Lime Treatment For Expansive Soils

Presented by
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Benefits of Soil Stabilization with Lime

- Eliminates excavation & disposal costs
- Provides a stable & uniform layer or paving structure
- Decreases expansion/swelling
- Improves foundation support
- Achieves long term strength & performance

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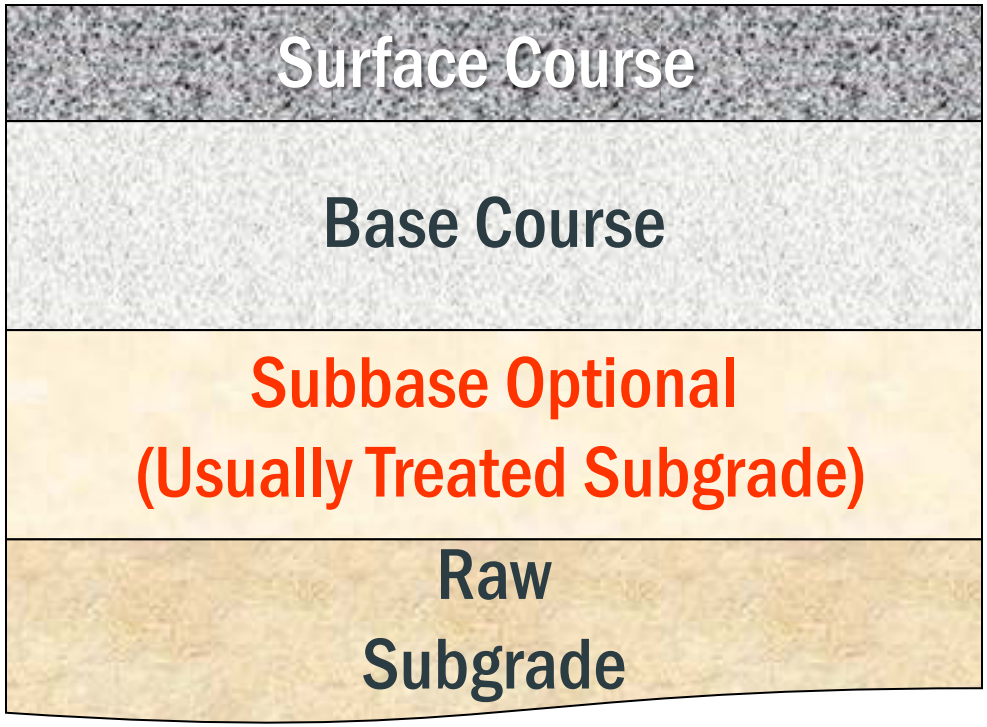
Subgrade Moduli



Moduli ≈ 500 ksi

Moduli ≈ 50 ksi

Moduli ≈ 30-50 ksi

Moduli ≈ 10 ksi

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Problems Associated with Clay Soils

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

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Structure of Clay Minerals

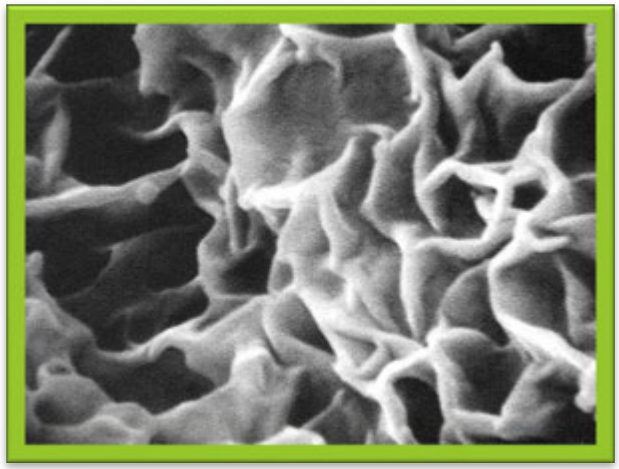
Kaolinite:

Hexagonal crystals

Size: 0.2 - 2 μm

Surface Area: 10 - 30 m^2/g

[Magn: 2000 x]



Montmorillonite:

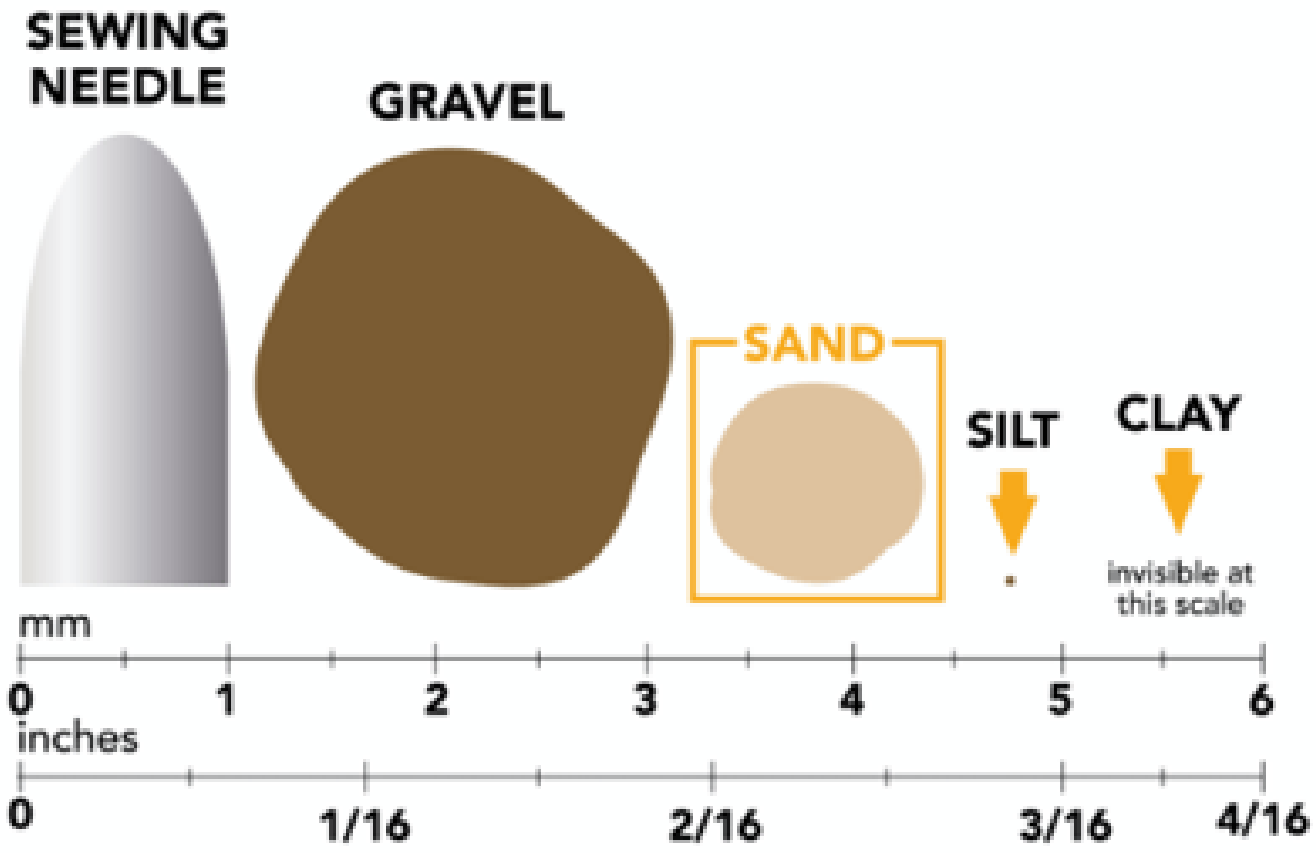
Flakes

Size: 0.01 - 1 μm

Surface Area: 650 - 800 m^2/g

[Magn: 20000 x]

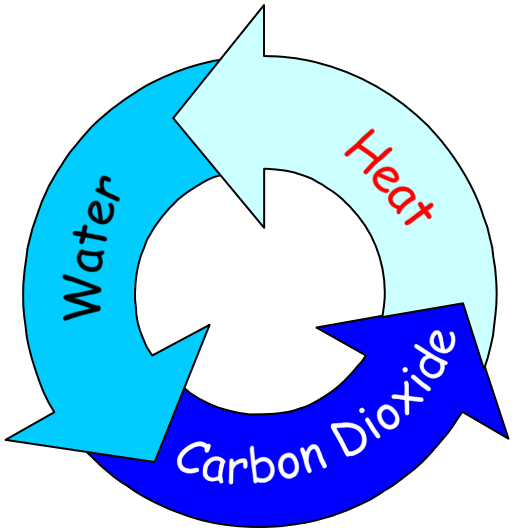
Layers of Silica & Alumina


SEWING NEEDLE
GRAVEL
SAND
SILT
CLAY
invisible at this scale
mm
0
1
2
3
4
5
6
inches
0
1/16
2/16
3/16
4/16

The Lime Cycle

CaO
Quicklime

$Ca(OH)_2$
Hydrated Lime



$CaCO_3$
Limestone

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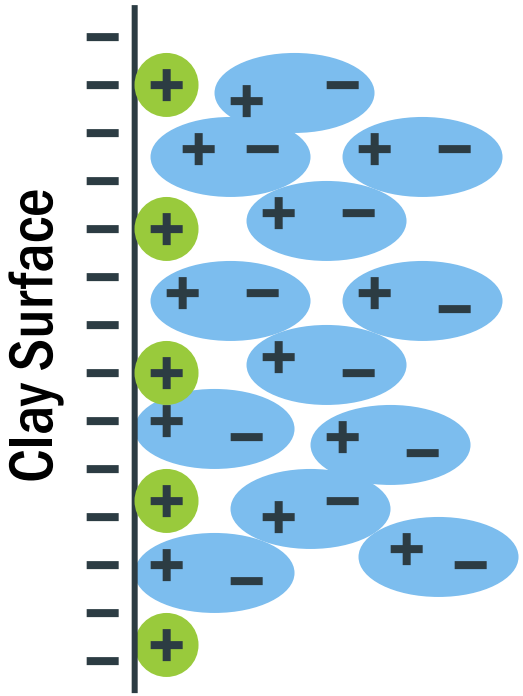
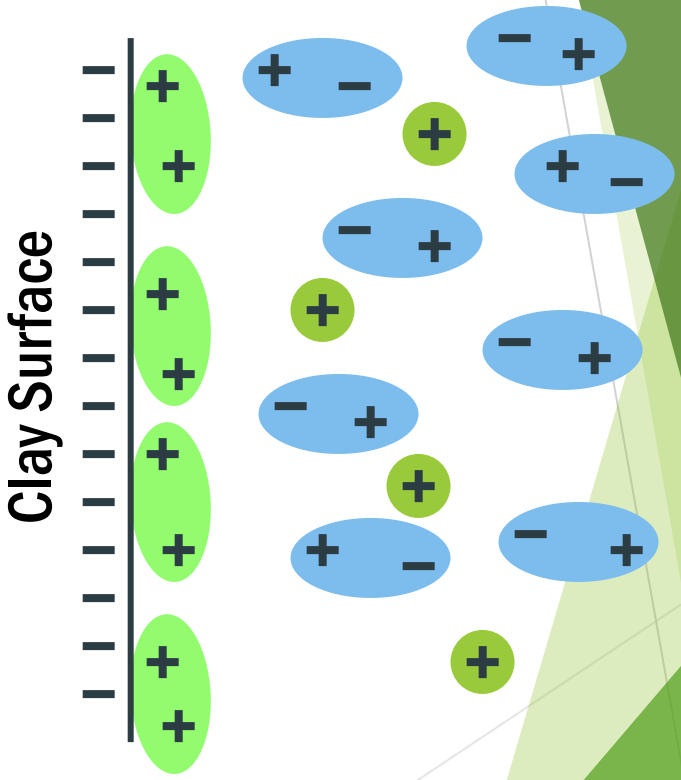
The System:
Clay – Water - Calcium

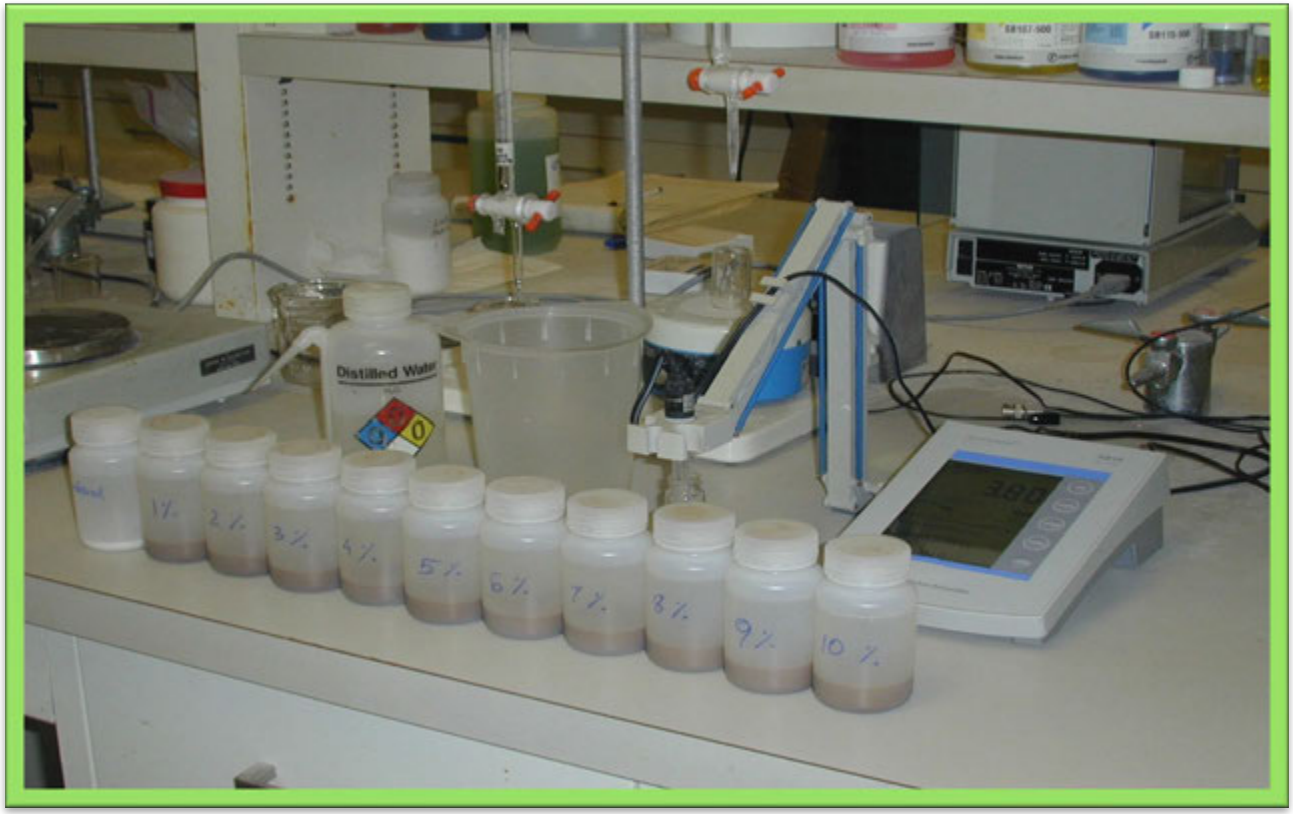


Negatively charged clay surface attracts cations (+) & water molecules (dipole), causing formation of a 'double diffused water layer'



Calcium cations (++) replace water and lessens ions so soil becomes more workable

Tex-121-E Part III



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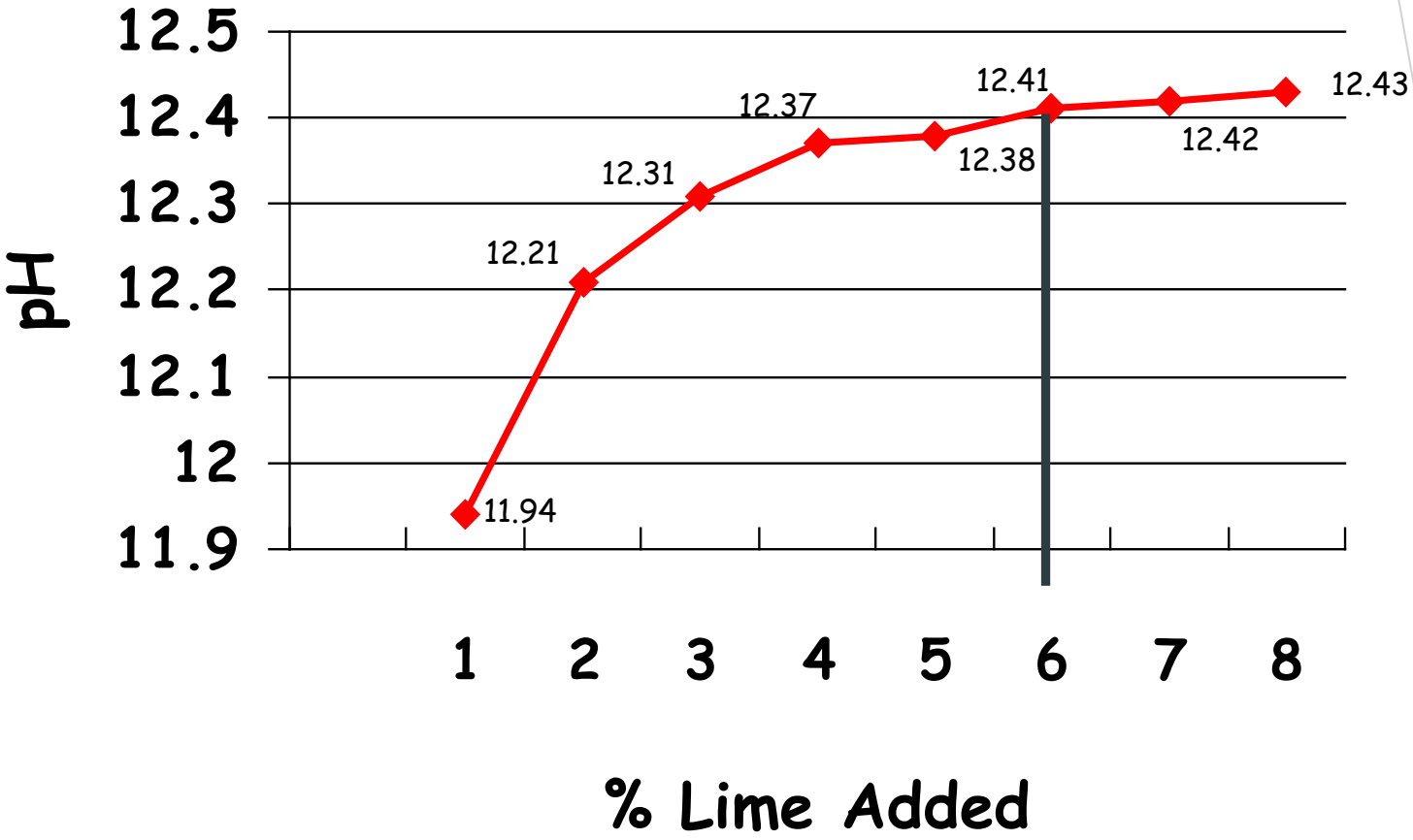
Tex-121-E Part III



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Rapid Change in Soil Texture

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Lime - Soil Reactions (1):

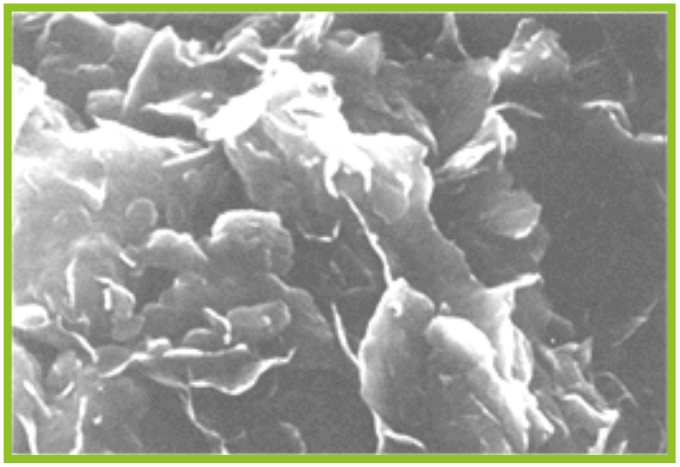
Immediate Reactions (within hours)

- **Reduction in Water Content** chemical reaction ($CaO + H_2O \rightarrow Ca(OH)_2 + heat$)* and mixing effect *: not for Hydrated Lime

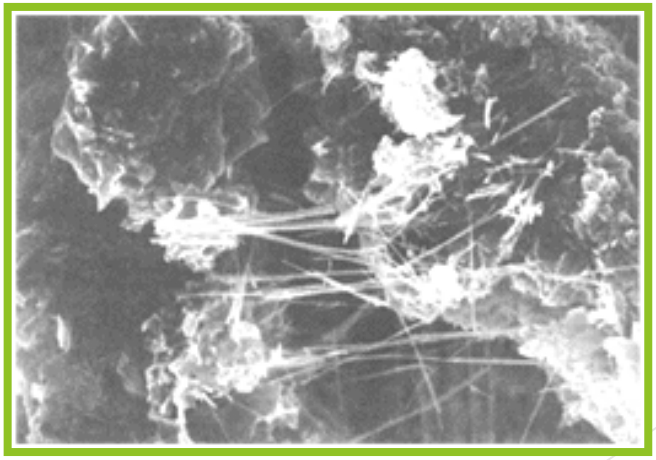
- **Flocculation / Agglomeration of Clay particles**
  textural change leads to decrease in PI & increase in workability

Lime Stabilization Process

Hydrated lime ($Ca(OH)_2$ ⟶ high pH)
+ water (H_2O)
+ Clay (Silica & Alumina dissolve)
= Cementitious material (CSH & CAH)



Natural Clay

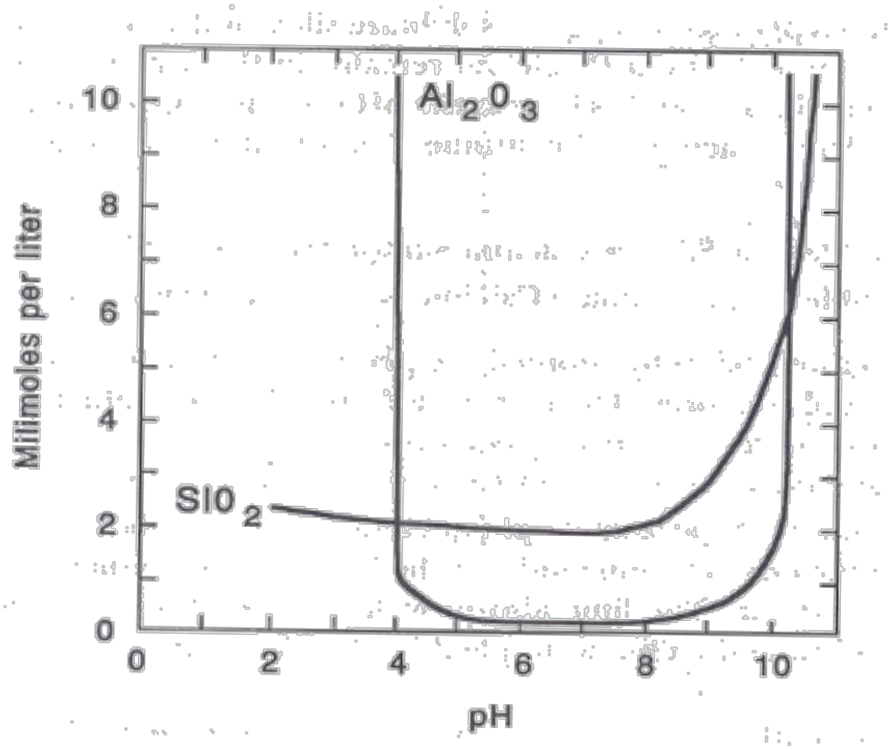


Pozzolanic Reaction Increases Bonds by Formation of Crystals

Lime-Soil Reactions

- Cation exchange
- Flocculation/agglomeration
- Pozzolanic reaction
- Carbonation

Pozzolanic Reaction (2):



Influence of pH on solubility of Silica and Alumina: In the high pH-environment provided by Lime (when saturated, pH = 12.4), Clay-silica and -alumina become available for the pozzolanic reaction:

$Ca^{2+} + OH^- + SiO_{2\ (soluble)} \rightarrow CSH$

$Ca^{2+} + OH^- + Al_2O_{3\ (soluble)} \rightarrow CAH$

The pozzolanic reaction will continue as long as a high pH is maintained and Ca^{2+}-Ions are available.

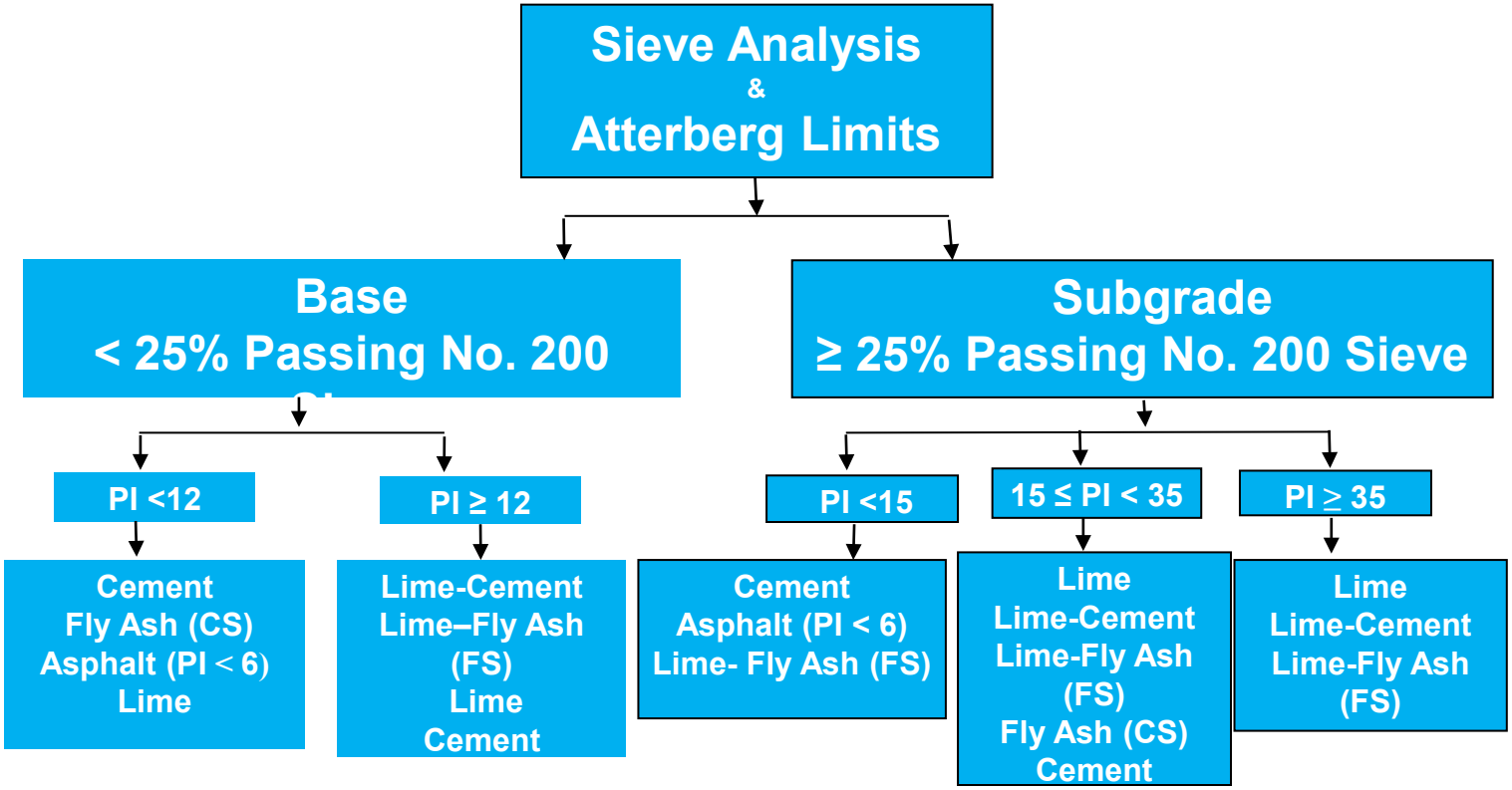
Treatment Guidelines for Soils and Base in Pavement Structures

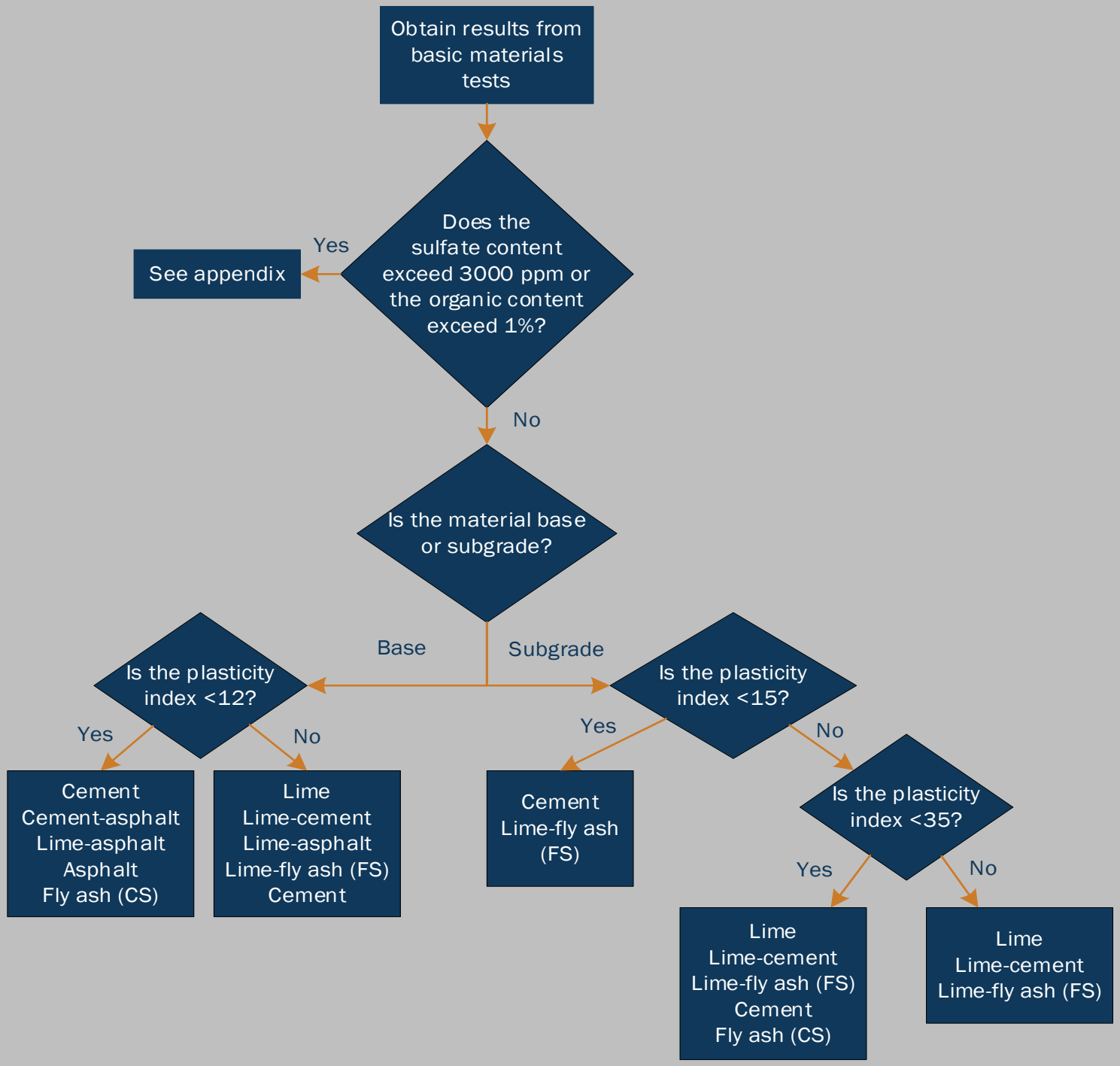
Materials & Tests Division

Soils & Aggregates Section

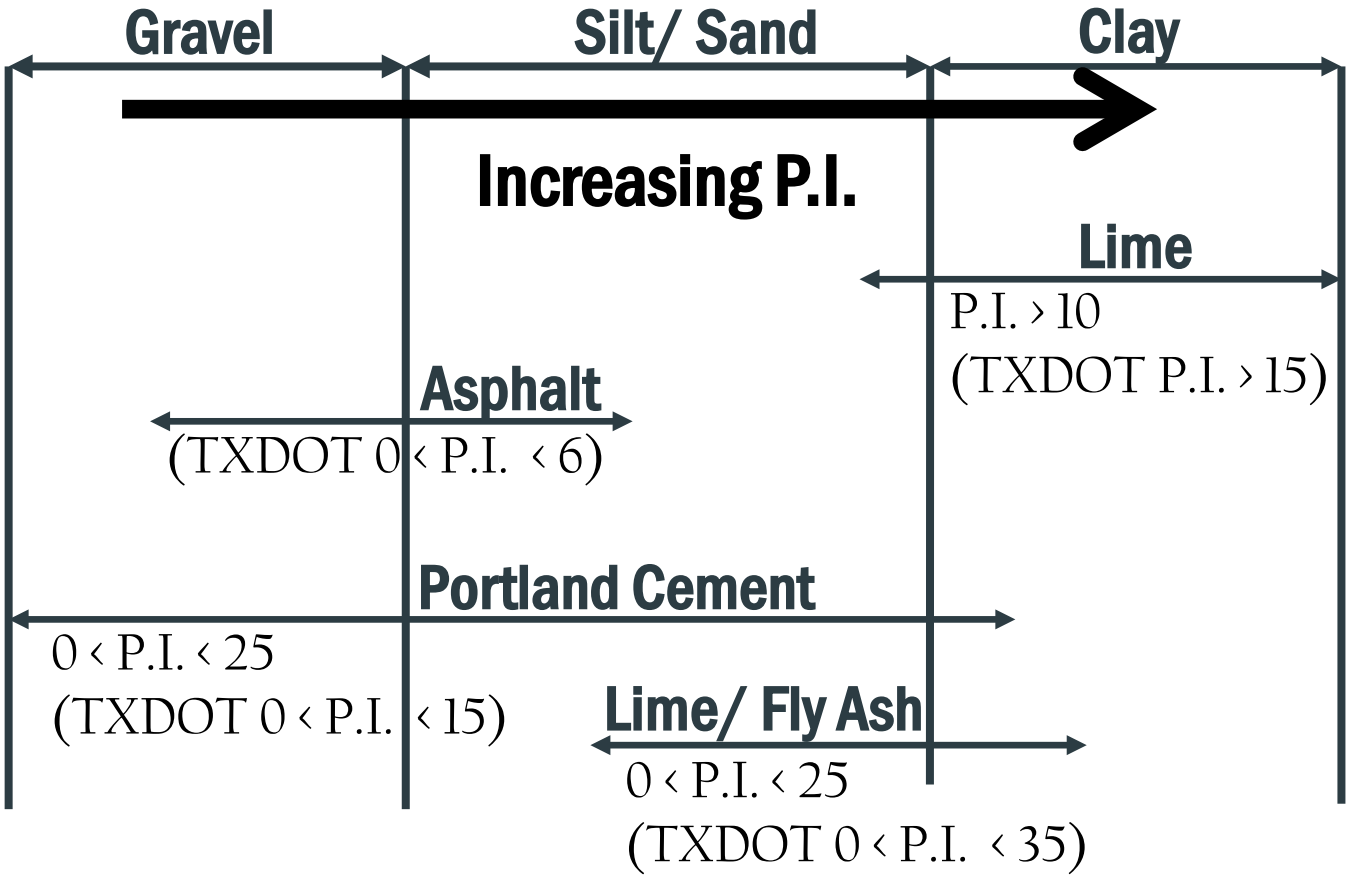
August 2019

TxDOT Guidelines for Soil Treatment




Obtain results from basic materials tests
Does the sulfate content exceed 3000 ppm or the organic content exceed 1%?
Yes
See appendix
No
Is the material base or subgrade?
Base
Subgrade
Is the plasticity index <12?
Yes
Cement
Cement-asphalt
Lime-asphalt
Asphalt
Fly ash (CS)
No
Lime
Lime-cement
Lime-asphalt
Lime-fly ash (FS)
Cement
Is the plasticity index <15?
Yes
Cement
Lime-fly ash (FS)
No
Is the plasticity index <35?
Yes
Lime
Lime-cement
Lime-fly ash (FS)
Cement
Fly ash (CS)
No
Lime
Lime-cement
Lime-fly ash (FS)

Common Additives for Soil Stabilization



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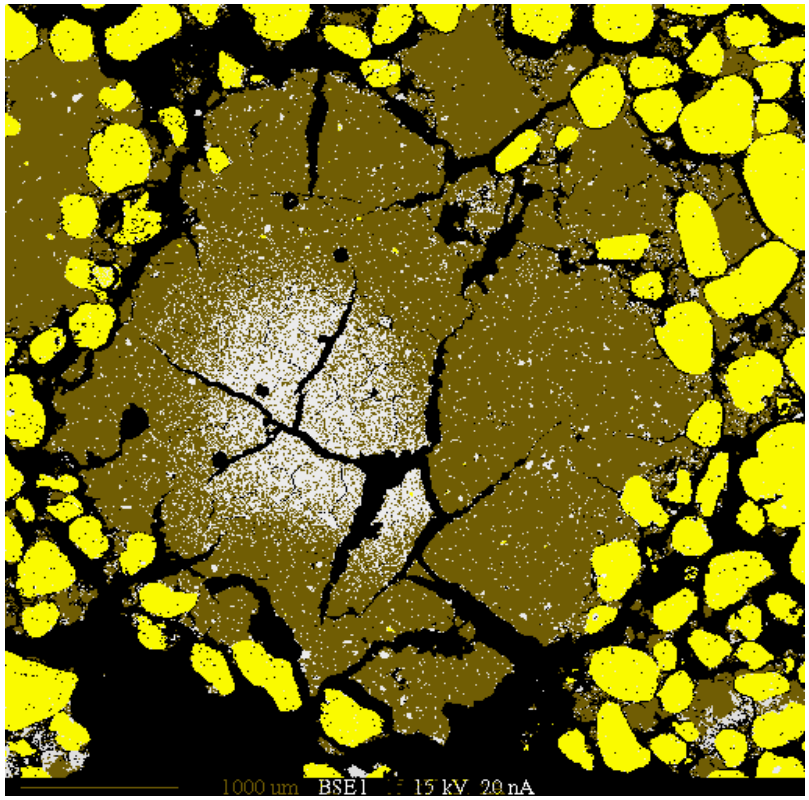
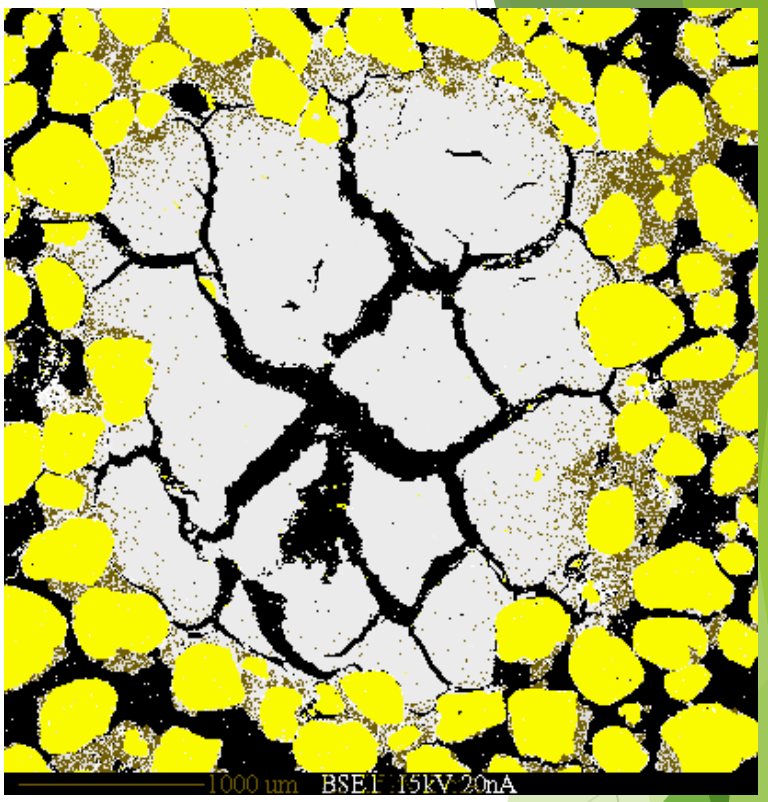
Cement in Lieu of Lime?

- Cement often promoted in the soils market as a calcium-based stabilizer that does the same thing Lime can do
  - Faster, higher strength, no mellowing, open roadway to traffic the same day
- Cement has about half the available CaO compared to Lime and more importantly it reacts differently than Lime
- **In high PI clay**, Cement is not equivalent or interchangeable with Lime since it does not complete the pozzolanic reaction that will permanently change the structure of clay. With Cement, the clay particle is not consumed, it is encapsulated
- Cement sets 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

Calcium Diffusion into Clay – 365 Days



Lime treated, 5mm



Cement treated, 4mm

Ref: Harris, et al

Si bearing

Porosity

Ca + Si + Al bearing

Si + Al bearing

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