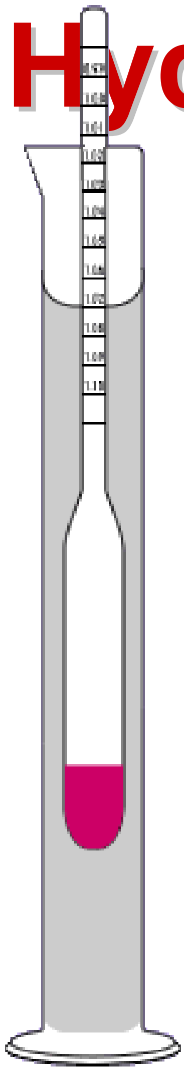
Sand

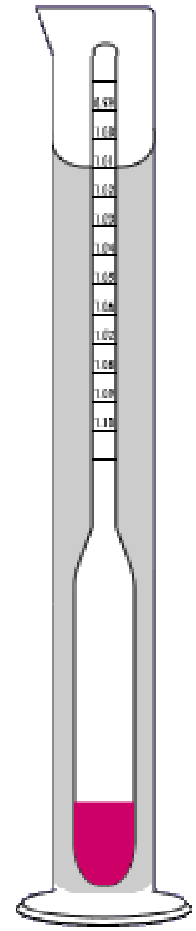
Silt

Clay



Hydrometer



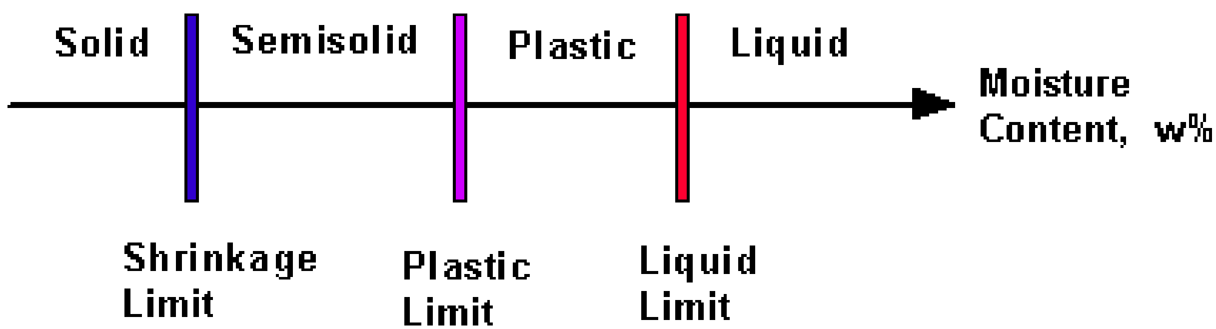


ASTM D4318

Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

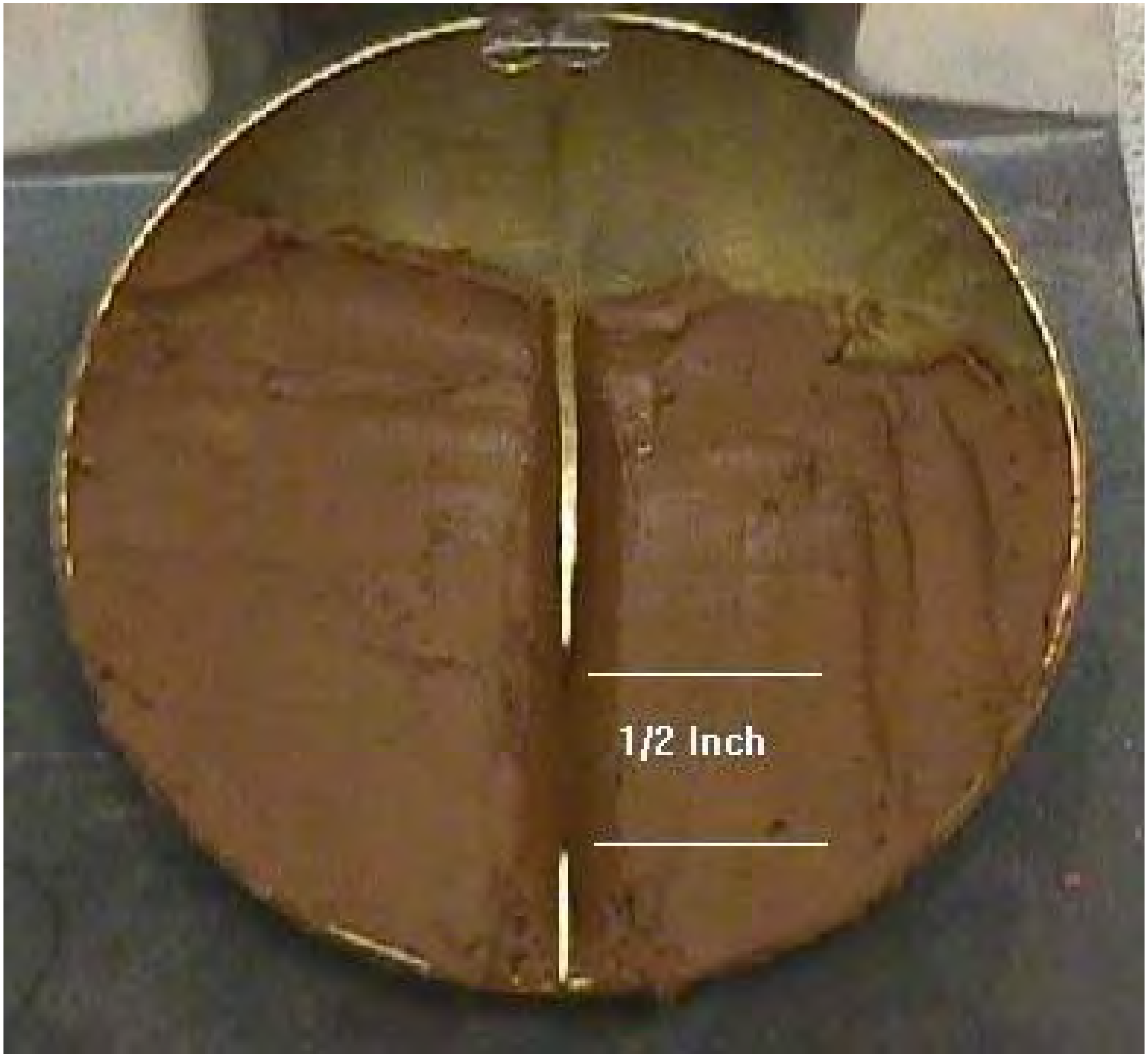
Plasticity Index (PI)

- The range of moisture through which a soil deforms under loading
- The measure of a soil's affinity to retain moisture
- Plasticity Index is the difference between the Liquid Limit and the Plastic Limit of a soil
- PI = LL - PL



Expansive Soils and PI Relationships

Degree	Percent Swell	Approximate PI
Non-Expansive	2 or less	0 to 10
Moderately Expansive	2 to 4	10 to 20
Highly Expansive	More than 4	20 and above


1/2 Inch

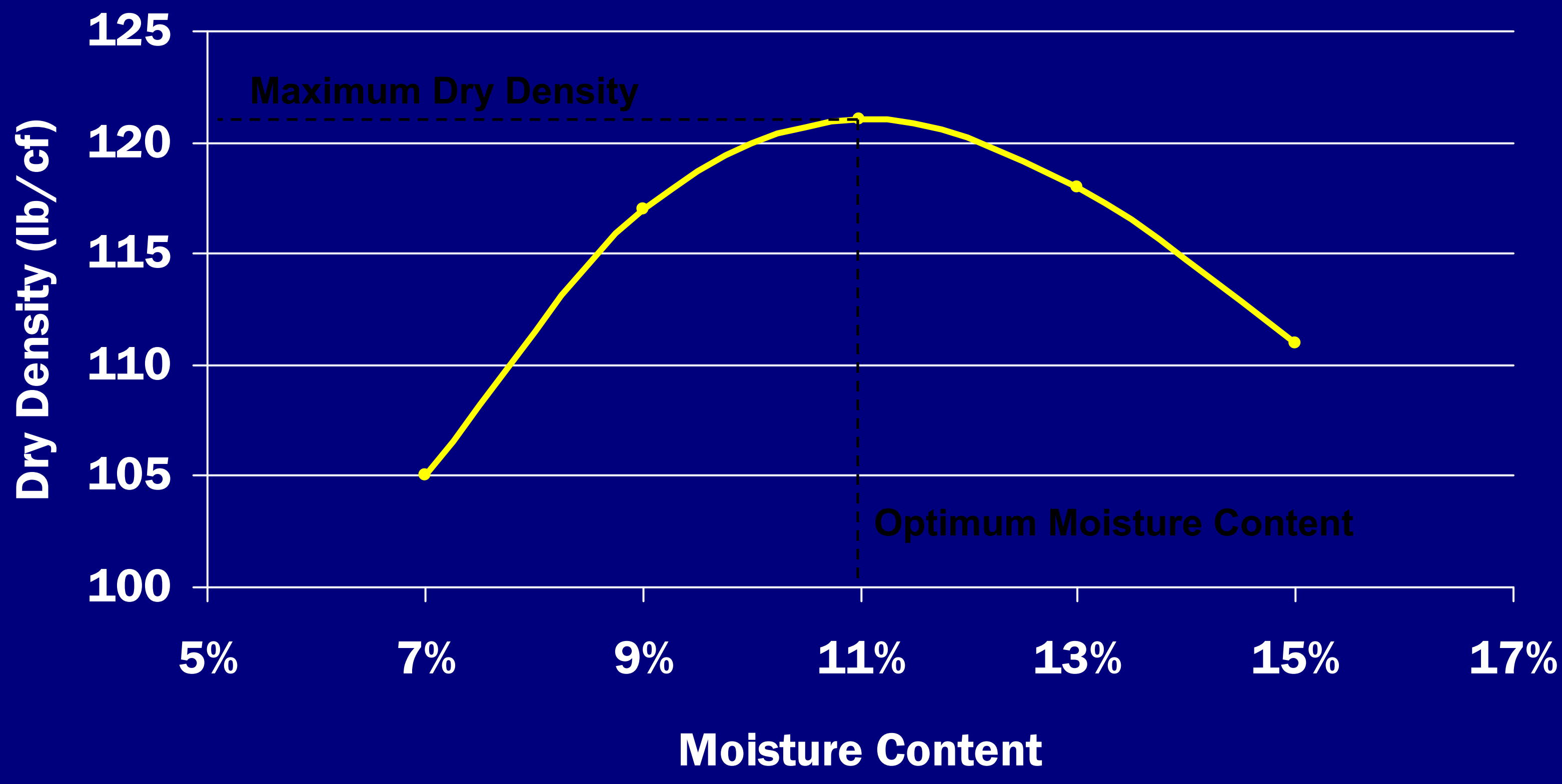
ASTM D558

Standard Test Methods for Moisture-Density Relations of Soil-Cement Mixtures

Standard Proctor Mold and Rammers

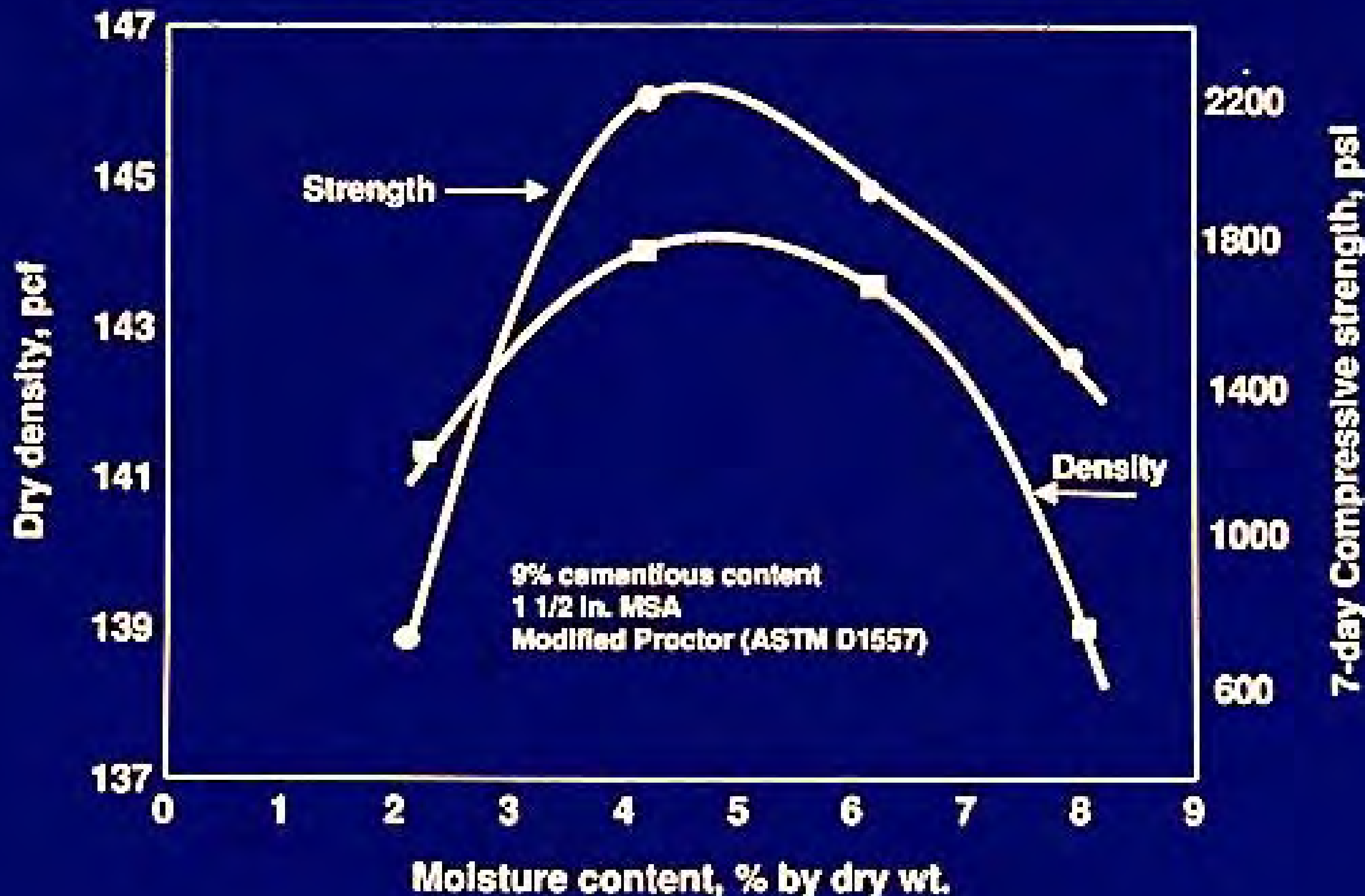
Moisture/Density Relationship

Moisture/Density Relationship



ASTM D558

RELATIONSHIP BETWEEN DENSITY AND COMPRESSIVE STRENGTH



ASTM D559

Standard Test Methods for Wetting and Drying Compacted Soil-Cement Mixtures

Wet-Dry Tests

- Three cement contents tested
- Separate specimens for W-D and F-T
- Standard Proctors used at optimum moisture and maximum dry density
- Moist cured for 7 days

Wet-Dry Tests

- **Wet-Dry**
  - Soaked in water for 5 hours
  - Dried at 70°C (158°F) for 42 hours
  - Brushed
  - Repeat 12 times

ASTM D516

Standard Test Method for Sulfate Ion in Water

0.00% to 0.30% - Sulfate Levels Too Low to be of Concern
0.31% to 0.50% - Sulfate Levels of Moderate Risk
0.51% to 0.80% - Sulfate Levels of Moderate to High Risk
0.81% and up - Sulfate Levels of High and Unacceptable Risk

ASTM D1633

Standard Test Method for Compressive Strength of Molded Soil-Cement Cylinders


5%
7%
9%

CMS Strength Determination

The objective of CMS is to amend undesirable properties of problem soils or substandard materials so that they are suitable for use in construction. The amount of cement added to the soil is less than that required to produce a hardened mass but is enough to improve the engineering properties of the soil.

It is important to remember that soil *modification* is different than soil *stabilization*

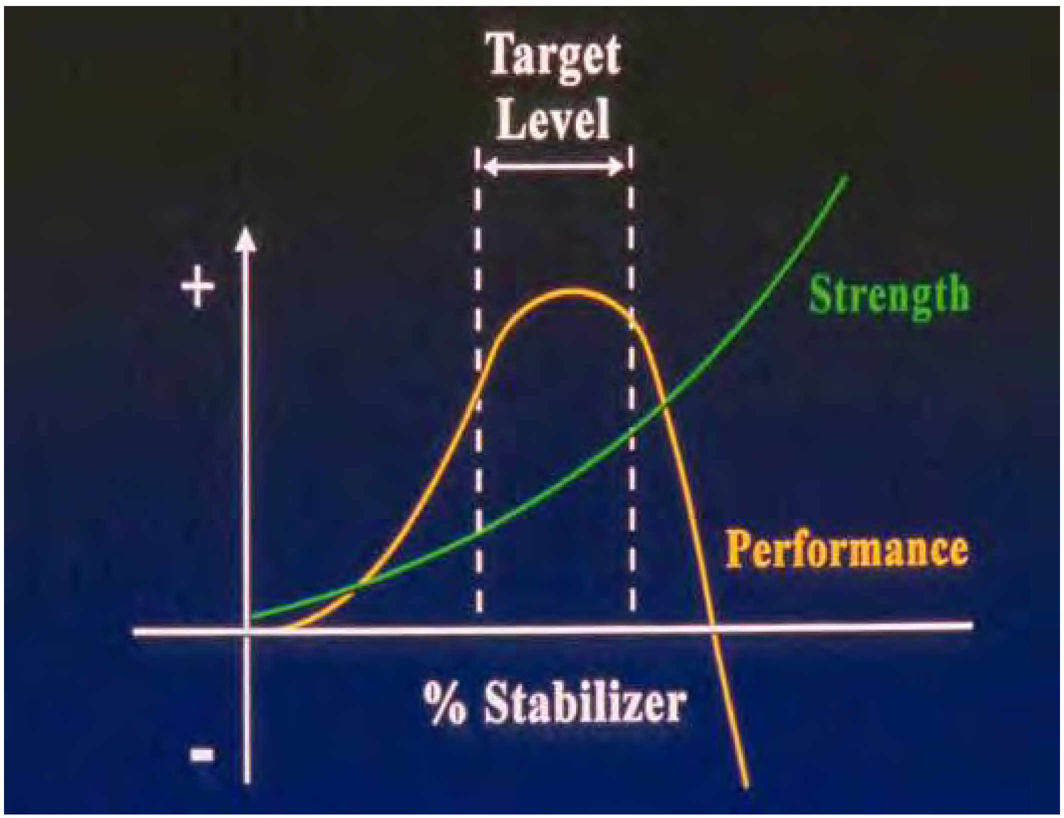
CTB Strength Determination

- **Unconfined Compressive Strength Testing**
  - Used by most State DOT's and FAA
  - Simple and quick procedure
  - 7-day strengths ranging from 300 psi to 800 psi (2.1 MPa to 5.5 MPa) are generally recommended
  - Strengths vary according to project requirements
  - 300 to 400 psi (2.1 to 2.8 MPa) mixed-in-place and 600 to 800 psi (4.1 to 5.5 MPa) plant mixed

FDR Strength Determination

- Unconfined Compressive Strength Testing
  - ASTM D1633
  - Used by most State DOT's and the FAA
  - Simple and quick procedure
  - 7-day strengths ranging from 300 psi to 400 psi (2.1 MPa to 2.8 MPa) are generally recommended
  - Proven strength (support) under heavy traffic conditions
  - Proven durability (performance) in both wet/dry and freeze/thaw environments

Please keep in mind that strength and durability are NOT the same thing!



The purpose of the mix design procedure is to select the correct additive that most closely balances both strength AND performance for the roadway materials!

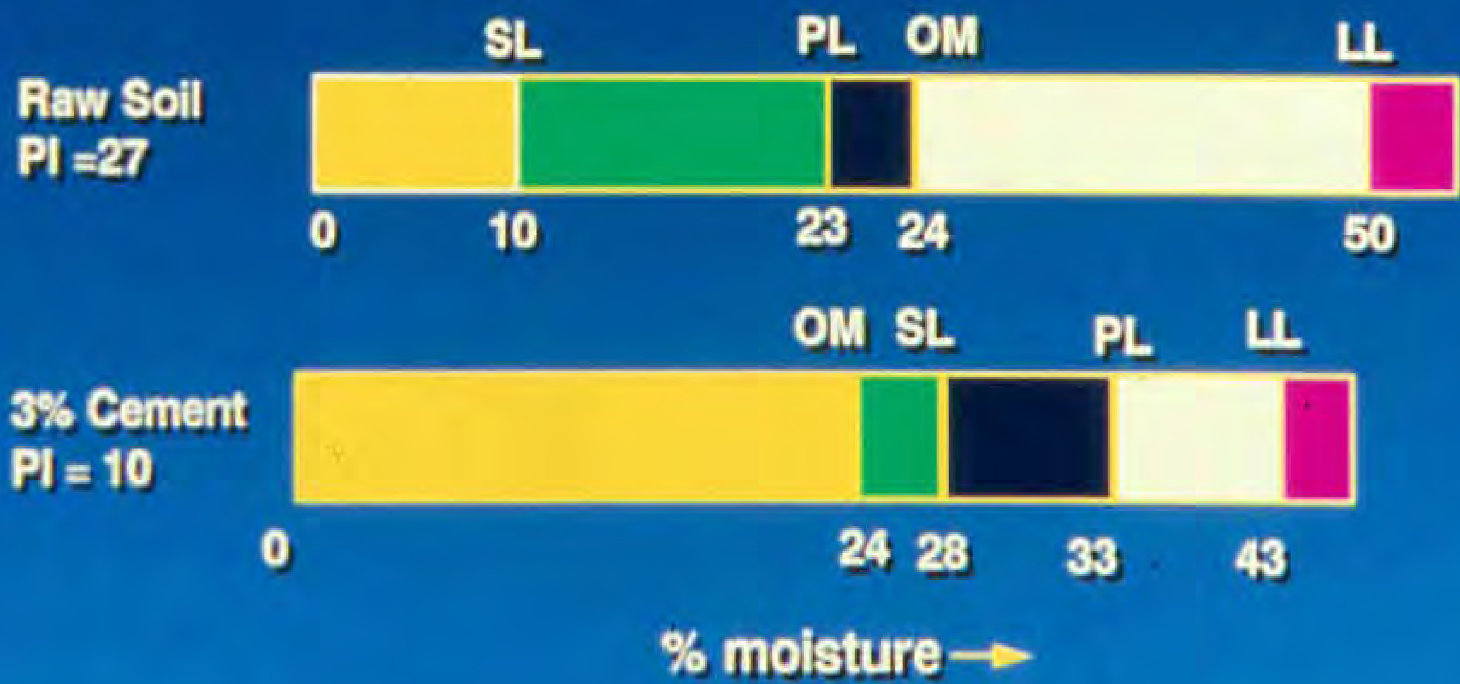
Early Research Involving Cement-Modified Soils

- *"Cement Modification of Clay Soils"*
  - A. P. Christensen
  - Portland Cement Association
  - 1969
- Studied the effects of treating clay soils with small amounts of portland cement
- He compared:
  - Plasticity Index (PI) reduction
  - shrinkage limits
  - cohesiveness
  - unconfined and triaxial compressive strengths

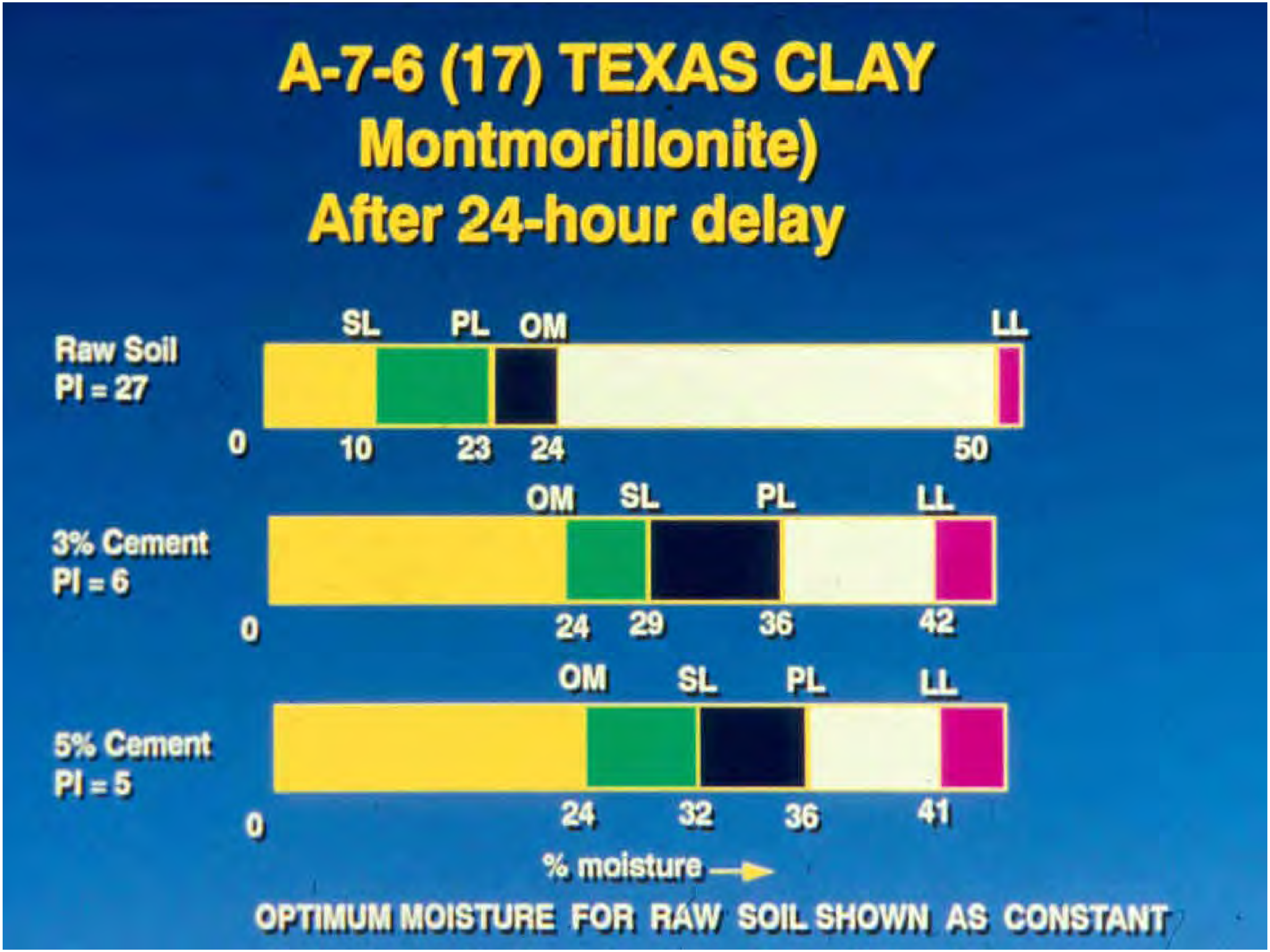
Study Soils

- Eight were clays, three were clay and silty-clay loams
  - Four were classification AASHTO A-6
  - Seven were classification AASHTO A-7-6
- The predominant soil used in the study was a Texas clay (Montmorillonite)
- Cement percentages used were 3% and 5% by weight of dry soil

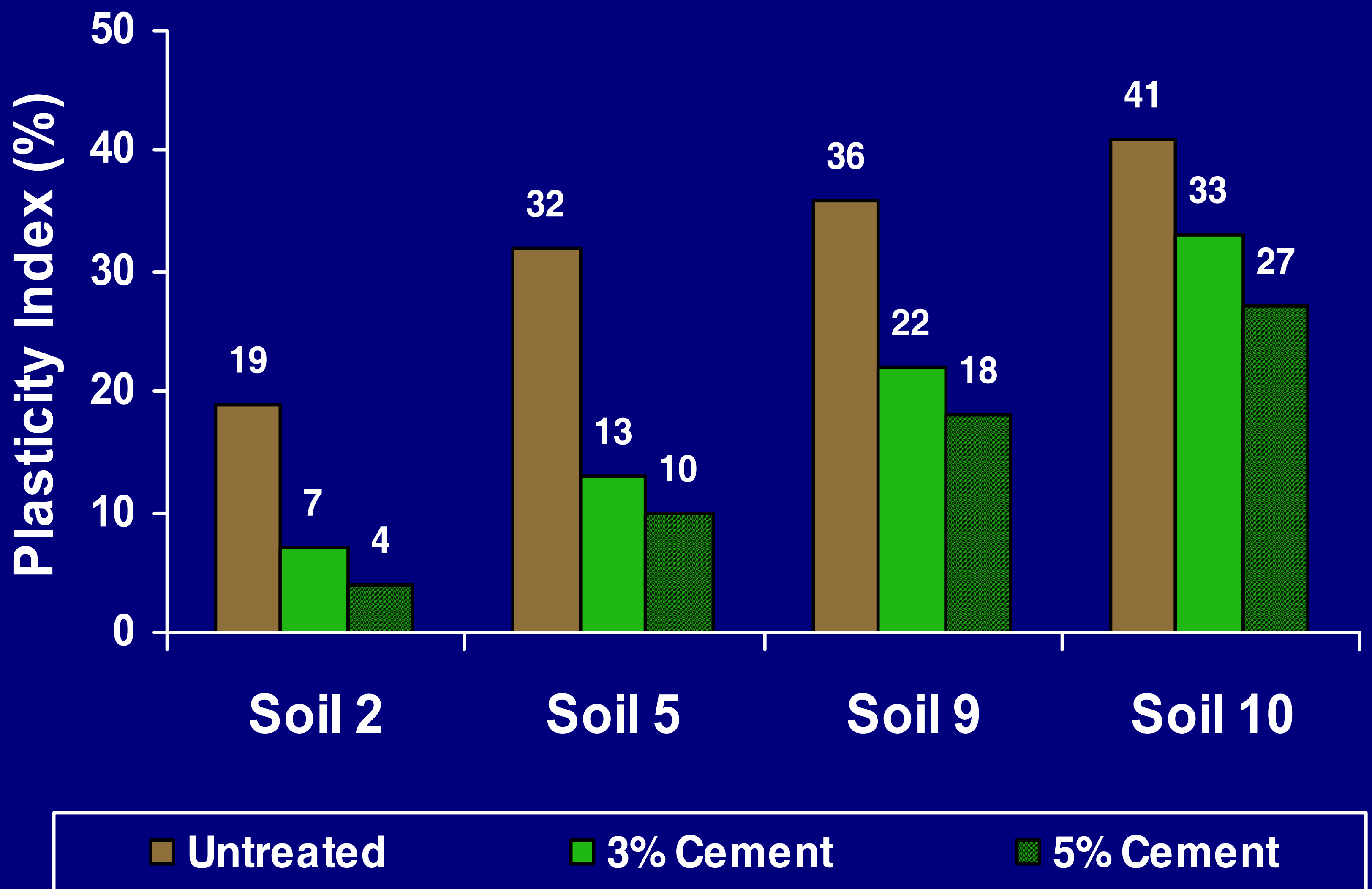
AASHTO A-7-6 (17) SOIL, TEXAS CLAY (Montmorillonite) After 1-hour delay



OPTIMUM MOISTURE FOR RAW SOIL SHOWN AS CONSTANT


A-7-6 (17) TEXAS CLAY
Montmorillonite)
After 24-hour delay
Raw Soil
PI = 27
SL
PL
OM
LL
0
10
23
24
50
3% Cement
PI = 6
OM
SL
PL
LL
0
24
29
36
42
5% Cement
PI = 5
OM
SL
PL
LL
0
24
32
36
41
% moisture
OPTIMUM MOISTURE FOR RAW SOIL SHOWN AS CONSTANT

Effect of Modification on Plasticity Index

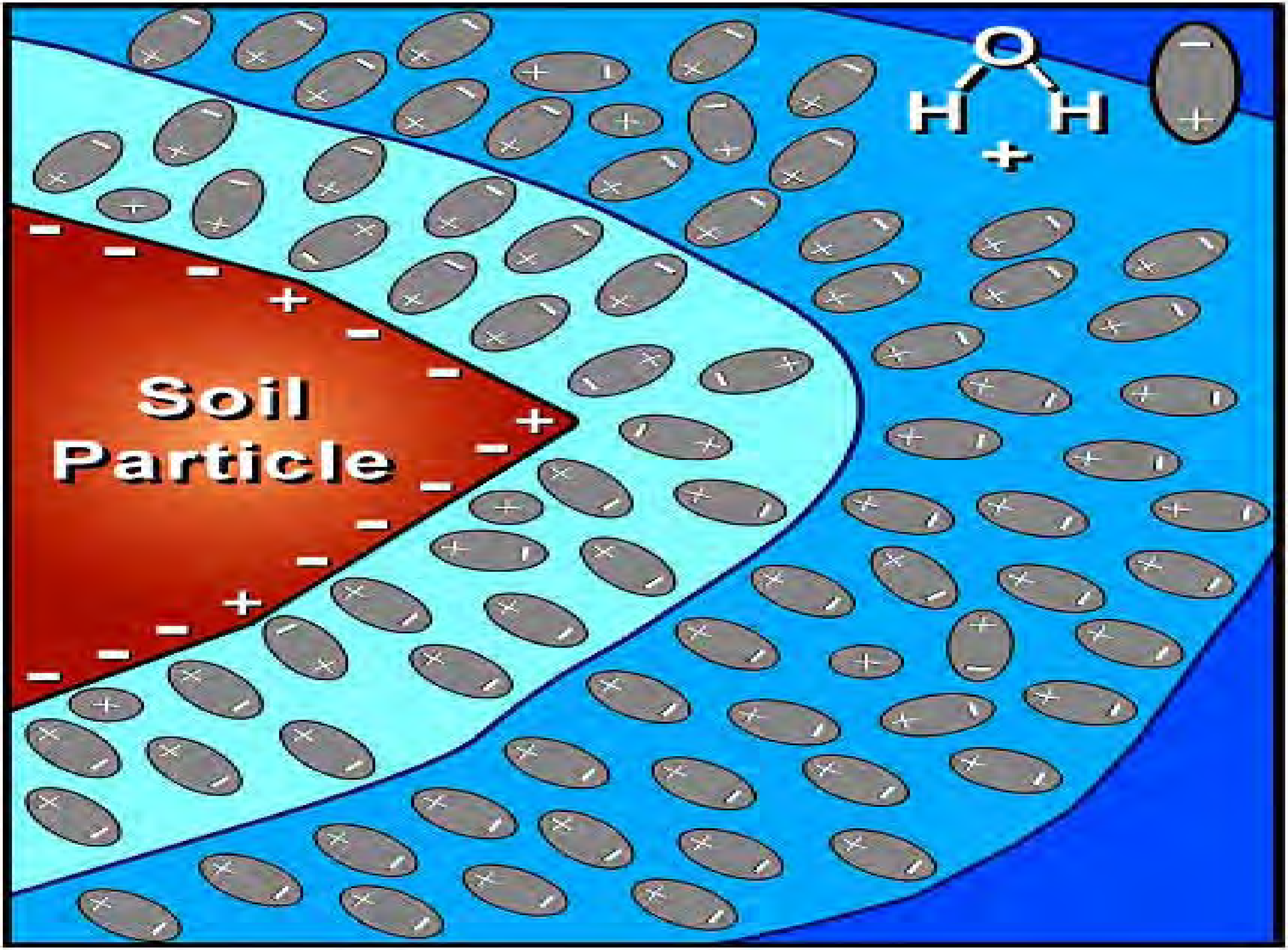


General Results of Christensen's Study

- Portland cement increased the shrinkage limits of clay soils to values greater than optimum moisture
- Soils with a Plasticity Index (PI) between 18 and 29 were reduced to 10 or less after a 24-hour compaction delay

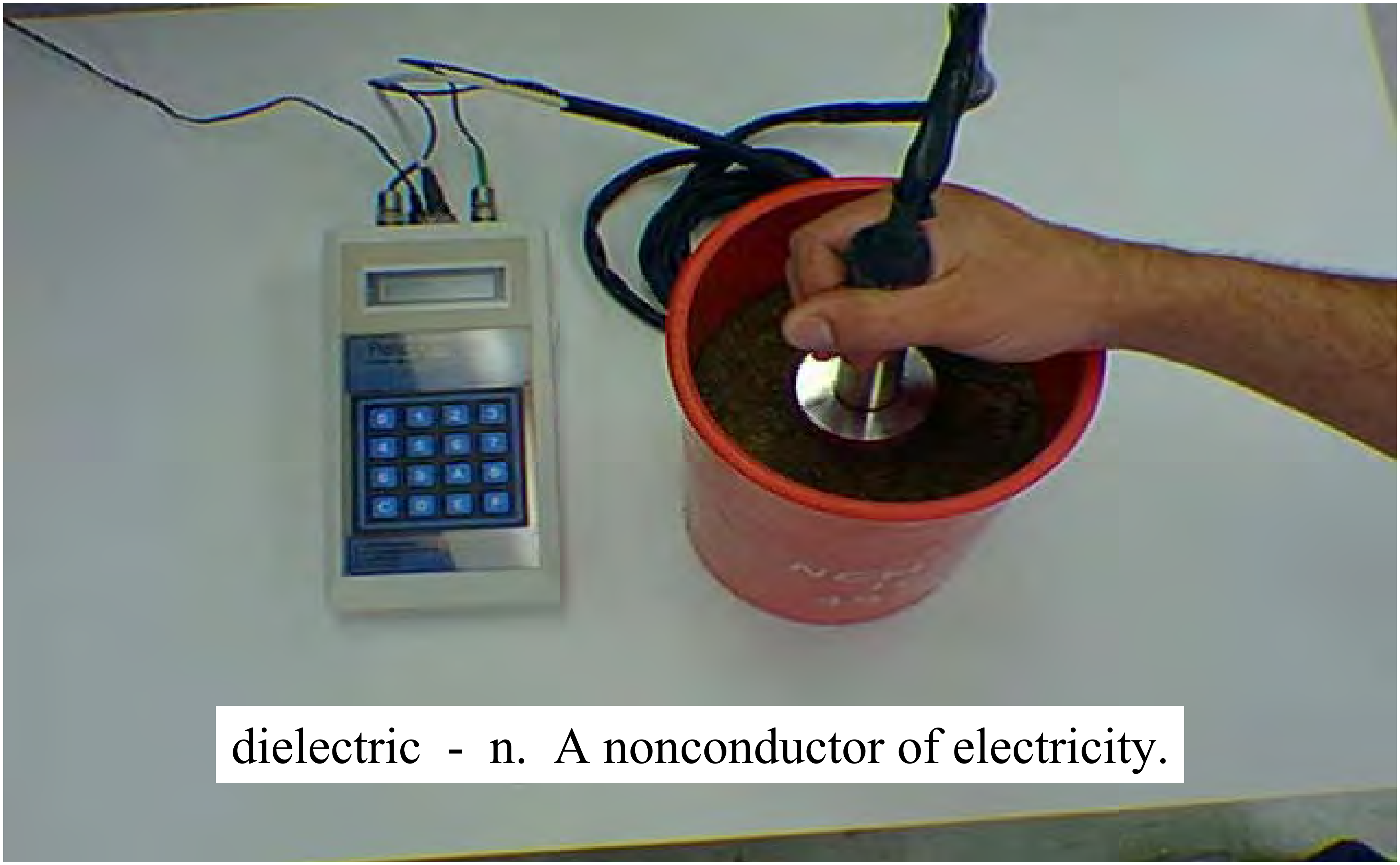
Current Research Involving Cement-Modified Soils

- *"Tube Suction Test for Stabilized Materials"*
  - Tom Scullion, P.E.
  - Texas Transportation Institute
  - 2001
- Evaluated the moisture susceptibility of subgrade soils used in roadway pavements
- Recognized an empirical relationship between laboratory electrical conductivity values and expected performance (durability) of subgrade materials in the field


Soil Particle
O
H H
+

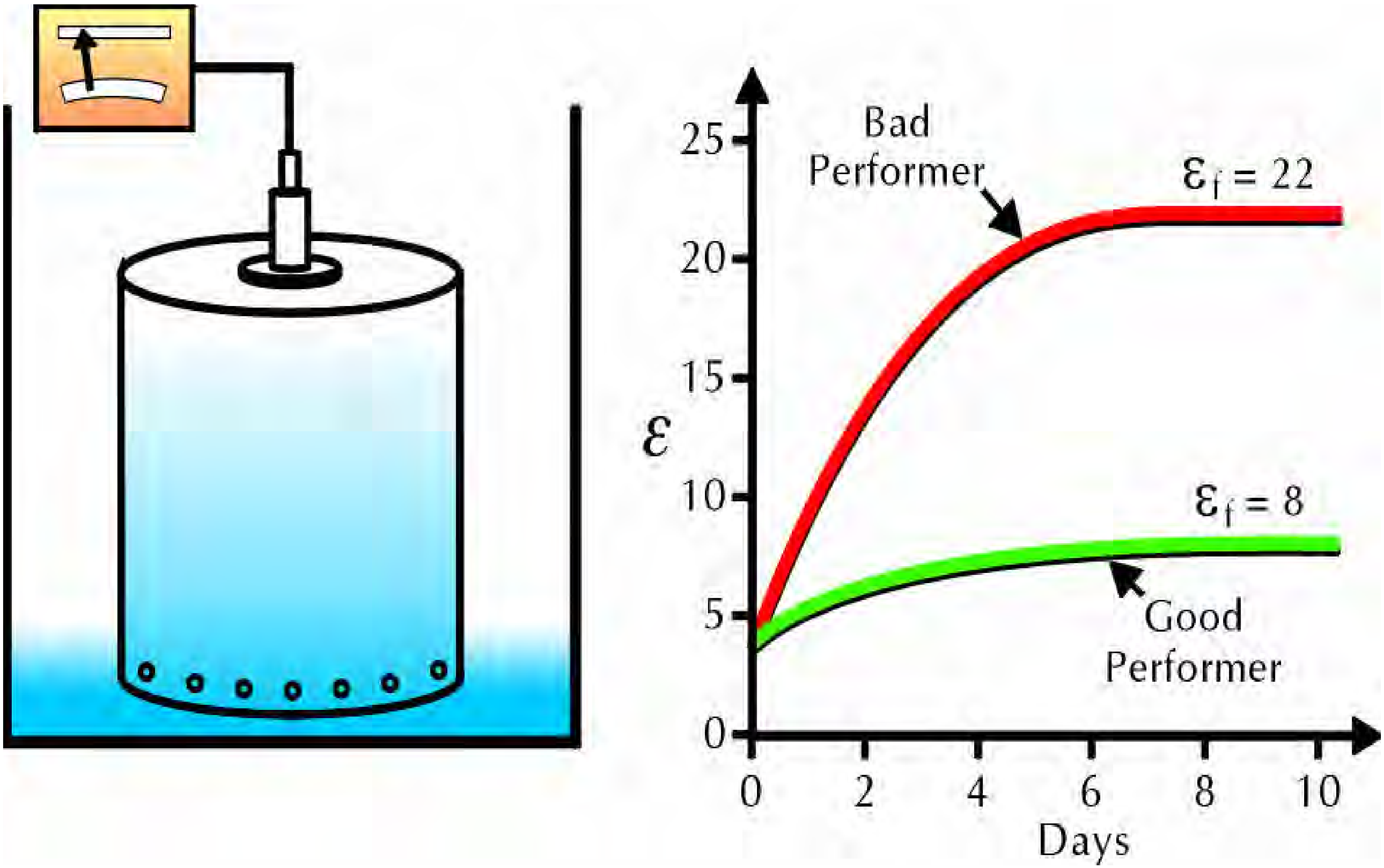
Tube Suction Test (TST) for Moisture Susceptibility

Using the Dielectric Probe

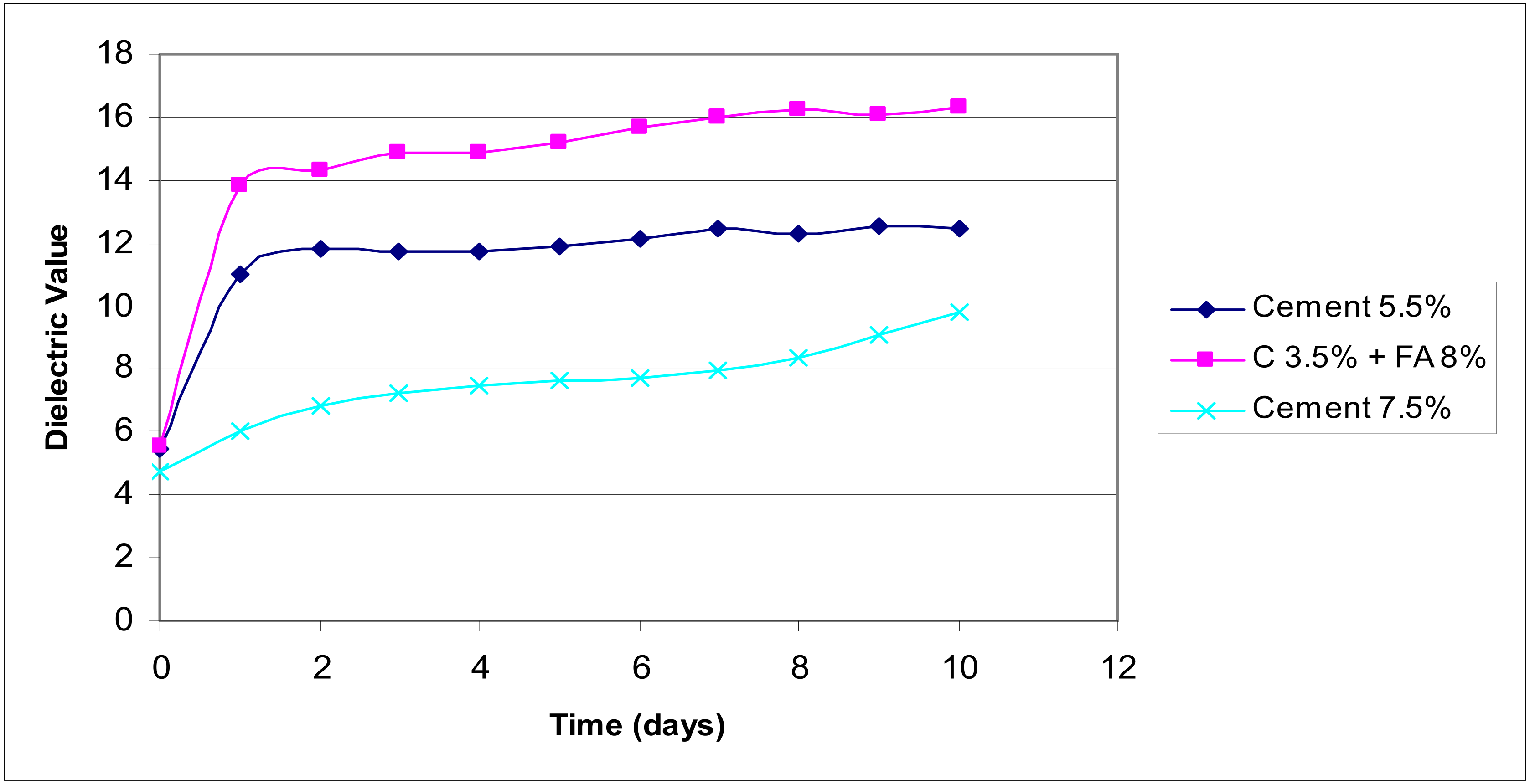


dielectric - n. A nonconductor of electricity.

Interpreting TST Results

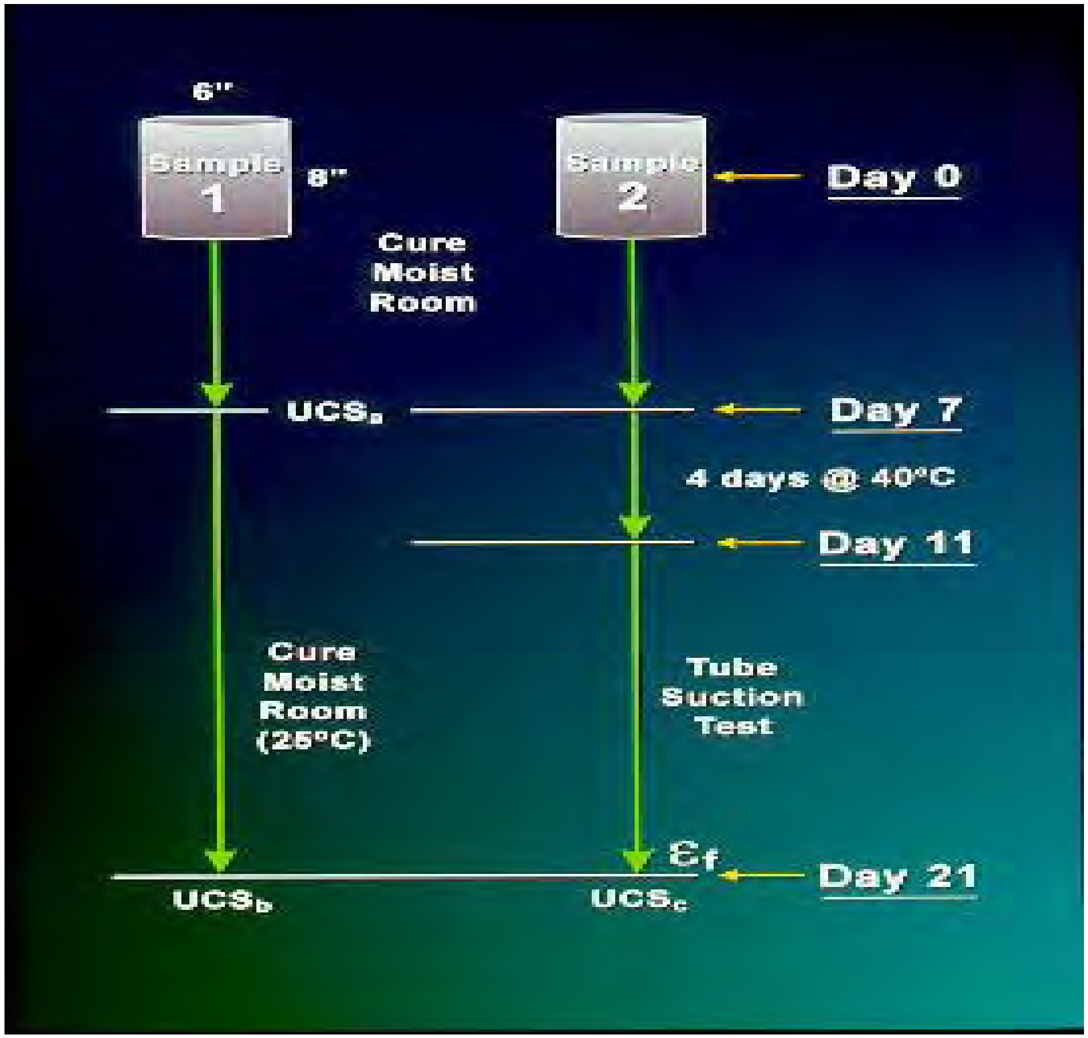


Sample Test Data




FT WORTH FM 1810
TUBE SUCTION SAMPLES
PROJECT 1712
0% CEMENT
2% CEMENT
3% CEMENT
4% CEMENT

Summary of Recommended Laboratory Test Procedure



General Results of the Texas Transportation Institute's Research

- A final dielectric value less than 16 appears to be indicative of a stabilized subgrade material adequately resistant to moisture susceptibility
- Reliable durability predictions can be made in two-thirds the time of the conventional W-D and F-T Tests


1/2 Mile
CONSTRUCTION


329


CR851


RLV 04
BOMAG

Subgrades before and after CMS


1/2 Mile
TESTING

Primary Testing Requirements

Gradation

A common gradation requirement is for 100% to pass the 1.5-inch (38 mm) sieve and a minimum of 60% to pass the No. 4 (4.75 mm) sieve (ASTM C136).

Moisture

A common moisture requirement is to be within 2% of the laboratory established optimum moisture content (ASTM D558).

Density

A common density requirement is to be between 95% and 98% of the established laboratory standard Proctor density (ASTM D558).

Secondary Testing Requirements

Thickness	Stiffness	Stability
		
Requirements for subgrade depths can vary from as little as 6 inches (150 mm) up to 2 feet (0.6 m) depending on governing agency.	Measures in-place engineering values using structural layer stiffness, klbf/in (MN/m) and Young's Modulus of a material, kpsi (MPa).	Modified subgrade **MUST** be stable before next pavement course is constructed! Proof-rolling is the most commonly accepted practice.

But what about strength?

The objective of CMS is to amend undesirable properties of problem soils or substandard materials so that they are suitable for use in construction. The amount of cement added to the soil is less than that required to produce a hardened mass but is enough to improve the engineering properties of the soil.

It is important to remember that soil *modification* is different than soil *stabilization*


1/2 Mile
PERFORMANCE

CMS can be used as a subgrade for either flexible or rigid pavement structures

The final impact of CMS

Summary: Cement-Modified Soil

- Cement factors normally 2% to 5%
- Significant and immediate reductions in the soil's Plasticity Index
- Increases bearing ability of granular or plastic soils
- Produces workable foundation for bases for both rigid and flexible pavements

Summary: Cement Effects

- Strength improves immediately and increases over years
- No long-term effects from leaching
- Compaction can occur immediately with no "mellowing period" necessary

Cement Council of Texas

Full-Depth Reclamation

Cement Council of Texas

Matthew W. Singel, PE

Full-Depth Reclamation with Cement

- Applications
- Design
- Construction
- Testing
- Performance

Definition of Reclamation

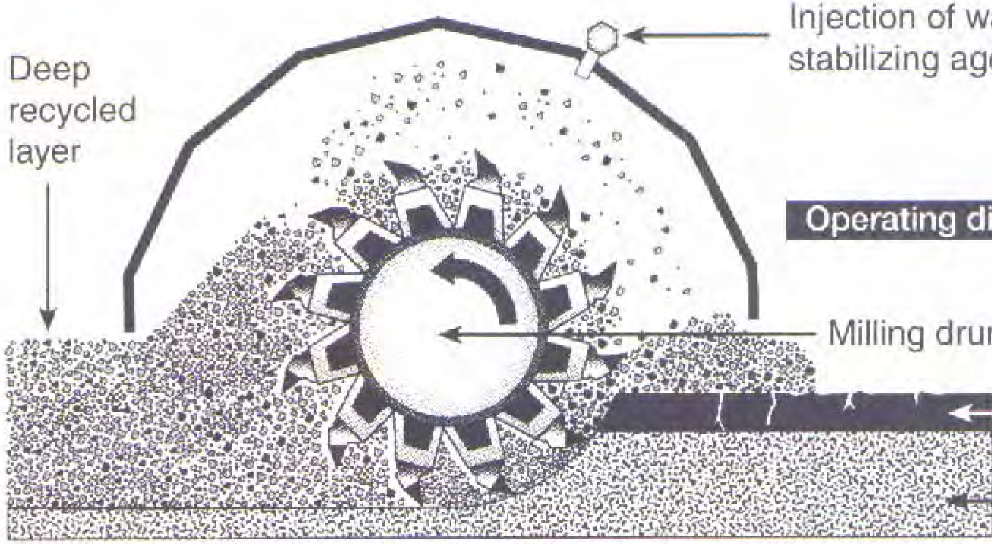
- Method of flexible pavement reconstruction that utilizes the existing asphalt, base, and subgrade material to produce a new stabilized base course for an asphalt, chip seal, or concrete wearing surface.

- Alternative Terms:
  - Full-Depth Recycling (FDR)
  - Cement Stabilized Reclaimed Base (CSRB)
  - Cement Recycled Asphalt and Base (CRAB)
  - Cement Recycled Asphalt Pavement (CRA……)

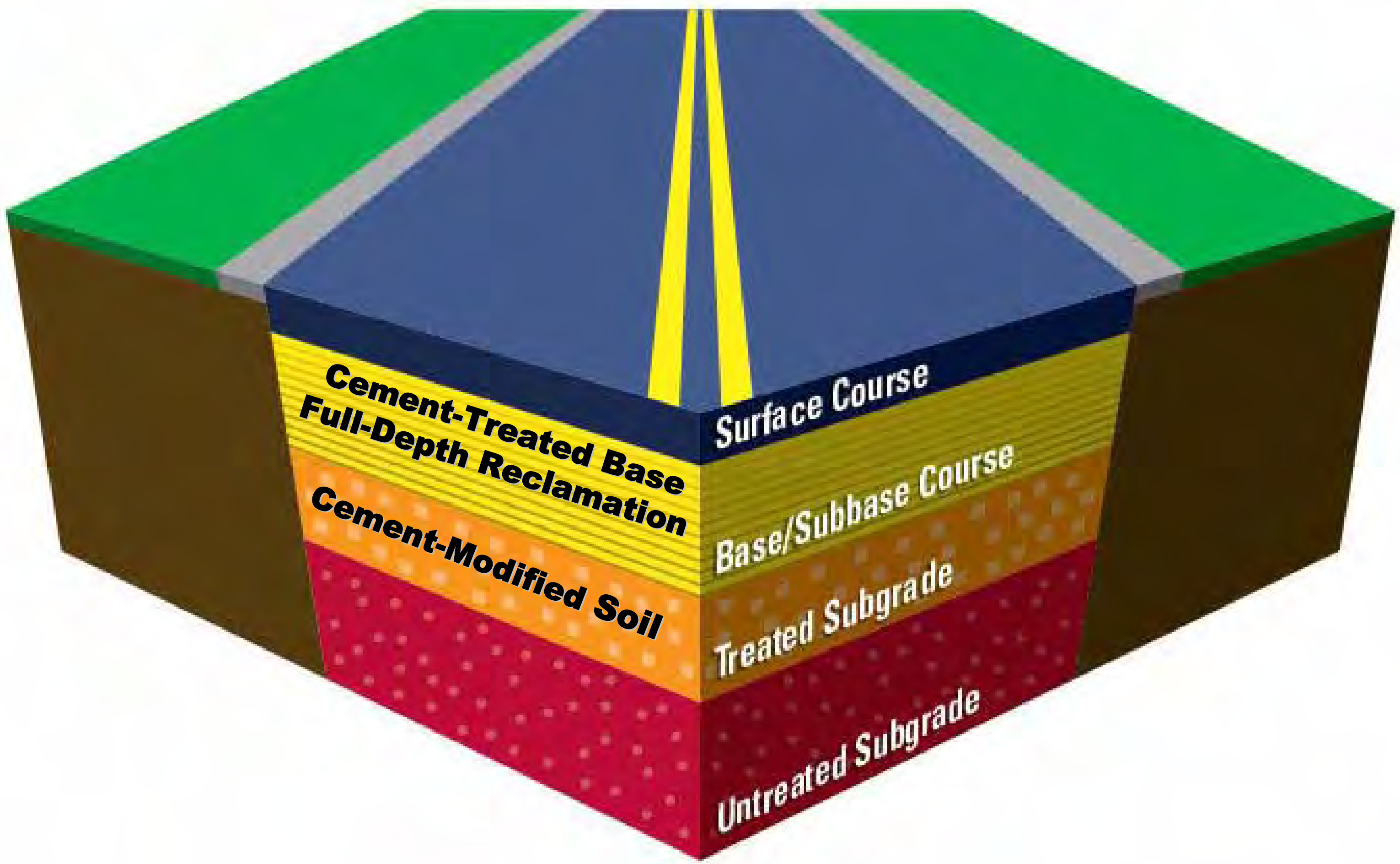
The New Base

The new cement recycled base will be stronger, more uniform, and more moisture resistant than the original base, resulting in a long, low-maintenance life

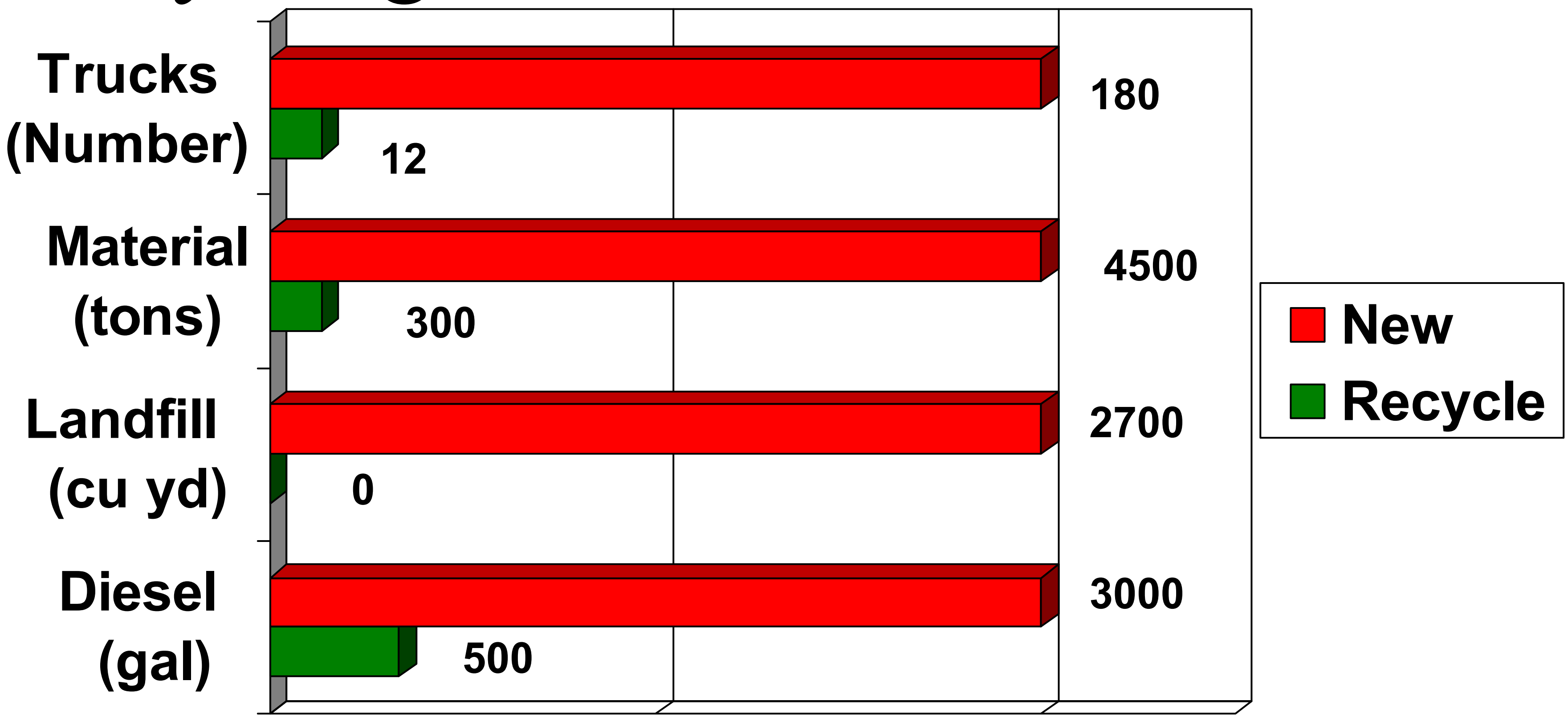
Inside a Reclaimer



Soil-Cement Materials in a Pavement Section



Equipment and Materials Recycling vs. New Base

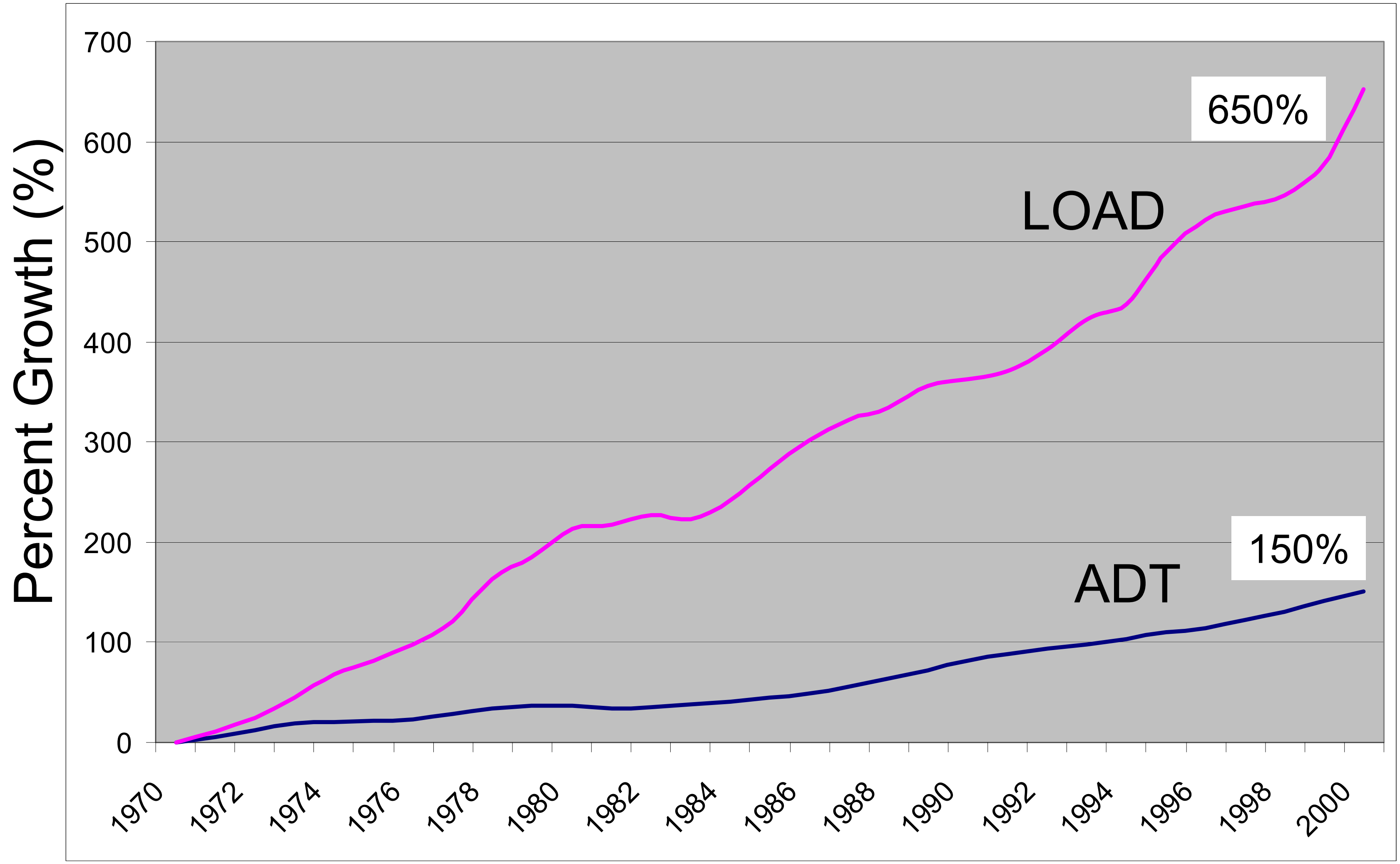


1 Mile of 24'-wide 2-lane road, 6" base + 2" asphalt surface

Pavement Loadings….

An Increasing Trend

Rural Interstates - Growth



Source: Highway Statistics 2000

Pavement Distress

Alligator Cracking

Pavement Distress

Rutting

Pavement Distress

Base Failure

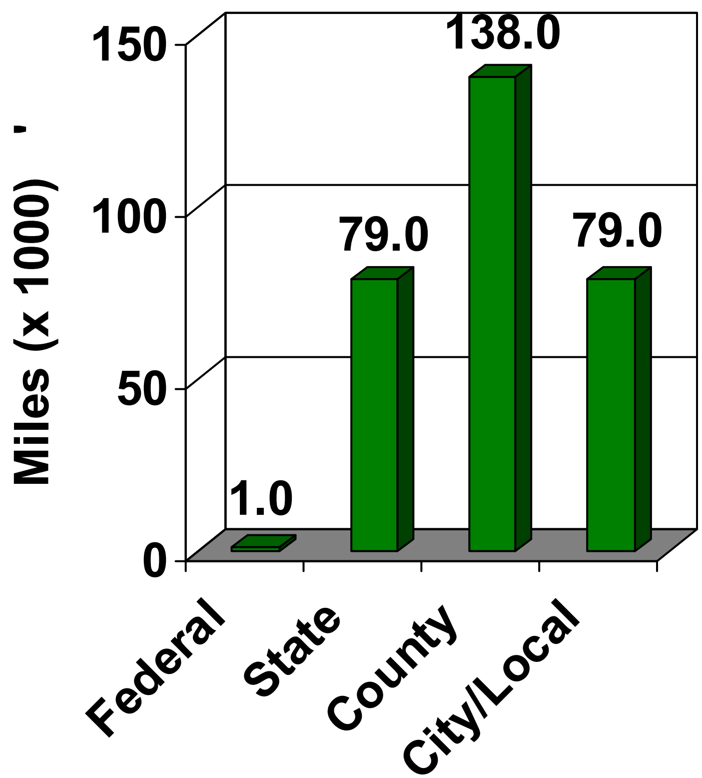
Pavement Distress

Moisture Infiltration

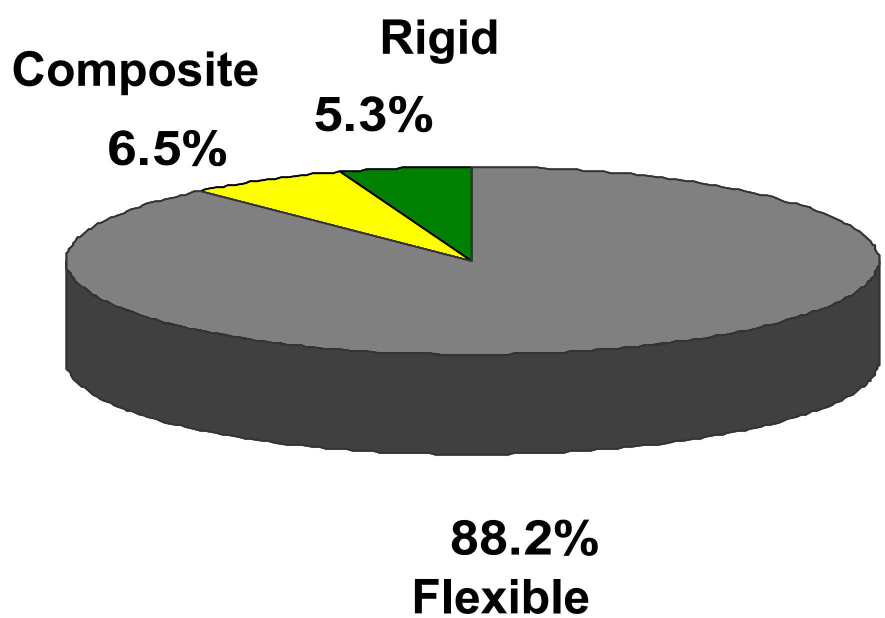
Pavement Distress

Potholes

Texas Pavements

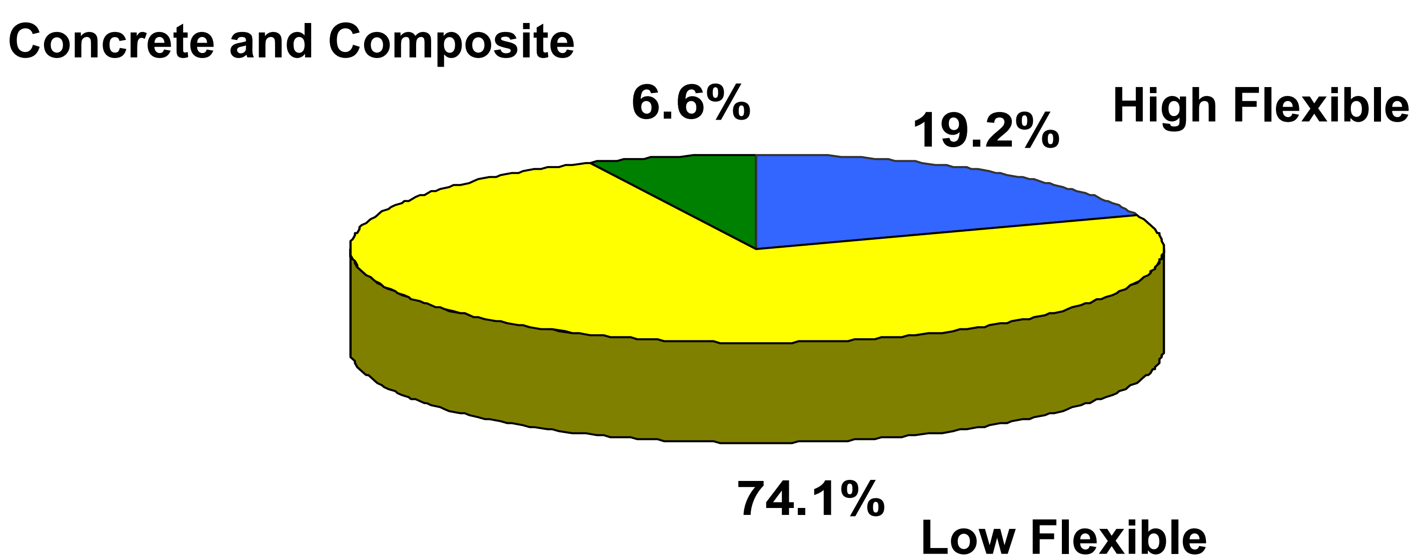


Centerline Miles of Road By Jurisdiction (296,000 Miles)



Type of Pavement

Pavements in the United States



2,450,000 miles of surfaced roads

Reclamation: A Logical Choice

- Aging road systems
- Most highway systems now in place
- Emphasis shifting to maintenance/rehabilitation
- Most roads are local, low-volume, unpaved or flexible pavements
- Possible strategies:
  - Thick structural overlays
  - Removal and replacement
  - Reclamation with cement & thin overlay

Applications

- Low volume roadways
- Residential streets
- Medium to high-volume roads
- Highways and interstates
- Airports
- Parking lots
- Industrial storage facilities

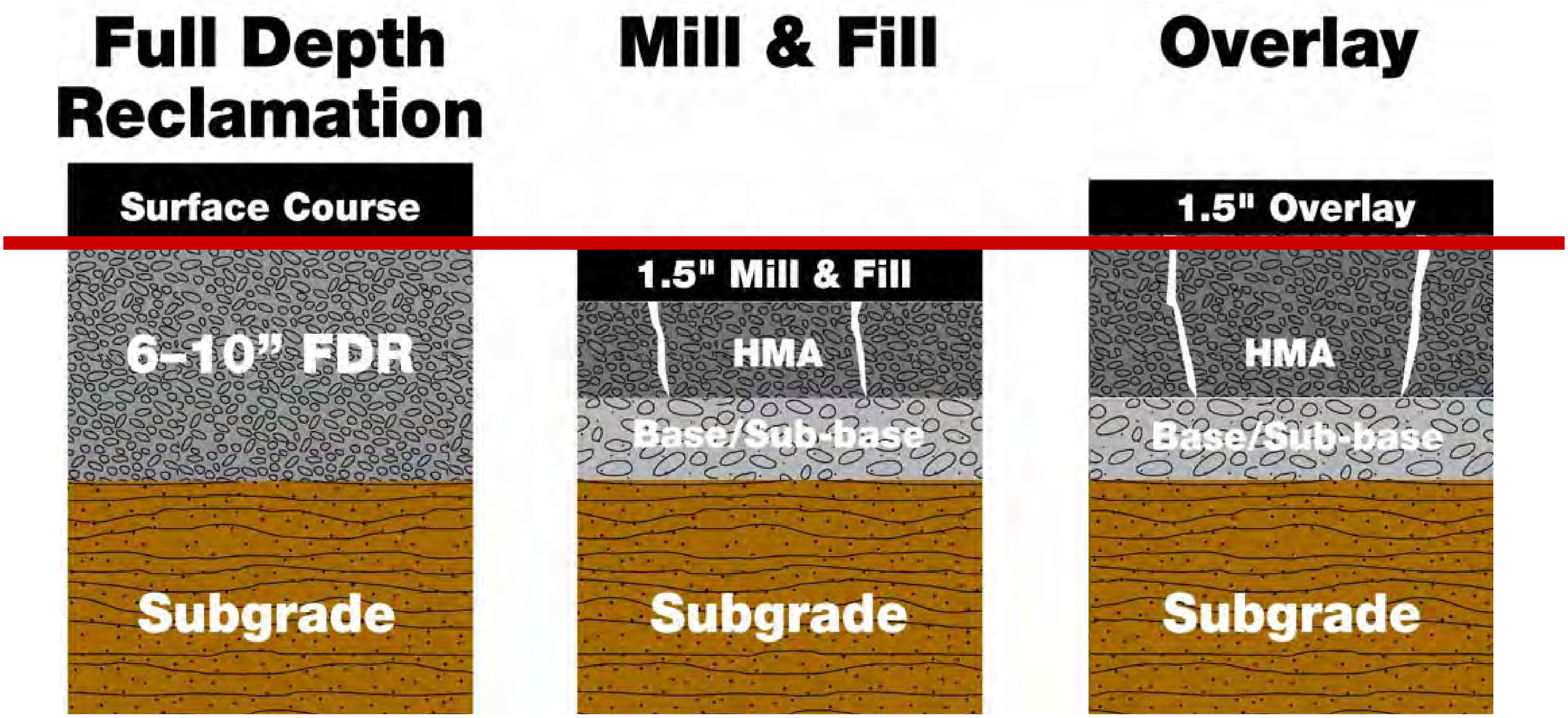
Advantages of Reclamation

- Save costs by reusing in-place materials
- Little or no material hauling
- Maintain or improve existing grade
- Conserve virgin materials
- Reduce construction time (quick return to traffic)
- Environmentally friendly

Engineering Benefits

- Retards Reflective Cracking
- Increased Rigidity Spreads Loads
- Eliminates Rutting Below Surface
- Reduced Moisture Susceptibility
- Reduced Fatigue Cracking
- Allows Thinner Pavement Section

Retards Reflective Cracking



Creates Stable Base

- Bonds particles together (increases strength, stiffness)
- Reduces plasticity
- Reduces permeability (fills voids, forms membrane)
- Improves compaction (lubrication, particle restructuring)

Easy Construction Process!

- Design
- Processing
- Compaction
- Finishing
- Curing
- Surfacing


DESIGN
(Preconstruction
Evaluation)

Preconstruction Testing

- The procedure includes the following steps:
  - **Site Investigation.**
    - The site should be investigated to determine the cause and depth of failure.
    - Cores or test holes should be used to determine layer thicknesses and to obtain material samples to be recycled including the asphalt surface, base course aggregate, and subgrade.
  - **Lab Evaluation.**
    - Representative samples from the site should be pulverized in the lab to simulate the aggregate-soil mix anticipated during construction.


UNITED UNITED WASTE SERVICE, INC

Mix Design

The mix design procedure uses PCA publication:

Soil Cement Laboratory Handbook

Includes the determination of:

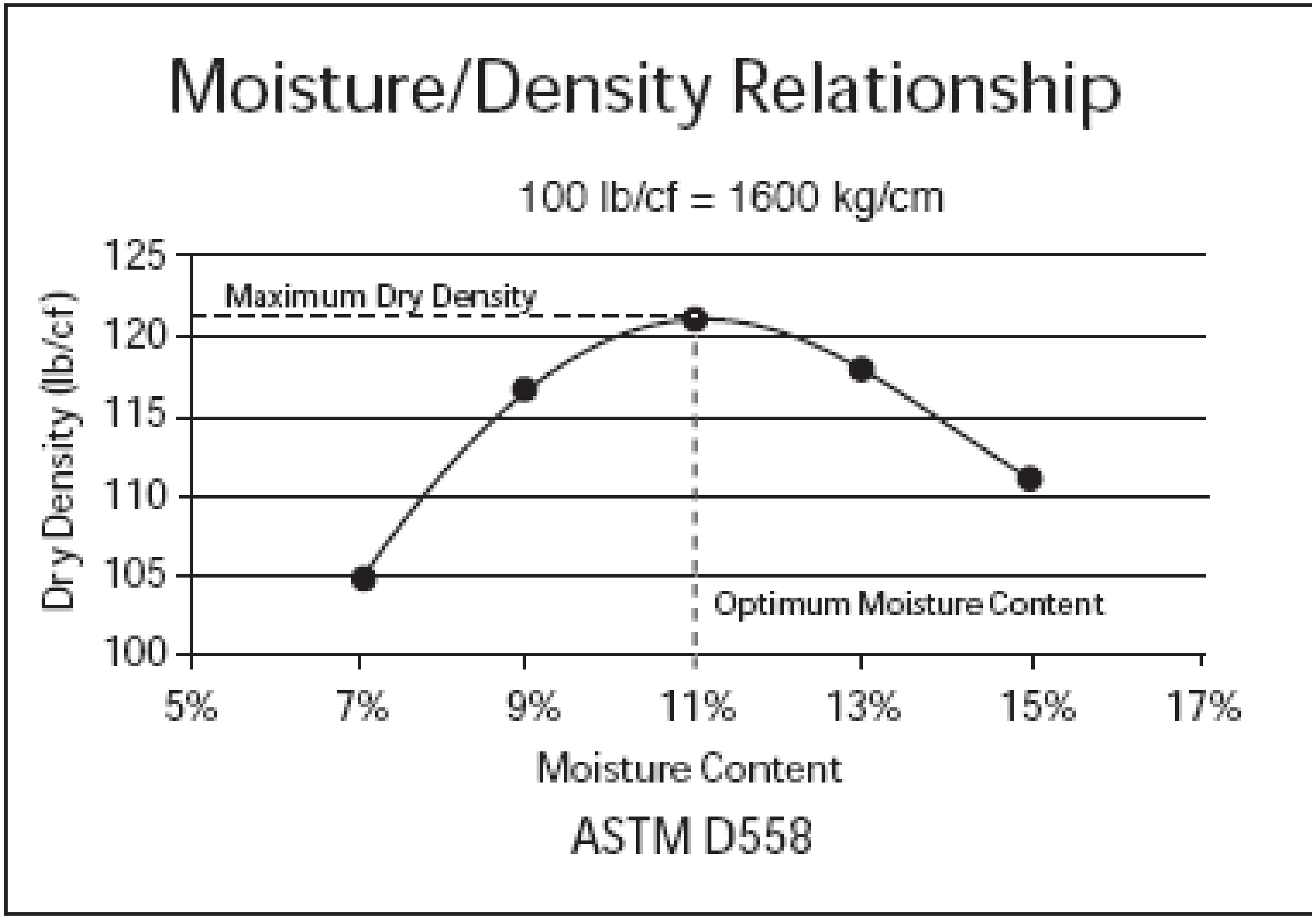
- maximum dry density,
- optimum moisture content, and
- compressive strength.

(If unconfined compressive strength is used to determine cement content, a 7-day strength of 300 to 400 psi is recommended)

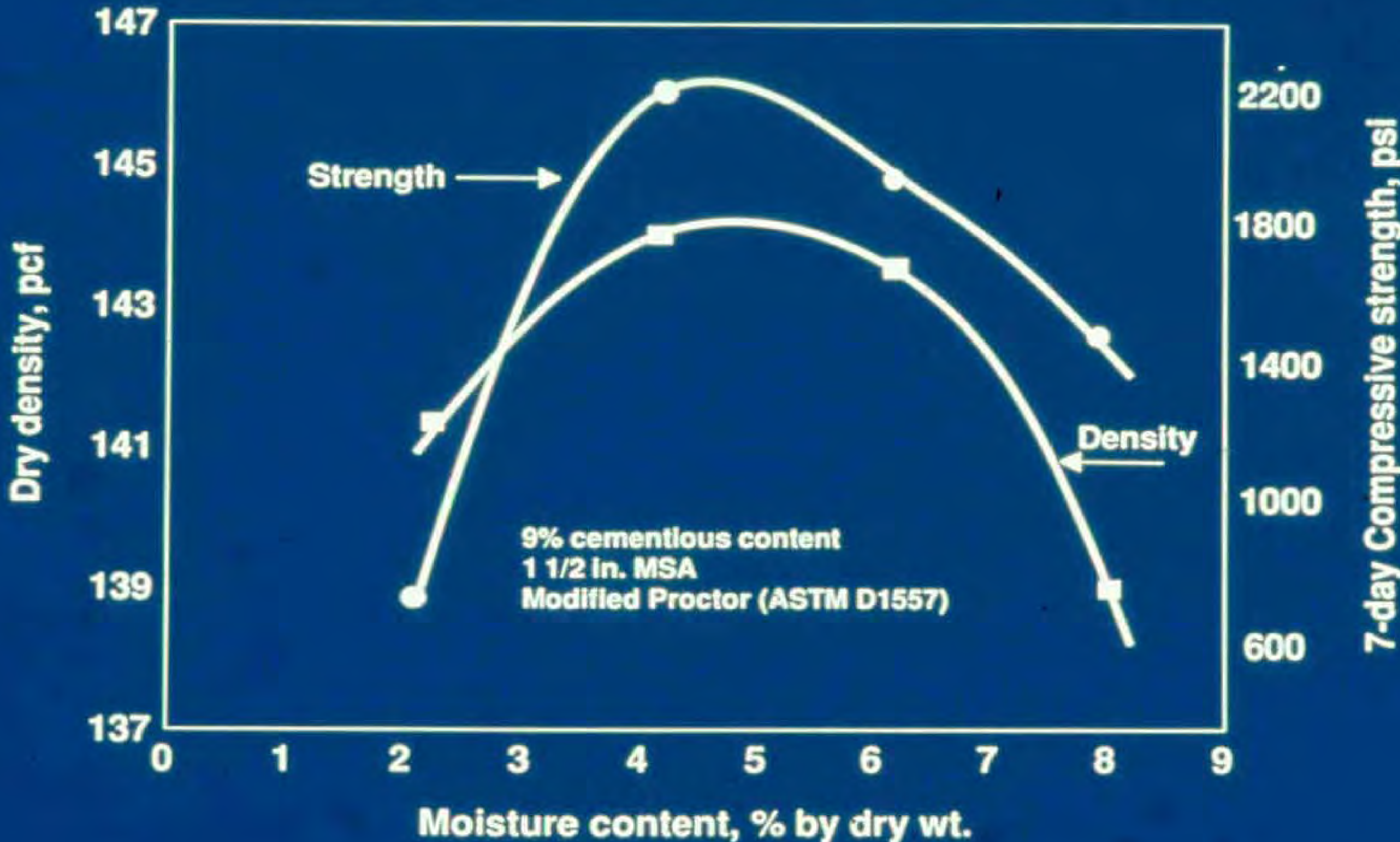
Mix Design Proportioning

- Obtain representative samples of roadway material
- Can use up to 50% Reclaimed Asphalt Pavement (RAP)
- Pulverize to anticipated gradation
  - 100% passing 50 mm (2”)
  - 55% min. passing 6 mm (#4)
- Estimate cement content
  - Usually 4 to 8%
  - By weight of dry material
- Run moisture/density curve
  - Standard Proctor
  - (ASTM D558)

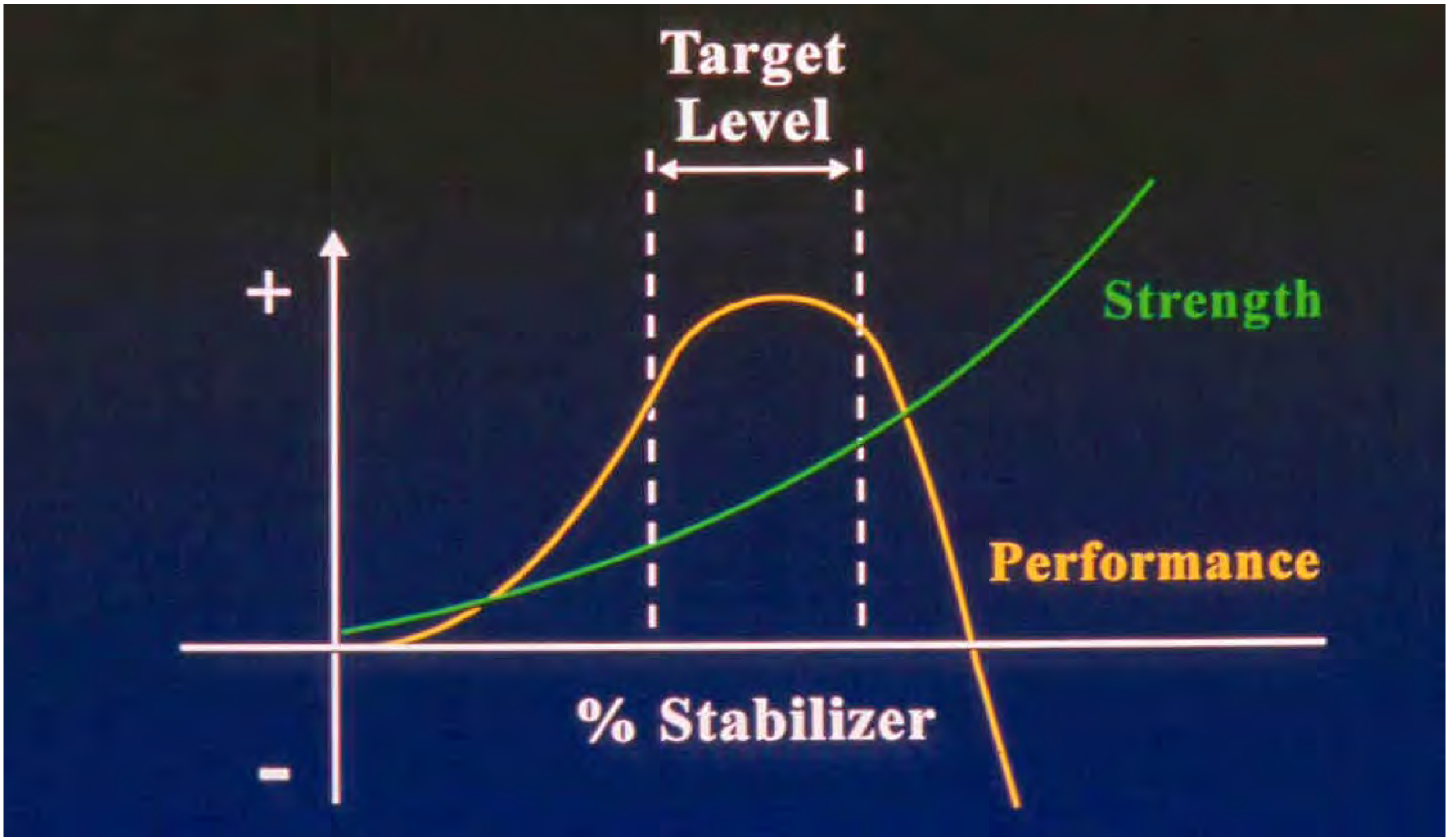
Moisture/Density Relationship



RELATIONSHIP BETWEEN DENSITY AND COMPRESSIVE STRENGTH



Strive for a Balance Between Strength and Performance



Test for Strength

- **Unconfined Compressive Strength Test**
  - Used by most State DOT's
  - Simple
  - Quick
  - 7-day requirements range from 200 psi to 800 psi
  - 300 psi to 400 psi is generally recommended


CONSTRUCTION

Aggregate Adjustment (if necessary)


BarcoMill
100

Pulverization

- Pulverize to required depth and gradation
- 1 to 4 passes

Material Removal

Excess material can be removed from roadway

(rare occasions)

Cement Spreading (Dry)

- Cement is spread on top of roadway in measured amount

Cement Spreading (Slurry)

Blending of Materials

- Cement is blended into pulverized, reclaimed material

Moisture Addition

- Water is added to achieve optimum moisture


M341

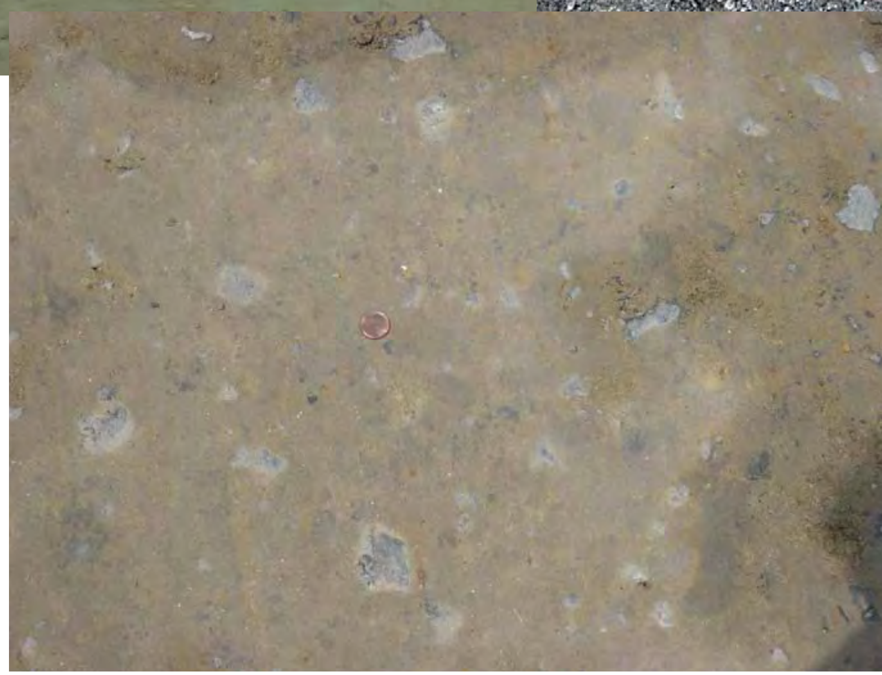
Grading

- Material is graded to appropriate grade, and cross-slope

Compaction

- Material is compacted
- 96% minimum Standard Proctor density





Curing

Water

Bituminous Compound

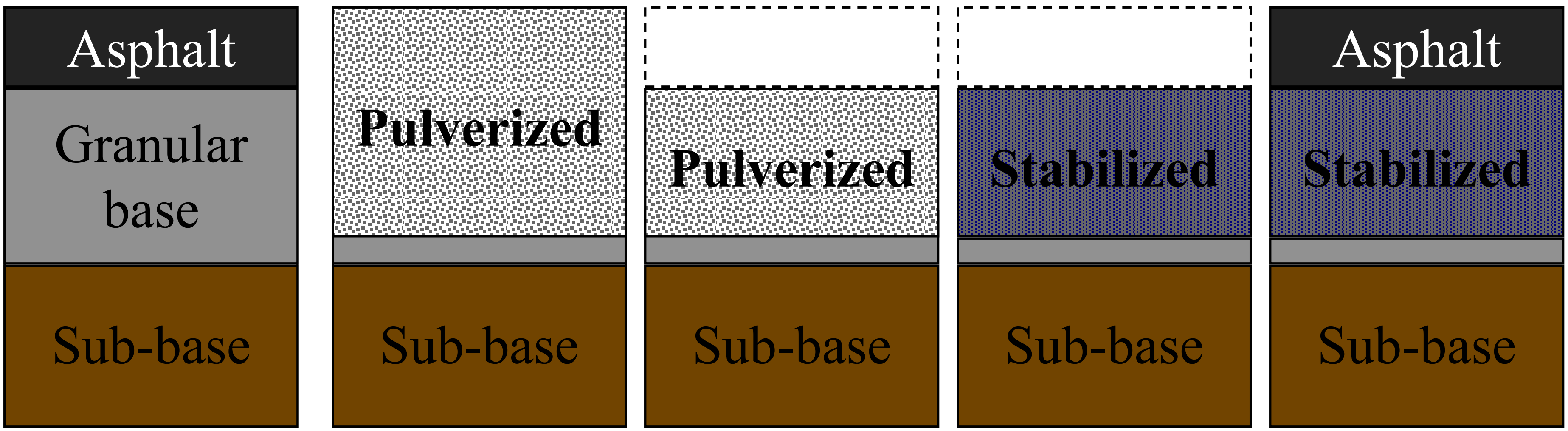
Surfacing

- Surface course is applied last
  - Conventional Concrete
  - Roller-Compacted Concrete
  - Hot-Mix Asphalt
  - Surface Treatment

Typical Recycled Base and Surface Thickness

Road Function	**Typical Thickness**	**Recommended Surface**
Residential	6 in	0.75 – 1.5 in
Secondary	8 in	1.5 – 2.5 in
Highway	10 in	2 – 3+ in

Review of Construction Procedure



Quality Control

Quality Control

The success of a recycling project depends upon the careful attention to the following specified control factors:

- pulverization
- cement content
- moisture content
- density
- curing

Reflective Cracking

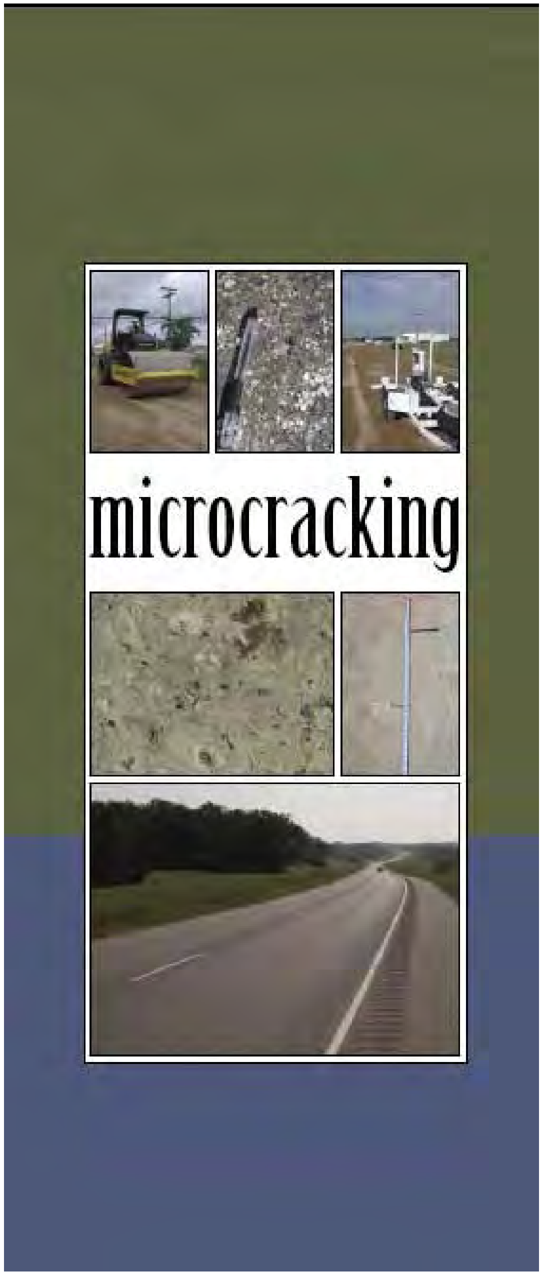
Can it be prevented?

Micro-cracking

Introduces a network of fine fractures into the base to mitigate the formation of major cracks

- 10-12 ton vibratory roller applied 1–2 day after placement
- Low Speed
- At High Amplitude
- 2 – 4 passes

PCA Document LT 299



TESTING

Testing

Moisture

Testing

Density

ASTM D 2922

AASHTO T 310

Testing

Thickness

Testing

Stiffness

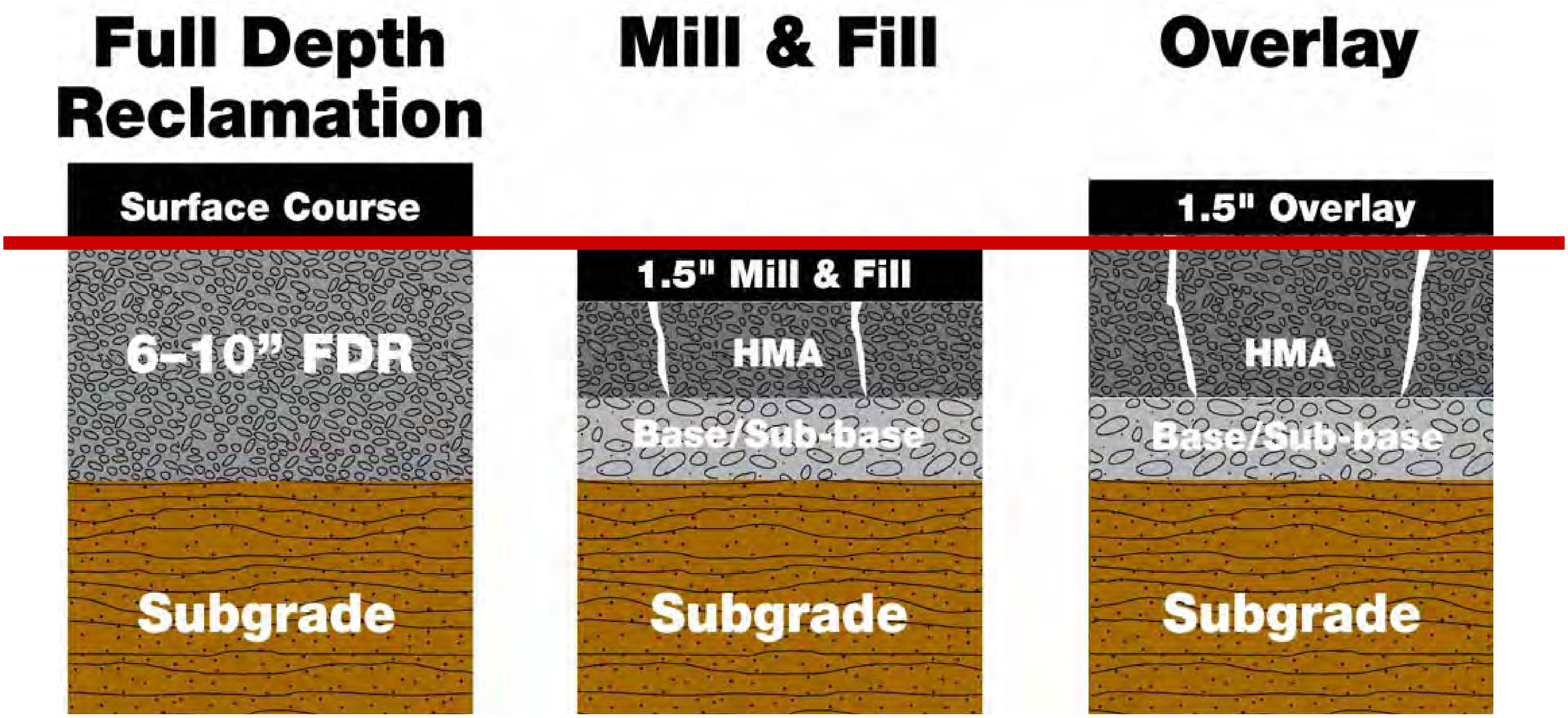
Testing

Stability

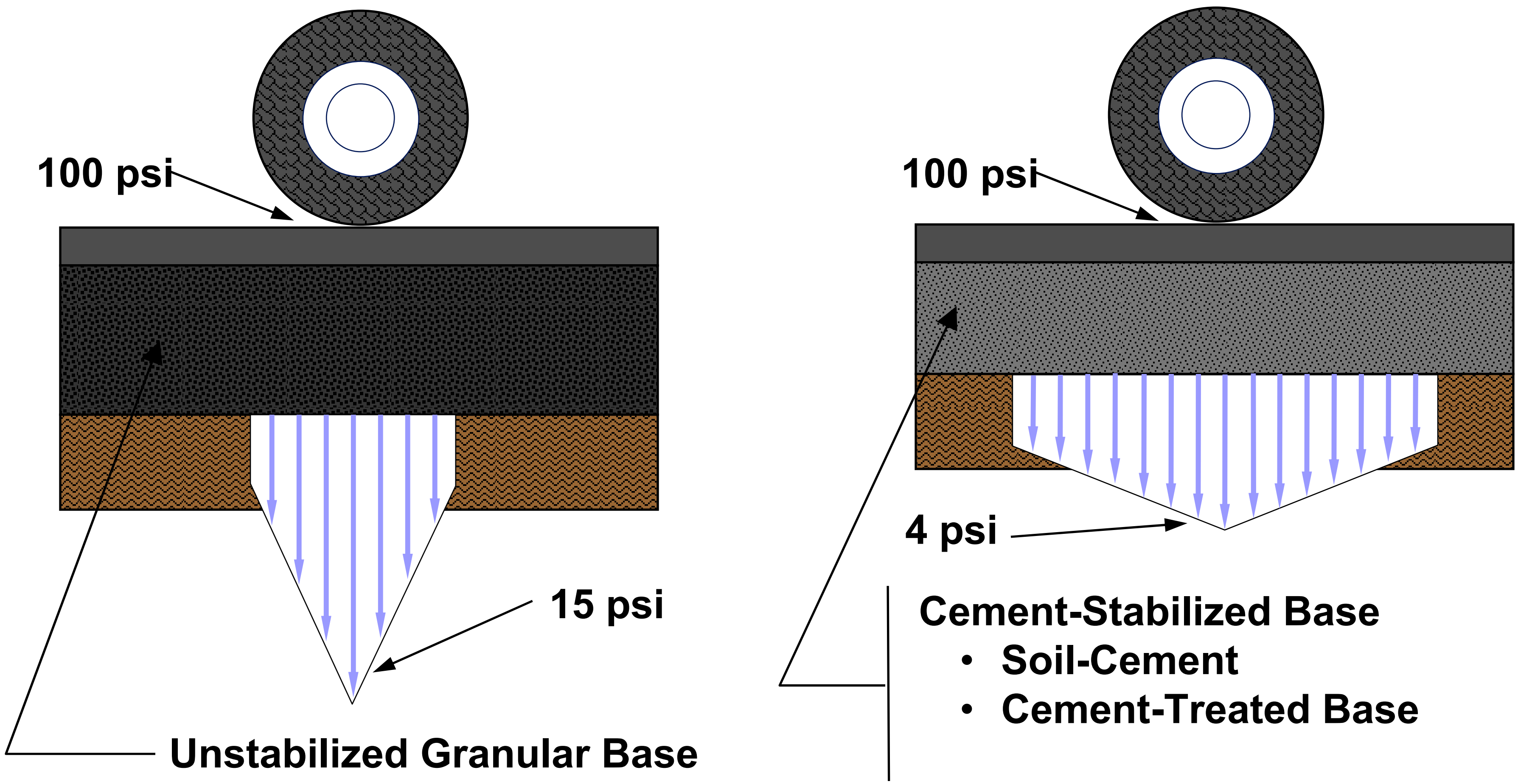
Engineering Benefits

- Retards Reflective Cracking
- Increased Rigidity Spreads Loads
- Eliminates Rutting Below Surface
- Reduced Moisture Susceptibility
- Reduced Fatigue Cracking
- Allows Thinner Pavement Section

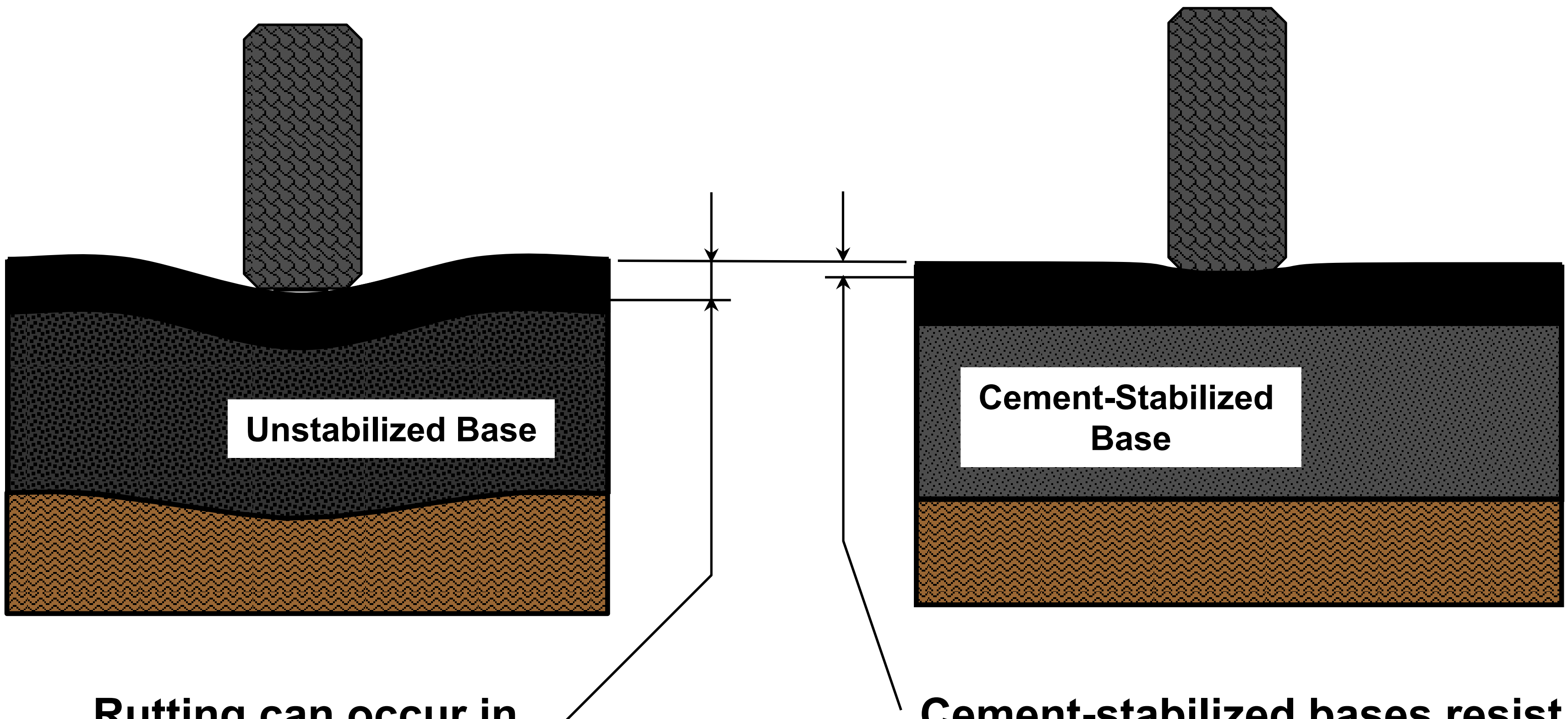
Retards Reflective Cracking



Increased Rigidity Spreads Loads

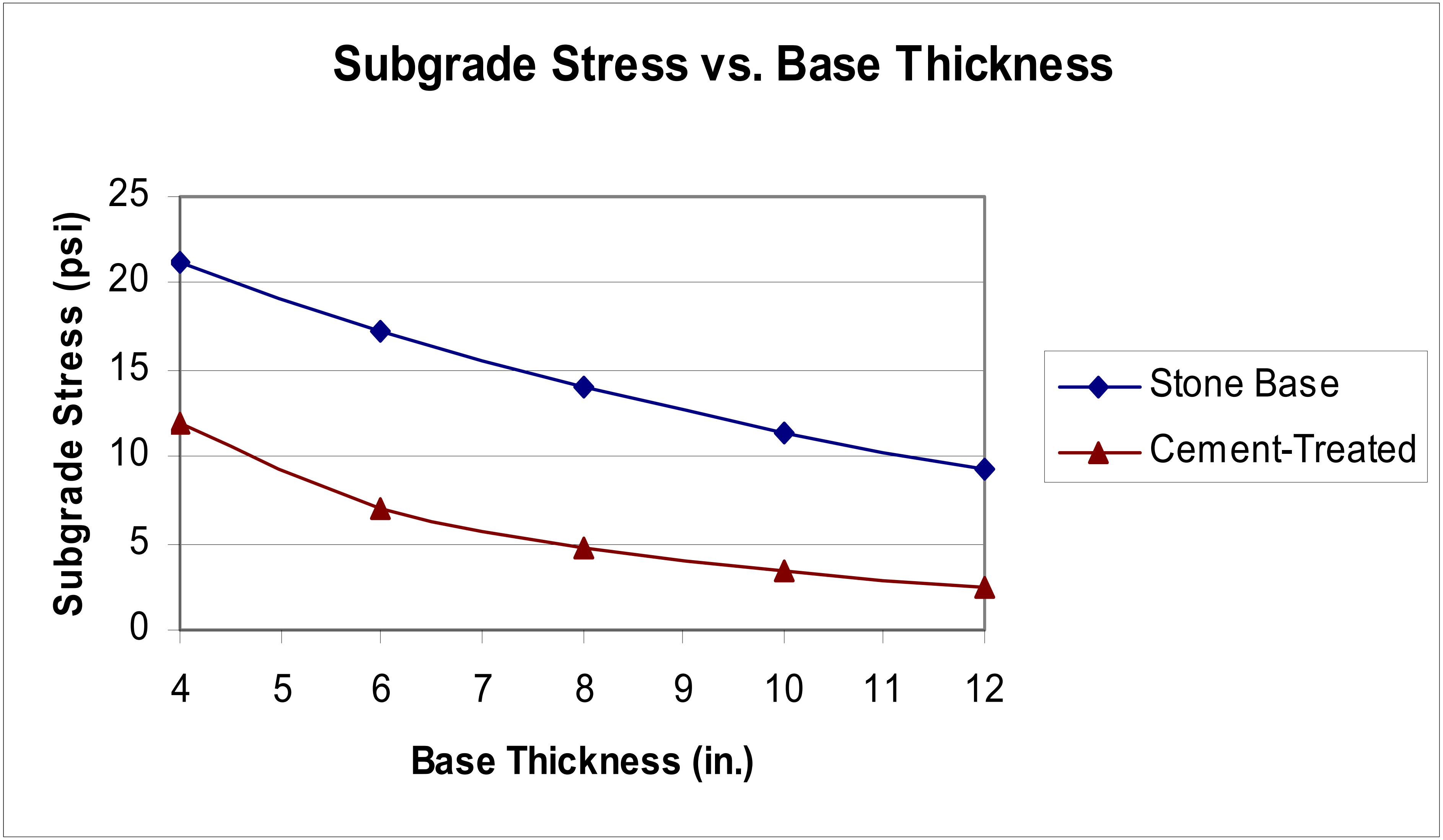


Eliminates Rutting Below Surface



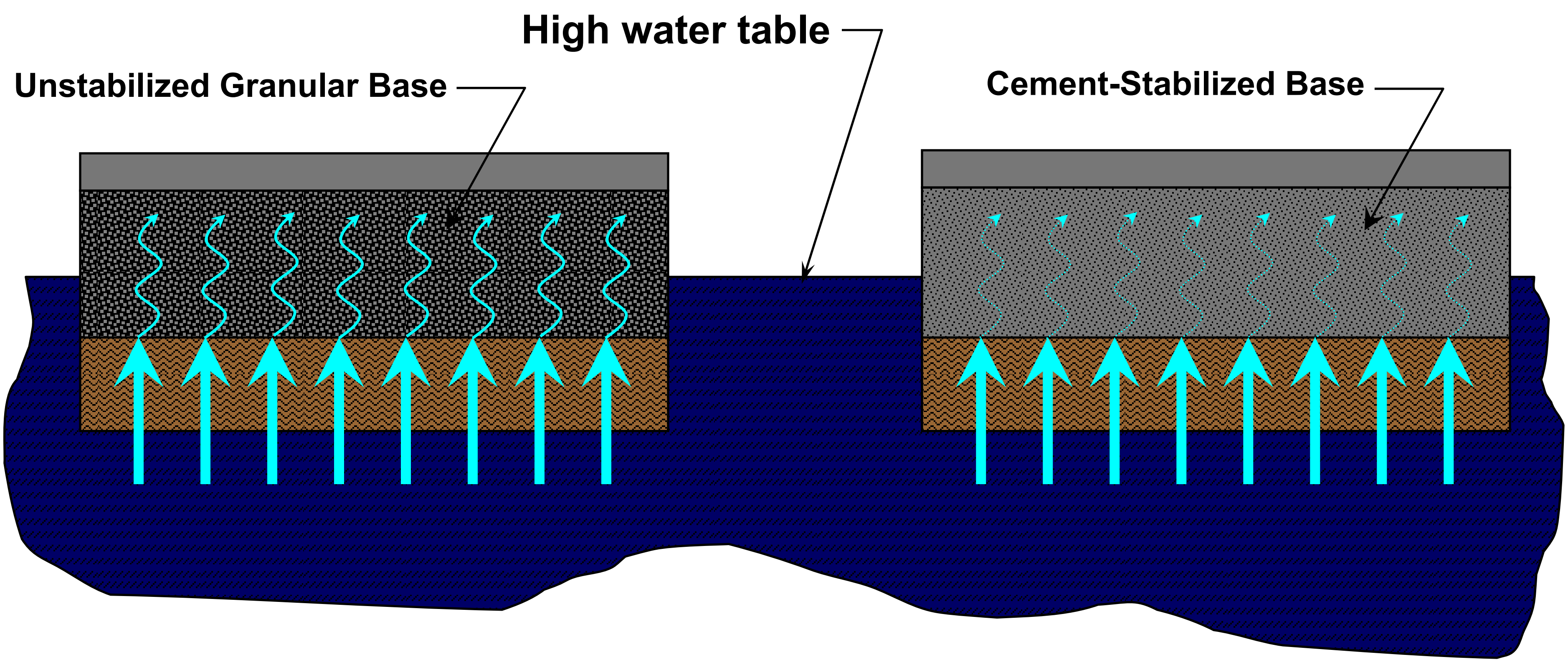
Rutting can occur in surface, base and subgrade of unstabilized bases due to repeated wheel loading

Cement-stabilized bases resist consolidation and movement, thus virtually eliminating rutting in all layers but the asphalt surface.



Subgrade Stress vs. Base Thickness
Subgrade Stress (psi)
25
20
15
10
5
0
4
5
6
7
8
9
10
11
12
Base Thickness (in.)
Stone Base
Cement-Treated

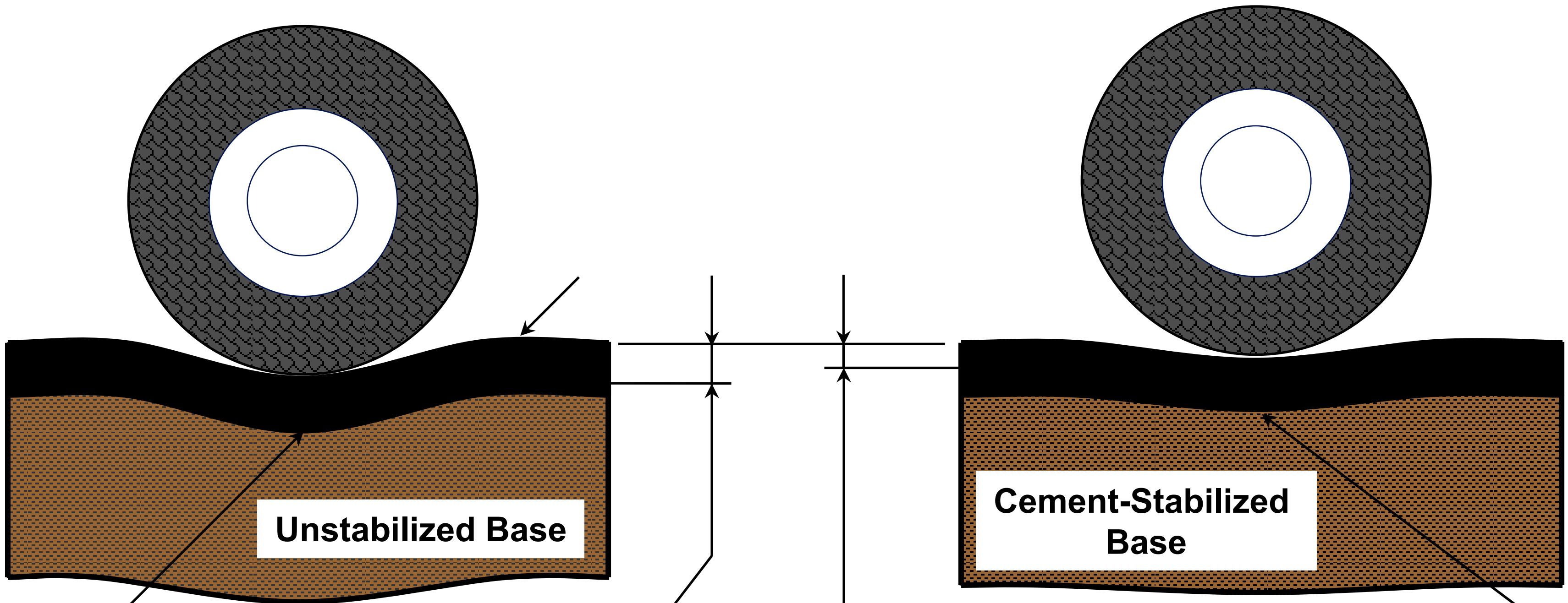
Reduced Moisture Susceptibility



Moisture infiltrates base
- Through high water table
- Capillary action
- Causing softening, lower strength, and reduced modulus

Cement stabilization:
- Reduces permeability
- Helps keep moisture out
- Maintains high level of strength and stiffness even when saturated

Reduced Fatigue Cracking

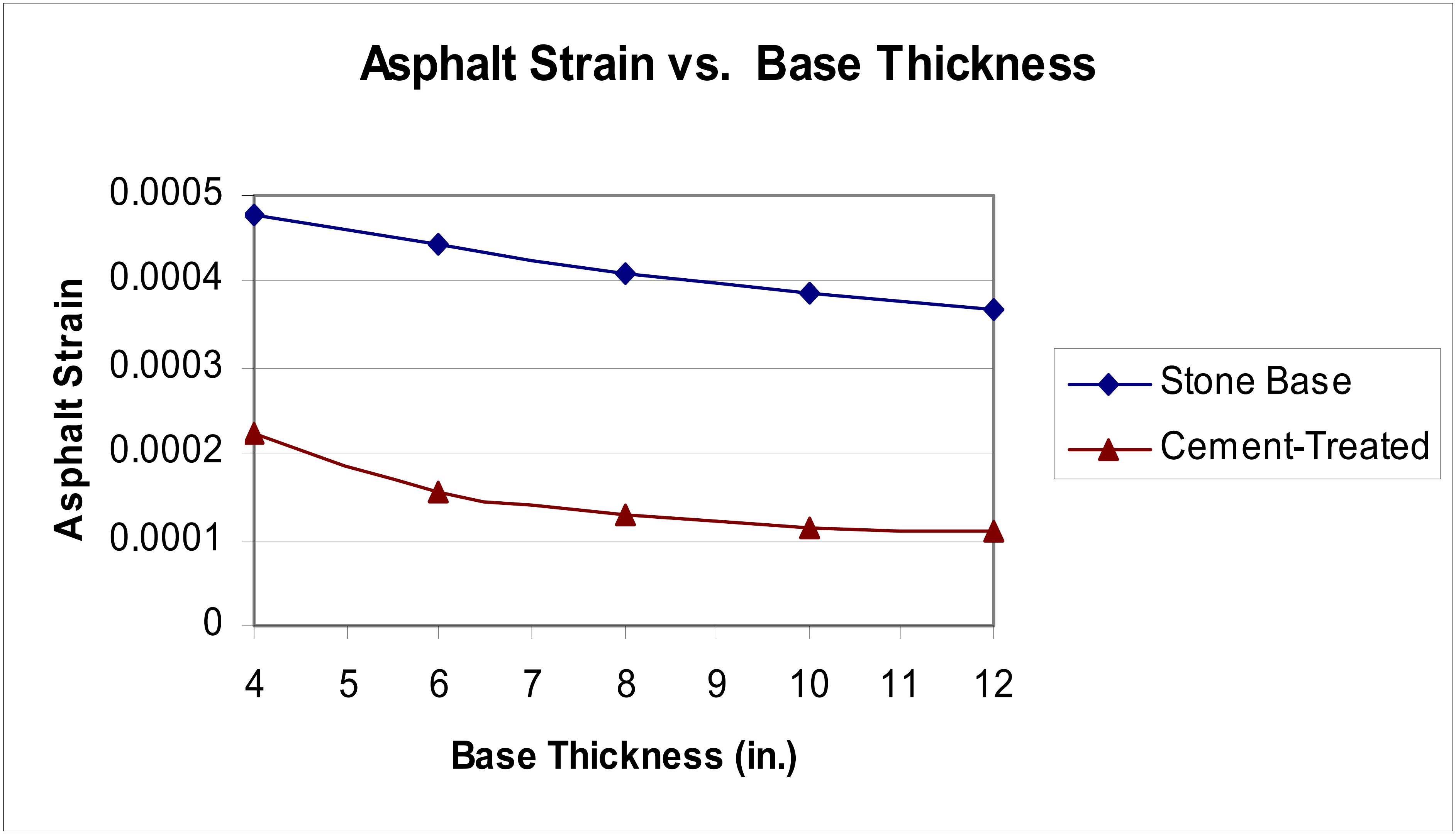


High deflection due to low base stiffness

Results in high surface strains and eventual fatigue cracking

Higher stiffness of cement-stabilized base produces lower deflections

Resulting in lower surface strains and longer pavement life


Asphalt Strain vs. Base Thickness
Asphalt Strain
0.0005
0.0004
0.0003
0.0002
0.0001
0
4
5
6
7
8
9
10
11
12
Base Thickness (in.)
Stone Base
Cement-Treated

Projects

Welcome to Navasota, TX

- Population 6,296

“More Bang for the Buck”

- Began recycling program to get people “out of the mud”
- Has recycled well over 300,000 SY of residential streets
- 2002: 93,000 SY in 20 days.

- Rents CMI 425 for $14,000 ($20,000 w/maintenance and operations).
- Mixes 4% cement
- Uses city crew
- Seal coats
- Cost = $1.92/SY
- Plans to overlay recycled streets w/asphalt.

$22,410 per mile

- 20 Days
- 8-hour days
- City Crews
- City Equipment
- Rented CMI
- Chip seal
- Delaying overlay is working well

FM 1017 Jim Hogg County (2002)

- Two $6M contracts
- Remove/Replace = roughly 23 miles vs. Recycling = 38 miles.
- Existing = 22’ wide hurricane evac route: 2” ACP/8” base

New FM 1017

- 44 feet wide
- 12” stabilized subgrade
- 8” stabilized flexible base
- 1.5” ACP
- One course seal coat applied between flexible base and ACP to facilitate traffic control and to protect against moisture.
- Contractors – Ballenger & Foremost – suggested widening road extra 4 feet for easier traffic control.

City of Fort Worth

City of Fort Worth FDR

1996: 296 lane-miles or 2.26 million SY

Spending 60% of $10-million budget on reclamation

Average material cost: $1.95 to $2.45 SY

Replace vs Recycle

Full reconstruction = $278,500 per lane mile replacing curbs, gutters, sidewalks & driveway approaches.

FDR = $200,000, a $78,500 cost-savings.

BUT city keeps 40% to 90% of concrete, cutting cost to $83,050 per lane mile.

FINAL Cost-savings = $116,950 lane mile

US 79 Jacksonville

- 11-mile stretch
- 8,000 tons of cement = 4%
- 333,864 SY
- 13-in deep

Tarrant County

- Reclaiming with cement since 2001.
- 4.5% cement six to eight inches deep.
- Two-inches of asphalt or a two-course surface treatment tops the roadways.
- Material costs = $1.25 - $1.50 per sq. yd.

TxDOT - Amarillo

- The Amarillo District recycled a portion of IH-40 pavement with cement
  - The existing pavement was 11” asphalt and 19” of flexible base
  - 4” of asphalt were removed with a milling machine
  - The treated base blended 7” asphalt and 4” of flex base
  - A cutback asphalt prime coat was used for curing
  - The final asphalt surface consisted of a 75 #/sy level-up layer and a 150 #/sy surface

TxDOT - Amarillo

- Construction process
  - Two recycling trains were used that included:
    - Milling machines
    - Trailer-mounted screening/crushing units
    - Cold mixing units w/ belt scale and liquid additive systems
  - Cement was applied by two vane spreading units

    The original cement content was specified at 4% but was lowered to 3-3.5% based on lab tests of the recycled material

TxDOT - Amarillo

- Construction process (con't)
  - One lane mile per day paved by each train
  - Project utilized excellent pulverization, mixing, and quality control
  - A month of construction time was saved
  - The method was slightly more expensive than other methods but the time saving was critical
- Performance
  - Highly consistent blended material

Texas DOT Bryan District

- On rural FM system
- Increased oil field and farm traffic
- District recycled 10 inches of base creating a layer
  - 300-400 psi, 4%
  - Roads were opened to traffic daily
- TTI Pavement evaluations of treated layers include
  Stiffness, Cracking, Moisture
  Susceptibility and performance

Successes

- TXDOT – Amarillo – IH-40
- NCTCOG - CMS Specification adopted; 100 cities in 16 counties
- TXDOT-Tyler - US 69 CMS (*2,200 tons*)
- TXDOT Bryan - Over 500 miles roads (*50,000 tons*)
- TXDOT San Antonio - I-37 S. TX - 18 miles of recycling (*17,000 tons*)

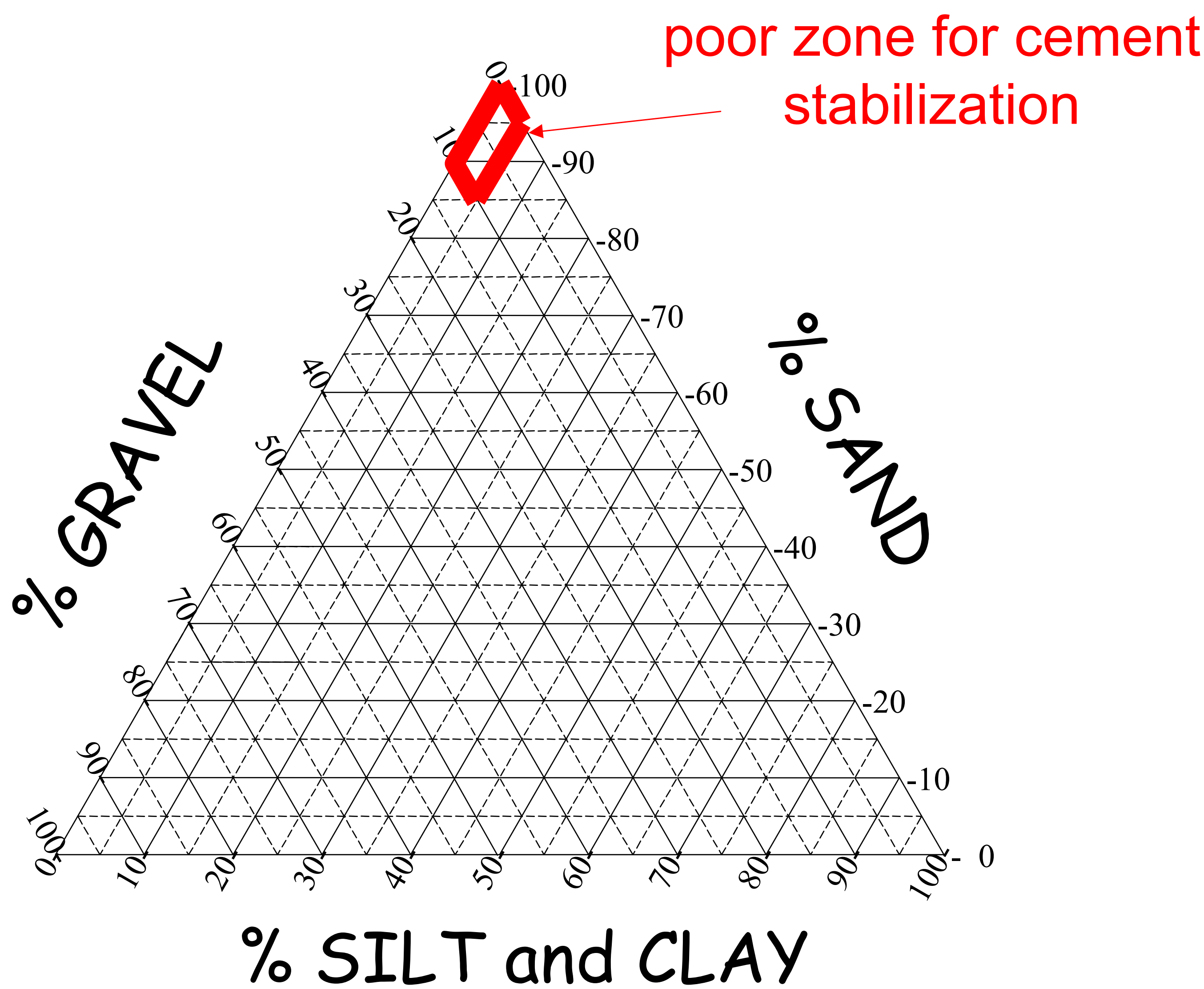
Who Is Using It In Texas?
(Partial List)

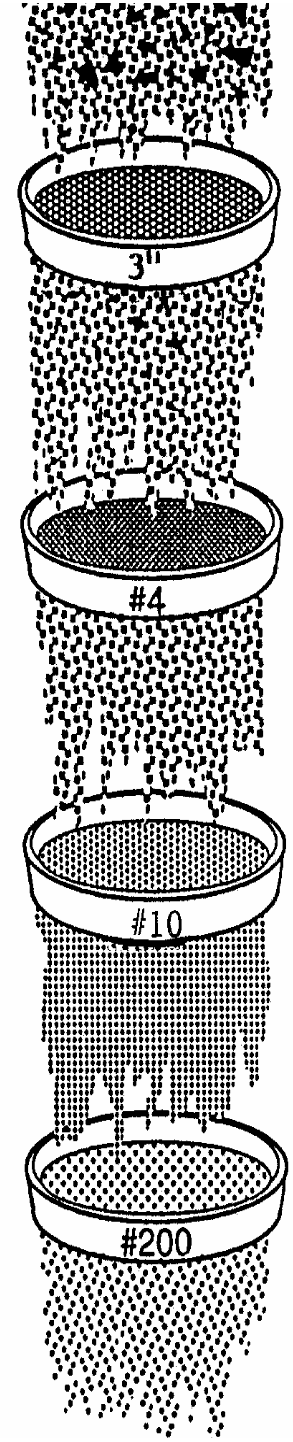
- Bedford
- Bell County
- Dallas
- Grand Prairie
- Fort Worth
- Tarrant County
- Goliad County
- Bexar County
- Lubbock District
- Corpus Christi District
- Bryan District
- San Antonio District

More Advantages

- **Minimizes inconvenience for both homes and businesses**
  - Less construction equipment
  - Fast operation
  - Can apply local traffic almost immediately

Base and Subbase Materials





The BIGGEST Advantage!

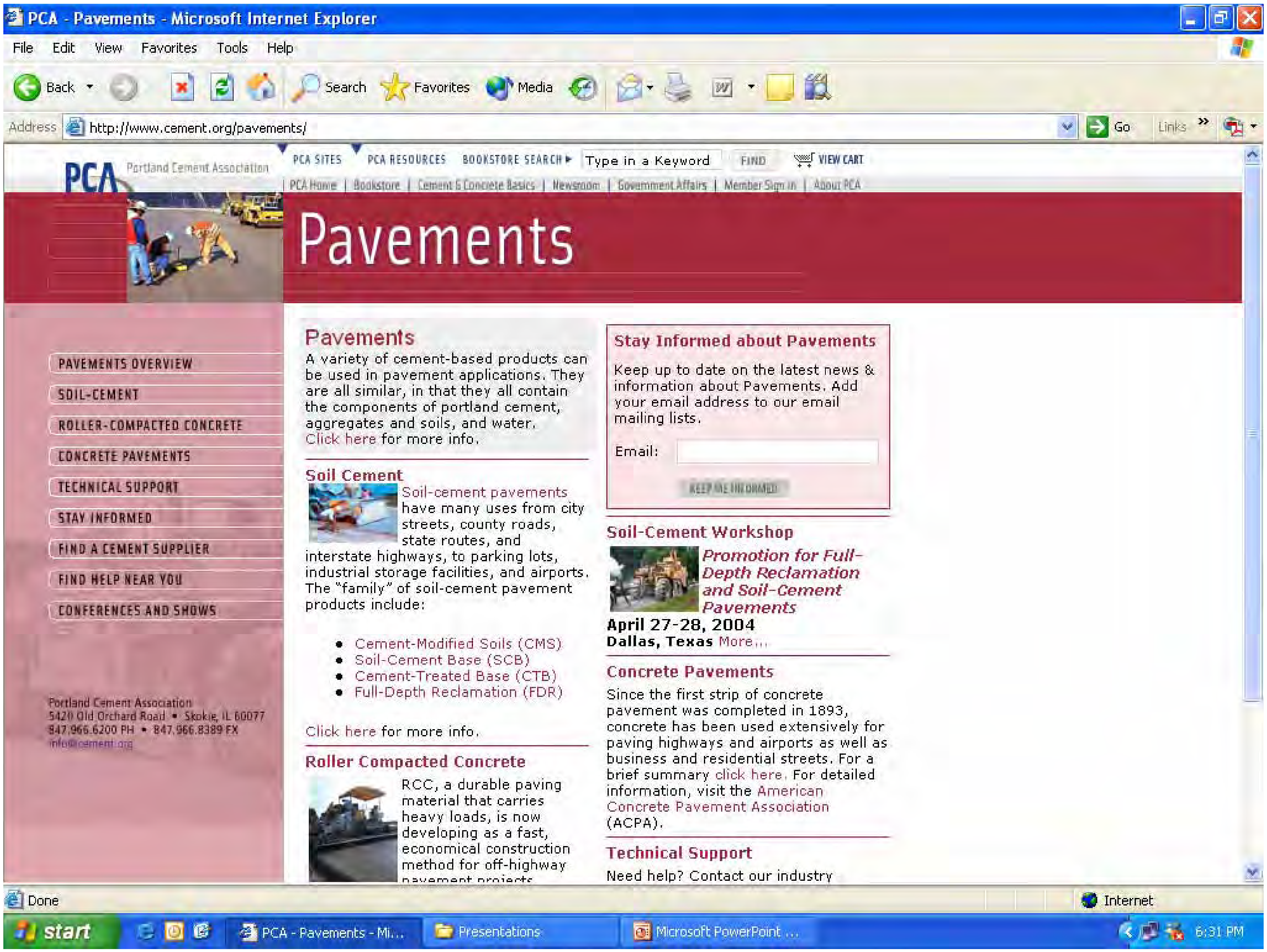
- **Versatility through use of portland cement**
- **Stabilizes many materials**
  - old base
  - asphalt surface
  - granular or plastic subgrade
  - blends

"Portland Cement is probably the closest thing we have to a universal stabilizer."

- From a U.S. Army Corps of Engineers Report dated September 2002

for additional information, please visit our website at

www.cement.org/pavements



Web Site: www.RecyclingRoads .org

- New and dramatic
- Tells all about the recycling process
- Describes ongoing and completed work
- Provides contact information about the owner, designer, contractor and specifics of each job
- Provides testimonials by user
- Includes “job reports” from each job written up

Thank You!

Matthew W. Singel, P.E.

Cement Council of Texas

cctmatt@earthlink.net

www.RecyclingRoads.org