Importance of a Stable Subgrade and Base for Pavement Performance

Houston 2026

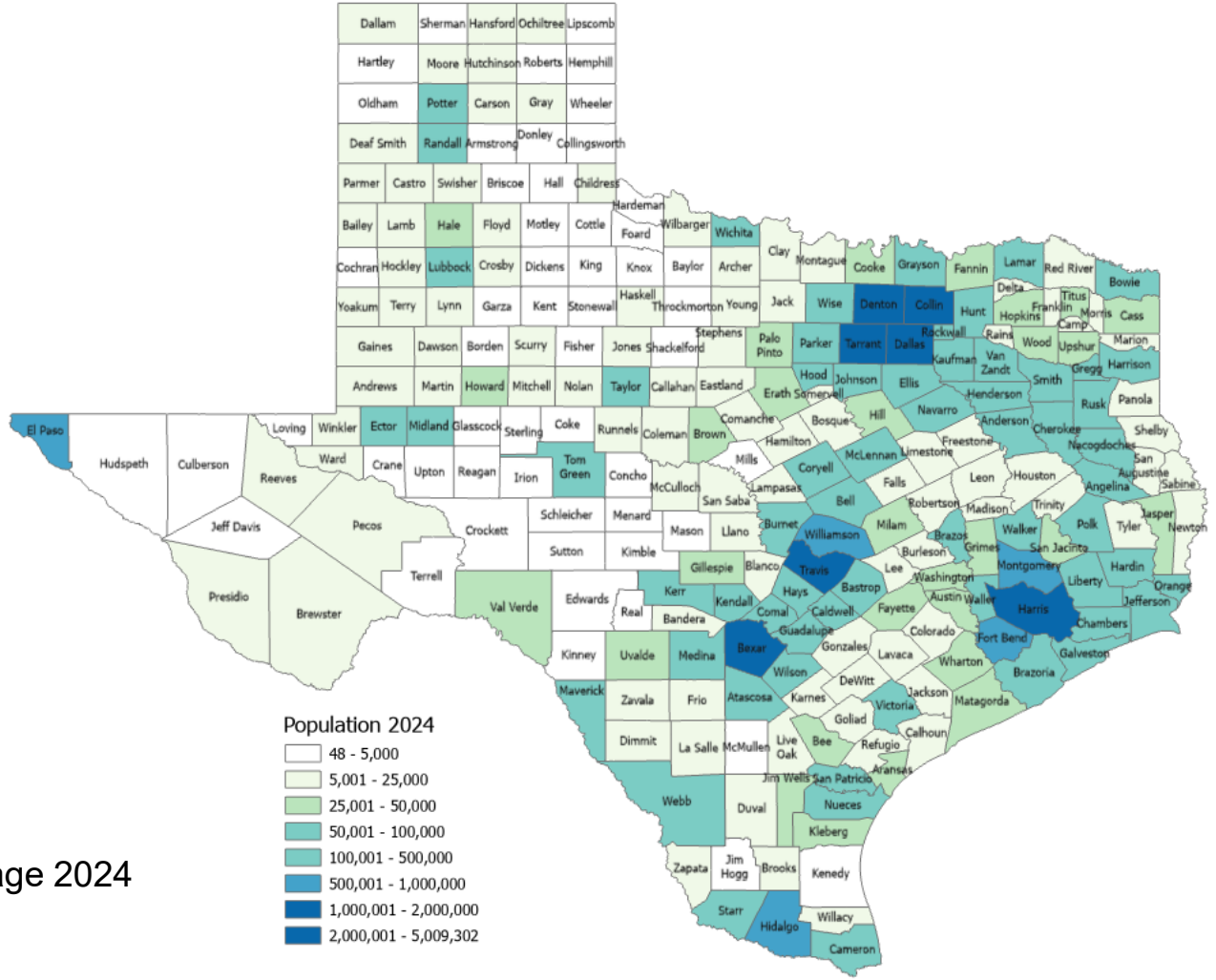
Larry Peirce - TXAPA

Optimum Pavement Performance

Depends On A Combination Of Factors

- Understanding of Your Objectives
- Choosing the Right Construction Materials
- Properly Designing Those Materials
- Constructing with Quality
- **Ensuring That You Have Created an Adequate Foundation**

Estimated Population, Texas Counties, 2024

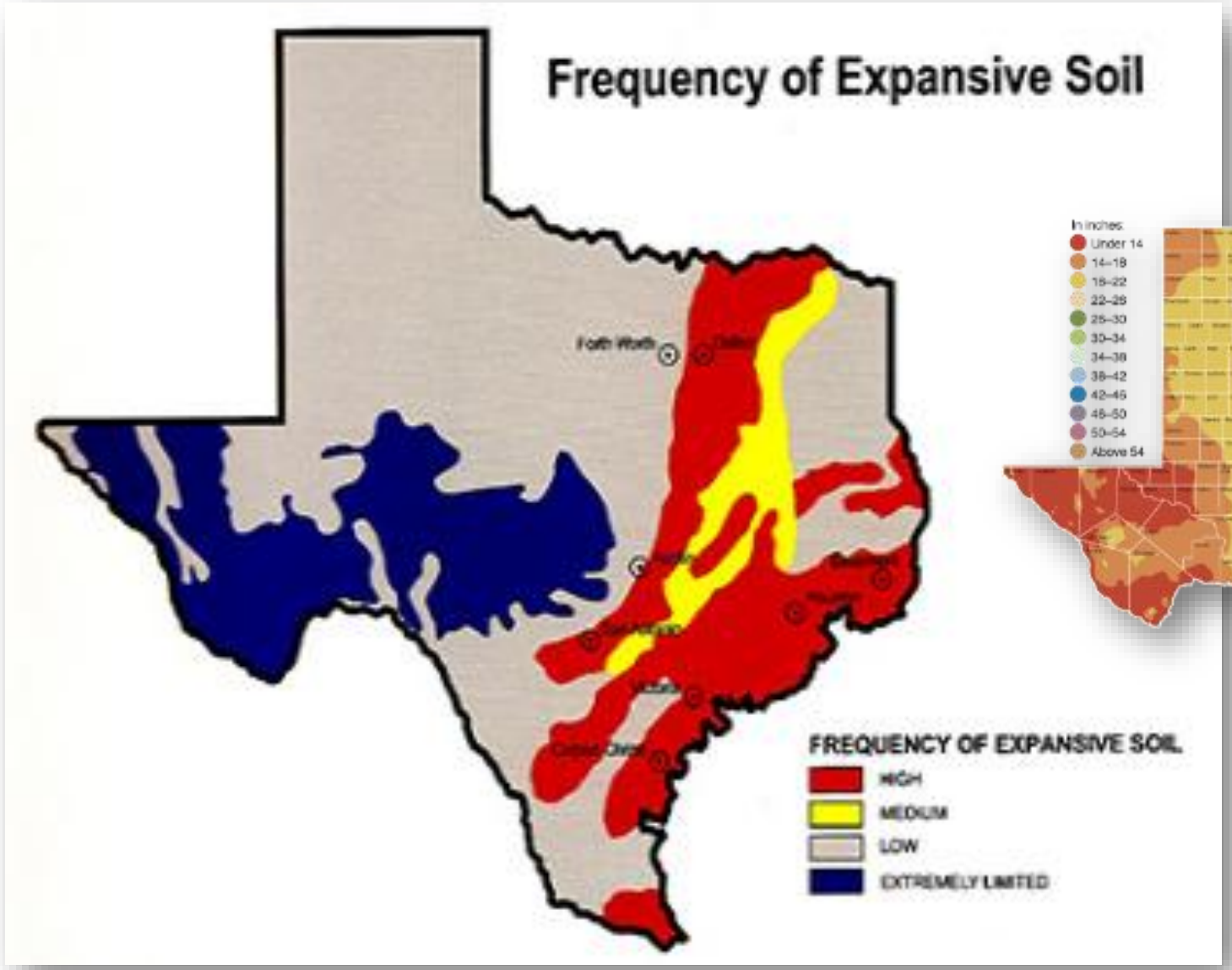


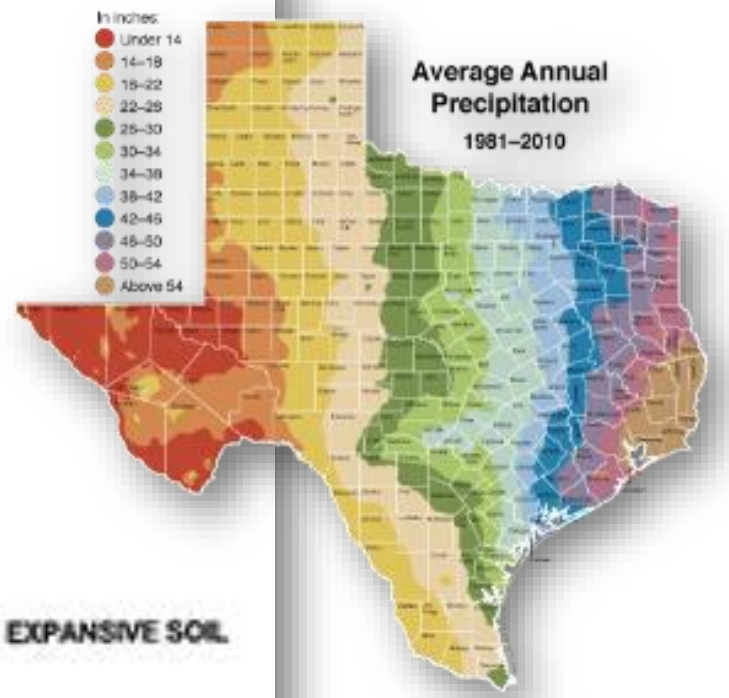
Source: U.S. Census Bureau, Vintage 2024 Population Estimates

Goals to ensure an adequate foundation (subgrade)

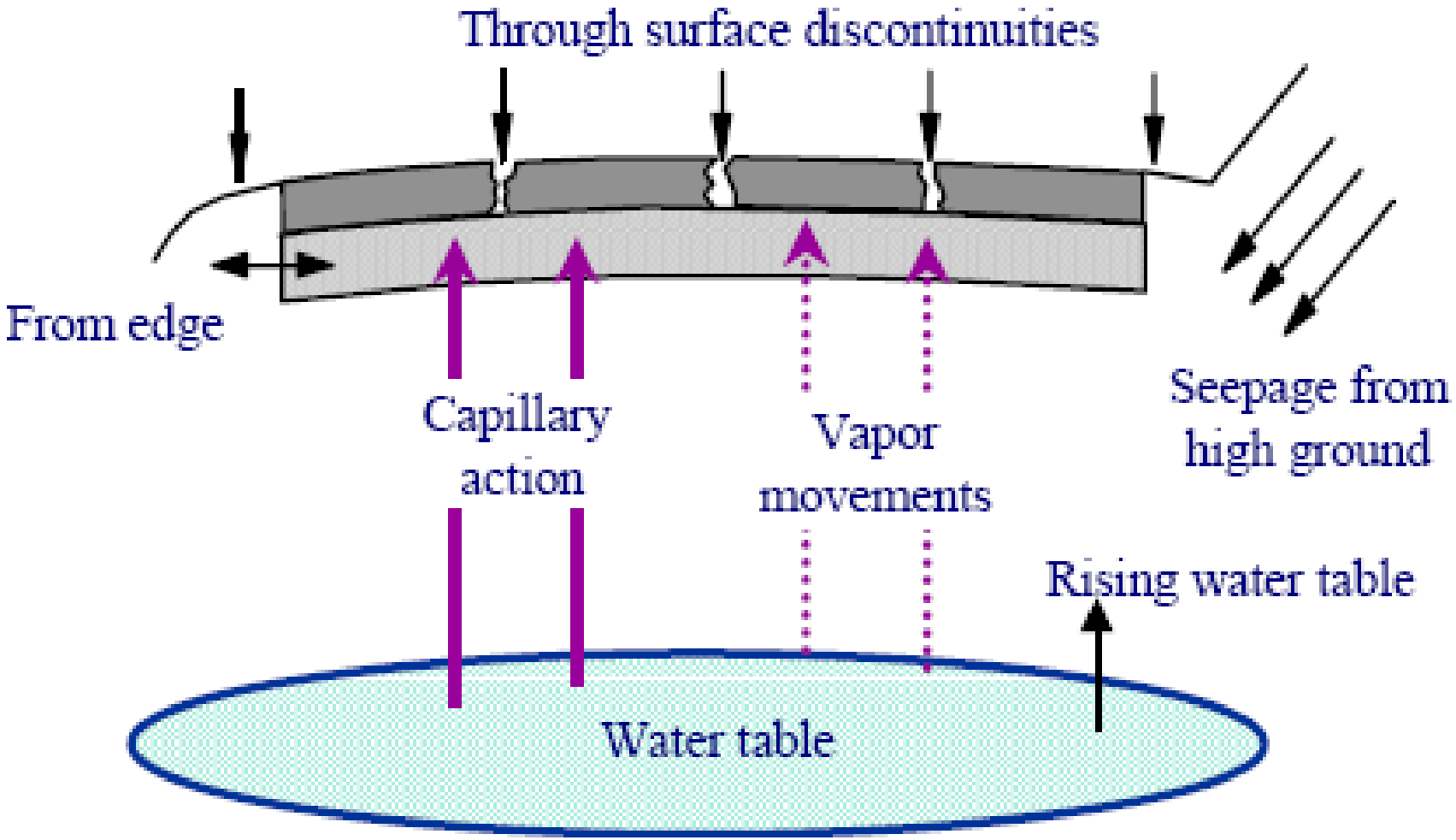
- Reduce soil PI and clay/silt-sized particles
- Improve workability and constructability
- **Reduce shrink/swell characteristics of expansive soils**
- **Improve strength and stiffness/modulus**
- Improve stability and durability
- **Reduce moisture susceptibility**

Expansive Soil and Expansive Clay





Moisture is the enemy of successful pavement performance

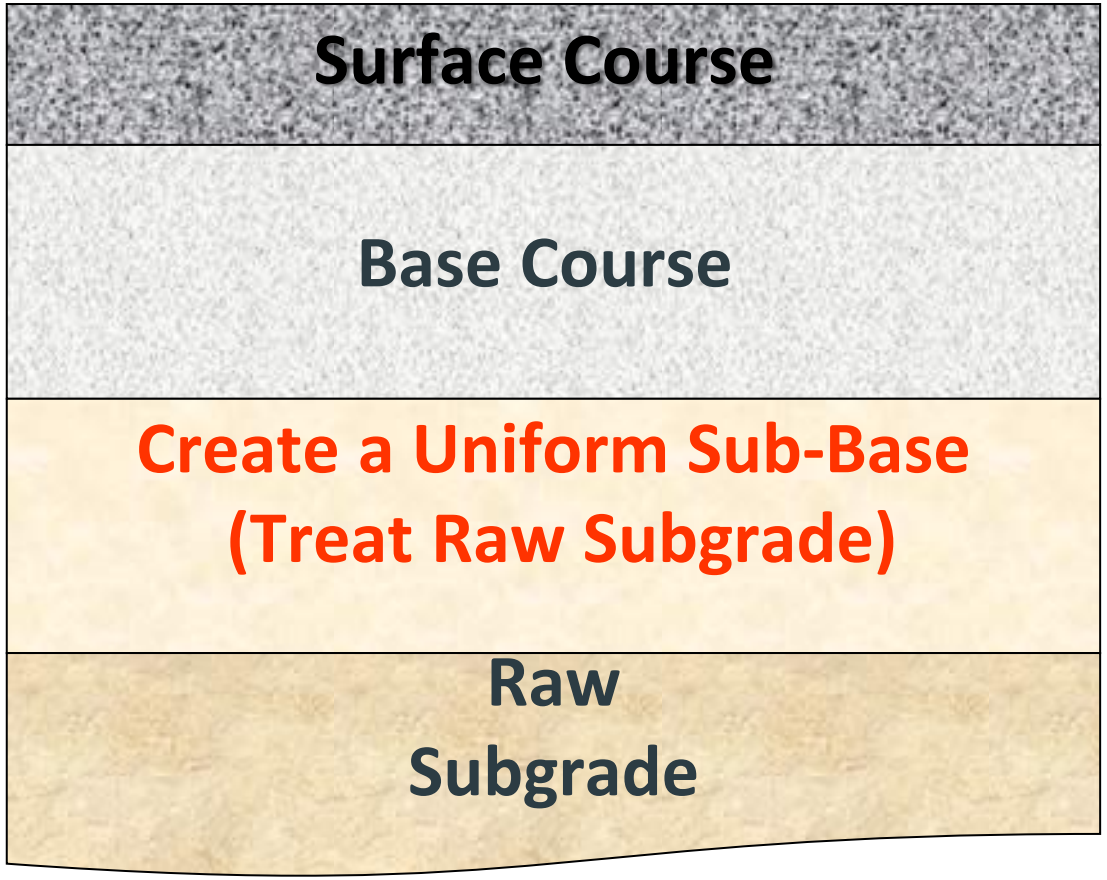


Problems Associated w/Clay Soils

- Typically moisture sensitive
  - expansion potential & swell pressure
- Exhibit poor pavement support
  - low R-values, CBRs, & unconfined compressive strengths
- Constructability problems
  - highly plastic - poor workability
  - hard to compact
  - yield or pump when wet
  - shrink when dry

Foundation Problems – Soil Moisture Fluctuation

Need Uniform, Quality Layers Beneath HMA Surface



Moduli ≈ 500 ksi

Moduli ≈ 50 ksi

Moduli ≈ 30-50 ksi

Moduli ≈ 10 ksi

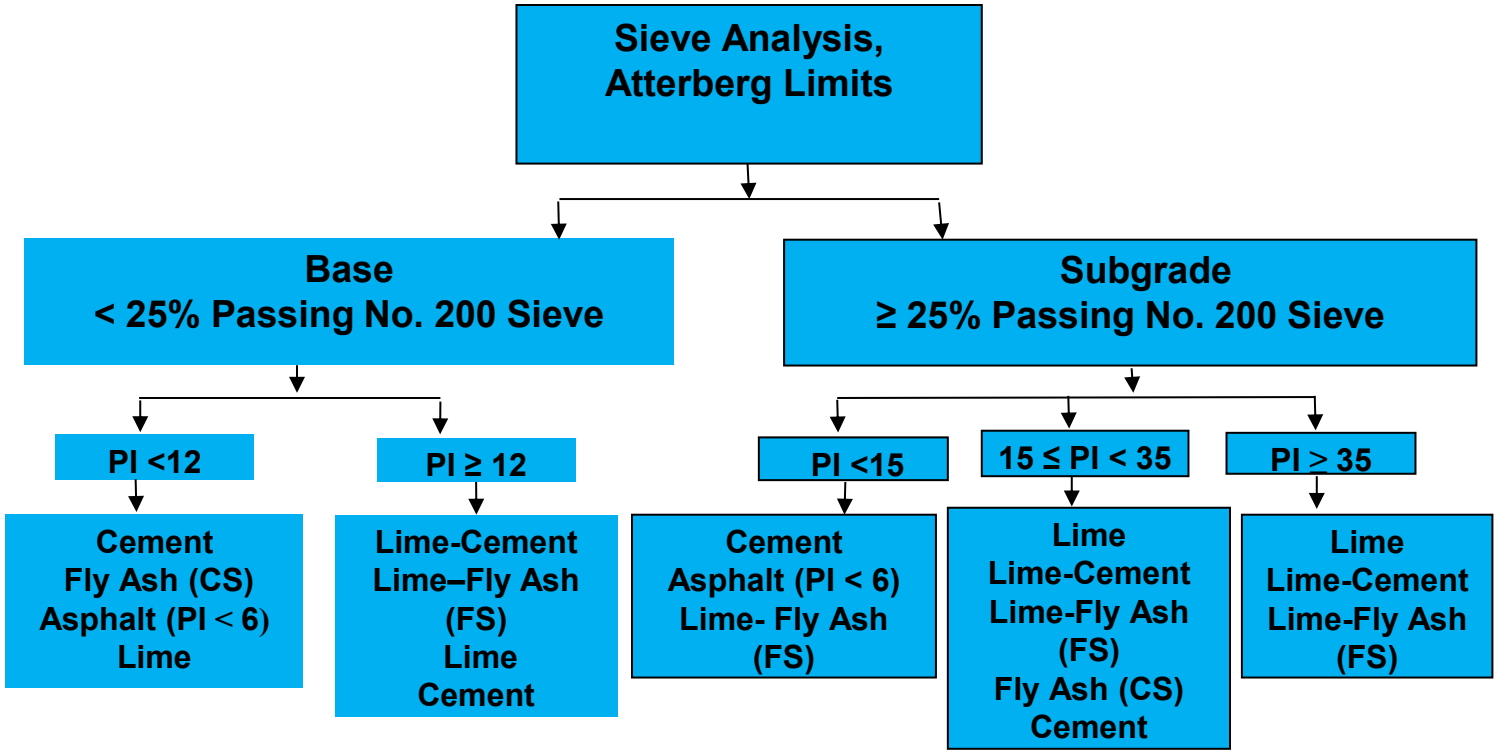
Purpose of the Treatment Guidelines

http://ftp.dot.state.tx.us/pub/txdot/mtd/treatment-guidelines.pdf

- **Provide personnel with all levels of experience with enough information to**
-
  - **Determine project suitability,**
  - **Identify goals of treatment,**
  - **Select appropriate type of additives,**
  - **Determine optimum amount of selected additives, and**
  - **Identify appropriate construction processes.**

- **The information in this document is applicable to both construction and maintenance.**

TxDOT Guidelines for Soil Treatment



TxDOT Specs (Road or Plant Mixed)		TxDOT Lab Mix Design Test Methods
Lime	Items 260 or 263	Tex-121-E
Cement	Items 275 or 276	Tex-120-E
Fly Ash	Item 265	Tex-127-E
Asphalt	Item 292	Tex-126-E

Select Additive(s) – Lab Mix Design

- Select Additives
  - Select the appropriate type of additive based on the goals of soil treatment and the project-specific soil classification (gradation and PI)
  - Perform the lab mix designs to determine the optimum amount of the selected additive on a project basis for the desired engineering properties
    - Soil-Lime (Tex-121-E); DMS 6350
    - Soil-Cement (Tex-120-E); DMS 4600
    - Lime-Fly Ash (Tex-127-E); DMS 4615
    - Asphalt Treated Base (Tex-126-E)

Key Points of Guidelines

- Soils are different
- Additives are different
- Reactions between soils and additives are different (binding versus chemically changing)
- **DO A MIX DESIGN**
- Evaluate the material engineering properties and field performance

Base Materials

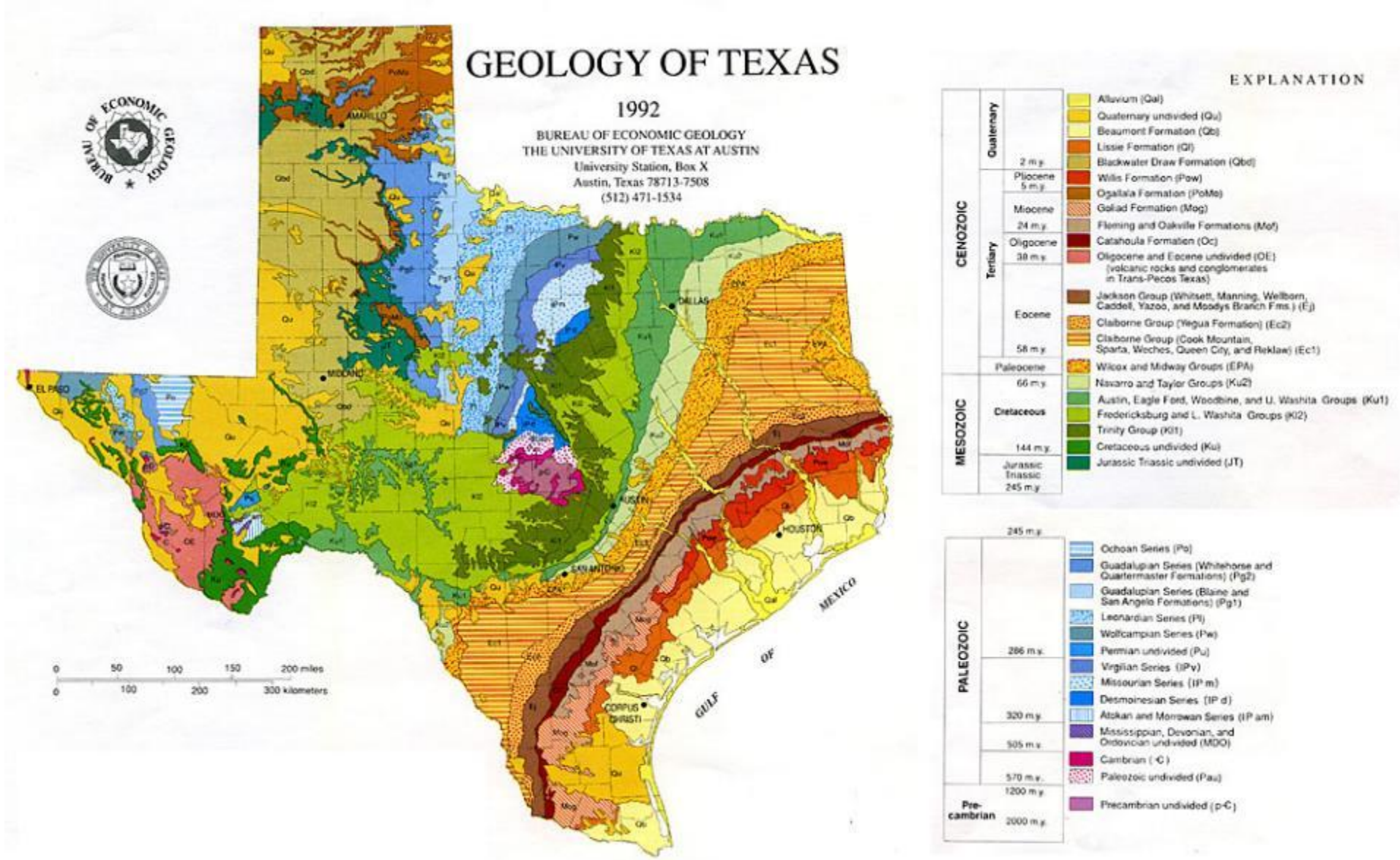
- Provide structure and support for asphalt layer
- Bases can be untreated, utilizing good source material
- Marginal quality materials can be used for bases
  - Must be treated w/ stabilizers if they are marginal in quality
- **Improve strength and stiffness /modulus**
- Improve stability and durability
- **Reduce moisture susceptibility (typical crushed stone base can lose up to 90% of its strength when completely saturated)**
- **This is why its so important to protect the base from moisture damage**

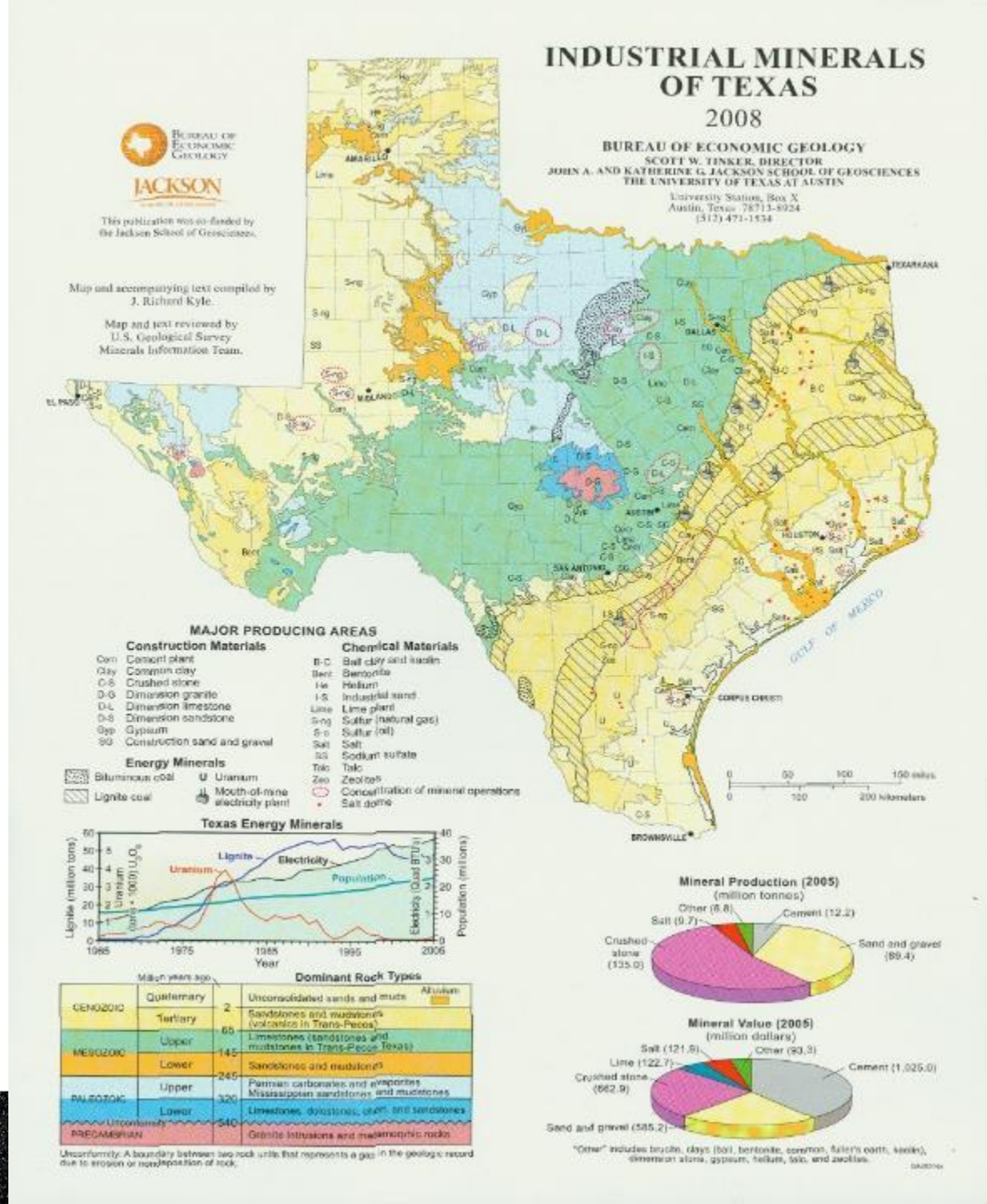
Base Failure Will Lead to Asphalt Failure

But Then We Hear “the Asphalt Didn’t Last”

Base Materials

- Texas is a very large and geologically diverse state
- Budget and other practical constraints require, to the extent possible, the use of local materials
- Local materials can vary in quality


GEOLOGY OF TEXAS
1992
BUREAU OF ECONOMIC GEOLOGY
THE UNIVERSITY OF TEXAS AT AUSTIN
University Station, Box X
Austin, Texas 78713-7508
(512) 471-1534
BUREAU OF ECONOMIC GEOLOGY
AMARILLO
EL PASO
MIDLAND
DALLAS
AUSTIN
HOUSTON
SAN ANTONIO
CORPUS CHRISTI
GULF OF MEXICO
0 50 100 150 200 miles
0 100 200 300 kilometers
EXPLANATION
CENOZOIC
Quaternary
2 m.y.
Tertiary
Pliocene
5 m.y.
Miocene
24 m.y.
Oligocene
38 m.y.
Eocene
58 m.y.
Paleocene
66 m.y.
MESOZOIC
Cretaceous
144 m.y.
Jurassic
Triassic
245 m.y.
Alluvium (Qal)
Quaternary undivided (Qu)
Beaumont Formation (Qb)
Lissie Formation (Ql)
Blackwater Draw Formation (Qbd)
Willis Formation (Pow)
Ogallala Formation (PoMo)
Goliad Formation (Mog)
Fleming and Oakville Formations (Mof)
Catahoula Formation (Oc)
Oligocene and Eocene undivided (OE)
(volcanic rocks and conglomerates in Trans-Pecos Texas)
Jackson Group (Whitsett, Manning, Wellborn, Caddell, Yazoo, and Moodys Branch Fms.) (Ej)
Claiborne Group (Yegua Formation) (Ec2)
Claiborne Group (Cook Mountain, Sparta, Weches, Queen City, and Reklaw) (Ec1)
Wilcox and Midway Groups (EPA)
Navarro and Taylor Groups (Ku2)
Austin, Eagle Ford, Woodbine, and U. Washita Groups (Ku1)
Fredericksburg and L. Washita Groups (Kl2)
Trinity Group (Kl1)
Cretaceous undivided (Ku)
Jurassic Triassic undivided (JT)
245 m.y.
PALEOZOIC
286 m.y.
320 m.y.
505 m.y.
570 m.y.
Pre-cambrian
1200 m.y.
2000 m.y.
Ochoan Series (Po)
Guadalupian Series (Whitehorse and Quartermaster Formations) (Pg2)
Guadalupian Series (Blaine and San Angelo Formations) (Pg1)
Leonardian Series (Pl)
Wolfcampian Series (Pw)
Permian undivided (Pu)
Virgilian Series (IPv)
Missourian Series (IP m)
Desmoinesian Series (IP d)
Atokan and Morrowan Series (IP am)
Mississippian, Devonian, and Ordovician undivided (MDO)
Cambrian (-C)
Paleozoic undivided (Pau)
Precambrian undivided (p-C)


INDUSTRIAL MINERALS OF TEXAS
2008
BUREAU OF ECONOMIC GEOLOGY
SCOTT W. TINKER, DIRECTOR
JOHN A. AND KATHERINE G. JACKSON SCHOOL OF GEOSCIENCES
THE UNIVERSITY OF TEXAS AT AUSTIN
University Station, Box X
Austin, Texas 78713-8924
(512) 471-1534
JACKSON
This publication was co-funded by the Jackson School of Geosciences.
Map and accompanying text compiled by J. Richard Kyle.
Map and text reviewed by U.S. Geological Survey Minerals Information Team.
MAJOR PRODUCING AREAS
Construction Materials
Cem Cement plant
Clay Common clay
C-S Crushed stone
D-G Dimension granite
D-L Dimension limestone
D-S Dimension sandstone
Gyp Gypsum
SG Construction sand and gravel
Energy Minerals
Bituminous coal
Lignite coal
U Uranium
Mouth-of-mine electricity plant
Chemical Materials
B-C Ball clay and kaolin
Bent Bentonite
He Helium
I-S Industrial sand
Lime Lime plant
S-ng Sulfur (natural gas)
S-o Sulfur (oil)
Salt Salt
SS Sodium sulfate
Talc Talc
Zeo Zeolites
Concentration of mineral operations
Salt dome
Texas Energy Minerals
Lignite (million tons)
Uranium (tons × 1000) U_3O_8
Electricity (Quad BTU)
Population (millions)
Lignite
Electricity
Uranium
Population
1965
1975
1985
1995
2005
Year
Dominant Rock Types
Million years ago
CENOZOIC
Quaternary
Tertiary
2
65
MESOZOIC
Upper
Lower
145
245
PALEOZOIC
Upper
Lower
320
540
PRECAMBRIAN
Unconsolidated sands and muds
Alluvium
Sandstones and mudstones (volcanics in Trans-Pecos)
Limestones (sandstones and mudstones in Trans-Pecos Texas)
Sandstones and mudstones
Permian carbonates and evaporites
Mississippian sandstones and mudstones
Limestones, dolostones, chert, and sandstones
Granite intrusions and metamorphic rocks
Unconformity: A boundary between two rock units that represents a gap in the geologic record due to erosion or nondeposition of rock.
Mineral Production (2005)
(million tonnes)
Other (6.8)
Cement (12.2)
Salt (9.7)
Crushed stone (135.0)
Sand and gravel (89.4)
Mineral Value (2005)
(million dollars)
Salt (121.9)
Other (90.3)
Lime (122.7)
Cement (1,025.0)
Crushed stone (662.9)
Sand and gravel (585.2)
"Other" includes bauxite, clays (ball, bentonite, common, fuller's earth, kaolin), dimension stone, gypsum, helium, talc, and zeolites.
GULF OF MEXICO
AMARILLO
MIDLAND
EL PASO
DALLAS
AUSTIN
HOUSTON
SAN ANTONIO
CORPUS CHRISTI
BROWNSVILLE
TEXARKANA
0 50 100 150 miles
0 100 200 kilometers

Texas Department of Transportation

Flexible Base Selection and Information Guide

Materials & Tests Division

Soils & Aggregates Section

August 2019

Table 1: Flexible Base Material Types

Type	Description
A	Crushed stone produced and graded from oversize quarried aggregate that originates from a single, naturally occurring source. This does not include gravel or multiple sources.
B	Crushed or uncrushed gravel. Blending of two or more sources is allowed.
C	Crushed gravel with a minimum of 60% of the particles retained on a No. 4 sieve with two or more crushed faces as determined by Tex-460-A, Part I. Blending of two or more sources is allowed.
D	Type A material or crushed concrete. Crushed concrete containing gravel will be considered Type D material. Crushed concrete must meet requirements for recycled materials and be managed in a way to provide for uniform quality. The engineer may require separate dedicated stockpiles to verify compliance.
E	Caliche, iron ore, or as otherwise shown on the plans.

Table 2: Basic Recommendations for Type Selection

Type	Description
A or D*	Strongest, most durable base
B or C	Marginal base
E	Non-standard requirements

* When crushed concrete is allowed.

Type A and D materials are generally considered high-quality base since crushed materials have, in general, higher stability than rounded materials. Type A and D are often used in combination with Grade 1–2, which has the most stringent material requirements. Type D allows the use of Type A or crushed concrete. This option provides an alternative where crushed concrete may be used if economically feasible.

Types B and C are generally used for areas that have gravel as a local material.

Type E may be used for new or unspecified materials.

Table 3: Flexible Base Material Requirements from Item 247

Property	Test Method	Grade 1–2	Grade 3	Grade 4	Grade 5
Master gradation sieve size (cumulative % retained)	Tex-110-E			As shown on the plans	
2½"		0	0		0
1¾"		0–10	0–10		0–5
⅞"		10–35	–		10–35
⅜"		30–65	–		35–65
#4		45–75	45–75		45–75
#40		65–90	50–85		70–90
Liquid limit, % max[1]	Tex-104-E	40	40	As shown on the plans	35
Plasticity index, max[1]	Tex-106-E	10	12	As shown on the plans	10
Plasticity index, min[1]	Tex-106-E	As shown on the plans			
Wet ball mill, % max[2]	Tex-116-E	40	–	As shown on the plans	40
Wet ball mill, % max increase passing the #40 sieve	Tex-116-E	20	–	As shown on the plans	20
Compressive strength, psi, min	Tex-117-E			As shown on the plans	
Lateral pressure, 0 psi		35	–		–
Lateral pressure, 3 psi		–	–		90
Lateral pressure, 15 psi		175	–		175

[1] Determine plastic index in accordance with Tex-107-E (linear shrinkage) when liquid limit is unattainable, as defined in Tex-104-E.

[2] Grade 4 may be further designated as Grade 4A, Grade 4B, etc.

Full Depth Reclamation (FDR)

Special Specification 3088

Full Depth Reclamation Using Foamed Asphalt (Road-Mixed)

1. DESCRIPTION

Perform full depth reclamation (FDR) using an in-place mixing process to obtain a homogenous mixture of the existing surface and the underlying base material (with or without new material and additive added) using a foamed asphalt.

Item 291

Foamed Asphalt Treatment (Road-Mixed)

1. DESCRIPTION

Perform full-depth reclamation (FDR) using an in-place mixing process to obtain a homogenous mixture of the existing surface and the underlying base material (with or without new material and additive added) using a foamed asphalt.

Special Specification 3089

Full Depth Reclamation Using Asphalt Emulsion (Road-Mixed)

1. DESCRIPTION

Perform full depth reclamation (FDR) using an in-place mixing process to obtain a homogenous mixture of the existing surface and the underlying base material (with or without new material and additive added) using an emulsified asphalt.

Item 290

Emulsified Asphalt Treatment (Road-Mixed)

1. DESCRIPTION

Perform full-depth reclamation (FDR) using an in-place mixing process to obtain a homogenous mixture of the existing surface and the underlying base material (with or without new material and additive added) using an emulsified asphalt.

- TxDOT 2021. Pavement Manual. Maintenance Division, Austin, TX. https://www.txdot.gov/content/dam/txdotoms/mnt/pdm/pdm.pdf
- TxDOT 2019. Treatment Guidelines for Soils and Base in Pavement Structures. Materials and Tests Division, Soils and Aggregates Section, Austin, TX. https://ftp.dot.state.tx.us/pub/txdot/mtd/treatment-guidelines.pdf
- TxDOT 2005. Guidelines for Modification and Stabilization of Soils and Base for Use in Pavement Structures. Construction Division, Materials and Pavements Section, Geotechnical, Soils and Aggregates Branch, Austin, TX. https://ftp.txdot.gov/pub/txdot-info/cmd/tech/stabilization.pdf
- TxDOT 2005. Guidelines for Treatment of Sulfate-Rich Soils and Bases in Pavement Structures. Construction Division, Materials and Pavements Section, Geotechnical, Soils and Aggregates Branch, Austin, TX. https://ftp.dot.state.tx.us/pub/txdot-info/cmd/tech/sulfates.pdf
- TxDOT 2025. Guide Schedule of Sampling & Testing for Design Bid-Build (DBB) Projects (DBB Guide Schedule). Austin, TX. https://www.txdot.gov/content/dam/docs/division/mtd/design-bid-build-guide-schedule-may-2025.pdf

Texas Department of Transportation

Full-Depth Reclamation with Asphalt Binders

Construction Guidelines

Materials and Tests Division

Soils and Aggregate Section

February 2026

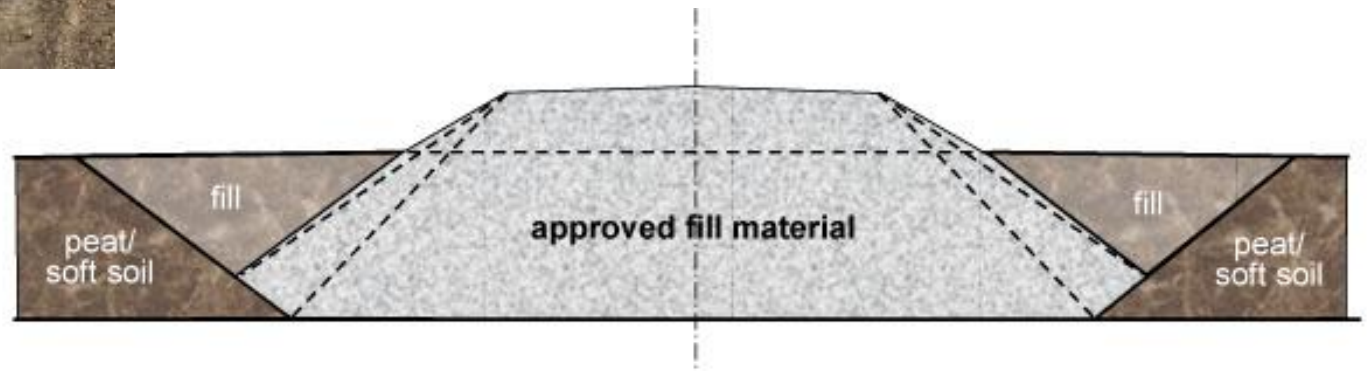
Common Misconceptions for treating expansive clay subgrade Soils

- Wrong Stabilizer
- Remove and Replace Existing Subgrade / Embankment
- Additional Base or Pavement Thickness Instead of Treating the Subgrade
- Alternative Stabilizers (Proprietary Liquids or Dry)

Cement instead of lime

- Cement, by its chemical nature, does not complete the pozzolanic reaction that will permanently change the structure of clay
- Cement will set up rapidly (3 hours), and does not have the time nor the available calcium to achieve what lime does to highly plastic clay on a one-to-one basis

Remove poor soils and import select fill or base material



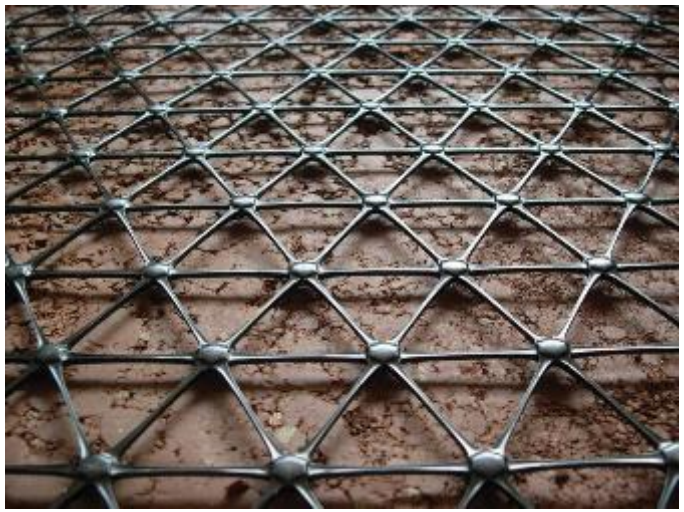
Remove expansive clay soils and import select fill or base material (cut and fill)

- Typically not as cost effective compared to soil treatment
- Highly variable determining cost of import material due to source and haul distance
- Can be other problems associated with this concept that aren't considered (variability of import fill source that isn't properly monitored)
- You will not significantly improve the long-term strength of the layer by importing fill

Increasing thickness of other layers in the pavement section

- **This alternative appears most commonly in municipal, commercial and subdivision type projects**
- The engineer/architect or sometimes a contractor will convince a developer or a smaller local agency to do away with subgrade treatment by adding an extra inch of concrete pavement, or extra flex base and sometimes Hot Mix Asphalt (HMA)
- This is a strategy that is driven by the belief you can save cost and time
- This will, in almost all cases, lead to poor performance for roadways, parking lots, and foundations because nothing has been done to treat the underlying problems of marginal / poor subgrade soils

The use of GeoGrid in place of soil stabilization



The use of GeoGrid in place of soil stabilization

- Using Geogrid directly on compacted but untreated high PI subgrade will not provide the benefits achieved by creating a uniform stabilized layer.
  - Moisture and the fines in the untreated subgrade layer will work their way up into the crushed stone base (fluctuations in moisture condition and capillary rise). This weakens the base layer significantly over time and can lead to premature failure of the pavement structure.
  - A properly treated sub-base layer provides significant protection for the overlying base layer by adding strength, waterproofing and stopping the swell potential of the treated layer that will not happen using Geogrid alone

Use of proprietary liquid or dry stabilization products

(1.) ionic stabilizers, reported to work through cation exchange within the clay mineral

(2.) enzyme stabilizers, described as consisting of various organic catalysts

(3.) polymer and “Bio-Polymer” stabilizers, comprised of various organic and inorganic polymers

Use of proprietary liquid or dry stabilization products

“Supplier claims of product effectiveness are often not well substantiated with independent field or laboratory evaluations performed under controlled conditions. The chemical composition of these products is usually considered proprietary, and the suppliers often give minimal or incomprehensible information regarding the mechanisms of soil modification.”

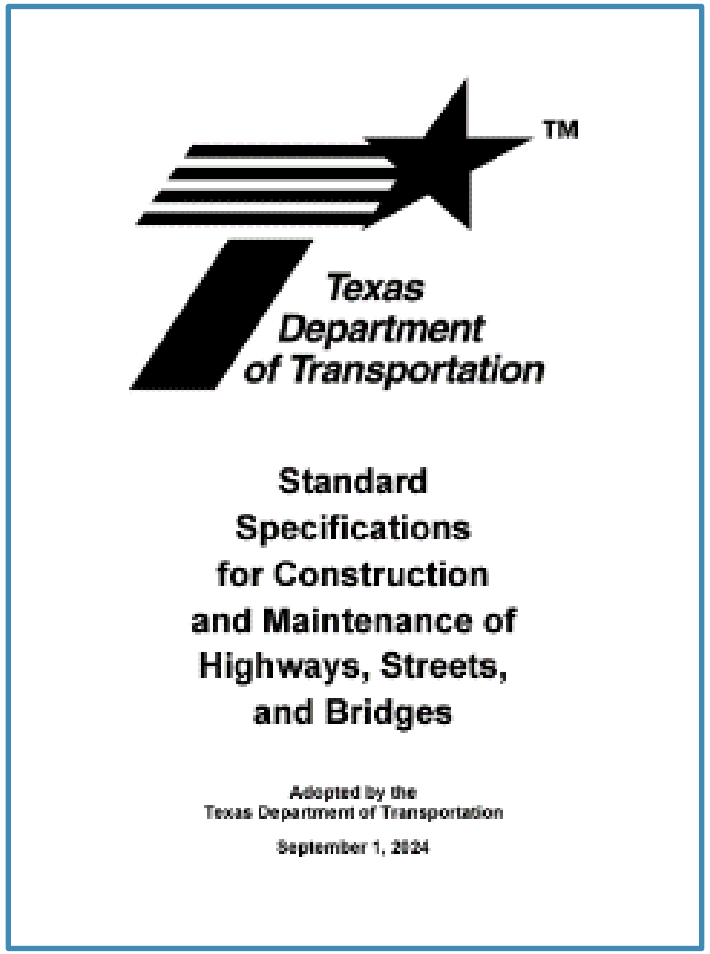
AN ANALYSIS OF THE MECHANISMS AND EFFICACY OF THREE LIQUID CHEMICAL SOIL STABILIZERS: VOLUME 1

May 2003

Alan F. Rauch, Lynn E. Katz, and Howard M. Liljestrand

Construction Specifications

- **A Perfect Laboratory Mix Design Will Only Work in the Field if Proper Construction Procedures Are Followed**



TxDOT Soil Treatment Construction Specifications

Item	Treatment	Special Requirements
260	Lime (road mixed)	Mellowing requirements apply depending on the type of lime and sulfate content of the material.
263	Lime (plant mixed)	Cure at least 7 days by sprinkling or by asphalt membrane.
265	Fly ash or lime-fly ash (road mixed)	Complete compaction within 6 hours of application of Class FS ash and within 2 hours of application of Class CS ash. Cure FS ash 7 days; CS at least 24 hours.
275	Cement (road mixed)	Complete compaction within 2 hours. Microcrack to reduce shrinkage cracks. Cure at least 3 days by sprinkling or asphalt membrane.
276	Cement (plant mixed)	Microcrack to reduce shrinkage cracks. Cure at least 3 days by sprinkling or asphalt membrane.
Asphalt Emulsion	Emulsion (road mixed)	Cure to 2 percentage points below optimum before placing the next course.
Foamed Asphalt	Foamed Asphalt (road mixed)	Special equipment is needed. Cure a minimum of 2 hours.

Proof Rolling

- Proof rolling provides a method to examine the entire subgrade or base surface as a compliment to standard random acceptance testing
- Simple, low-cost method to ensure prepared subgrade or base layer is good **prior** to next layer placement
- Will identify areas that need to be reworked
- Referenced in some specifications but often overlooked

Proof Rolling

Item 216
Proof Rolling

1. DESCRIPTION

Proof-roll earthwork, base, or both to locate unstable areas.

2. EQUIPMENT

2.1. **Specified Equipment.** Furnish rollers that weigh at least 25 tons when loaded. The maximum acceptable load is 50 tons. Provide rollers that meet the requirements of Section 210.2.4., "Pneumatic Tire Rollers."

2.2. **Alternative Equipment.** The Contractor may use alternate compaction equipment that produces results equivalent to the specified equipment in the same period of time as approved. Discontinue the use of the alternative equipment and furnish the specified equipment if the desired results are not achieved.

3. CONSTRUCTION

Perform proof rolling as directed. Adjust the load and tire inflation pressures within the range of the manufacturer's charts or tabulations, as directed. Make at least 2 coverages with the proof roller. Offset each trip of the roller by at most one tire width. Operate rollers at a speed between 2 and 6 mph, as directed. Correct unstable or nonuniform areas, if found, in accordance with the applicable Item.

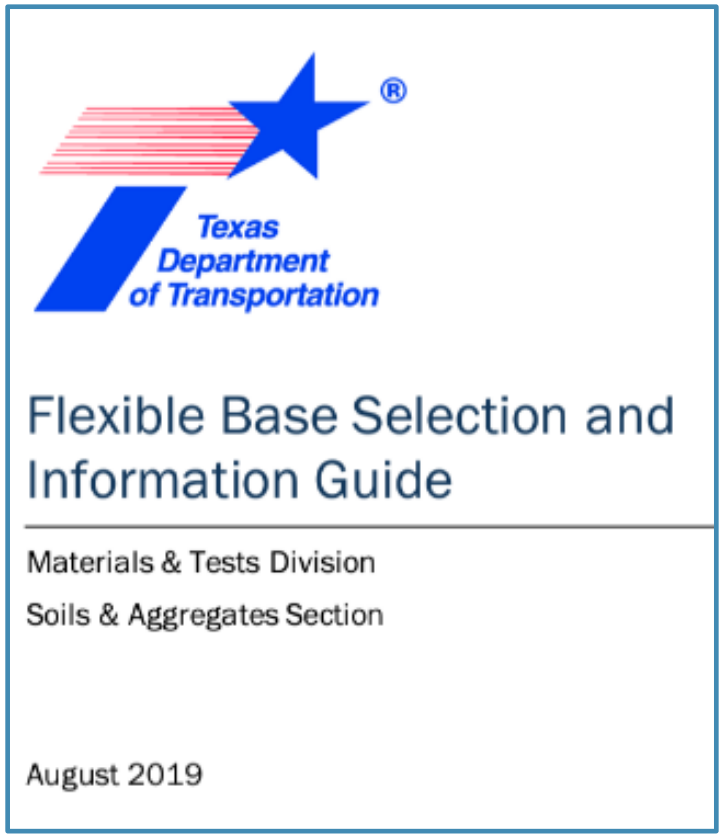
4. MEASUREMENT

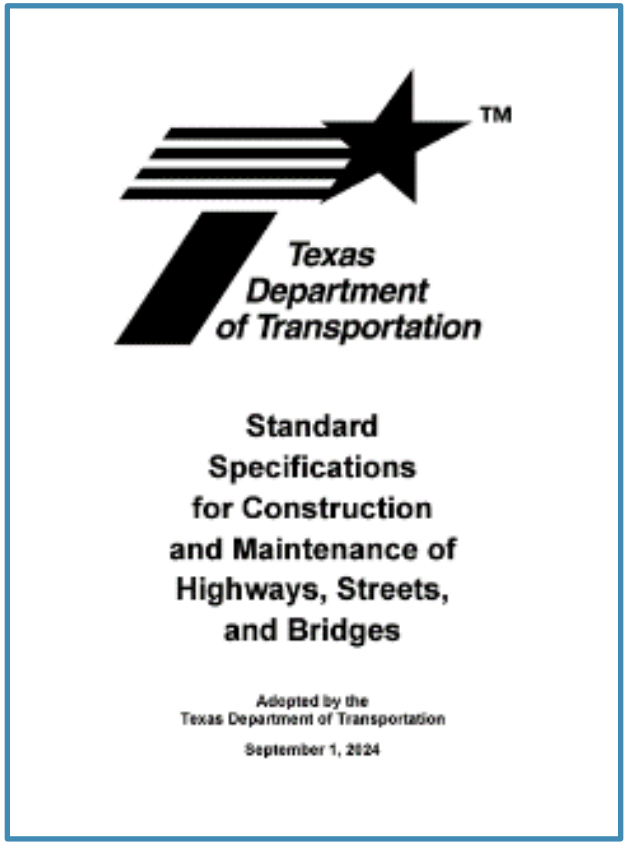
Rolling will be measured by the hour operated on surfaces being tested.

5. PAYMENT

The work performed and equipment furnished in accordance with this Item and measured as provided under "Measurement" will be paid for at the unit price bid for "Proof Rolling." This price is full compensation for furnishing and operating equipment and for labor, materials, tools, and incidentals.

Use the resources available to you





Smooth, Durable Asphalt Streets and Roads Can and Should be Expected. Let's Design and Build the Best!!

MATERIALS
& ASPHALT
PAVEMENT
SOLUTIONS

QUESTIONS?