Design Practice For Soil Stabilization in Subsidence Area

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Master Drainage Plan

Airport Master Plan

The IAH Master Plan will serve as an integral planning and decision tool in support of the short, intermediate, and long-term development and operation of IAH as defined in the *<u>2006 GBIAH Master Plan</u>* (DMJM & RS&H Aviation Sept. 2006 Technical Report).

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GBIAH MASTER PLAN

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Vertical Datums

- North American Vertical Datum of 1988 (NAVD 88)
- National Geodetic Vertical Datum of 1929 (NGVD 29)
  - 1973 Adjustment
- IAH
  - NGVD 1929, 1973 Adj.
  - NAVD 1988, 1991 Adj. (2001 Drainage Master Plan Update)
  - NAVD 1988, 2001 Adj. (2007 Drainage Master Plan Update)

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Converting Elevation Data

- In 2001 DMPU used a uniform Adjustment from NGVD 1929, 1973 Adjustment to NAVD 1988, 1991 Adjustment
- Adjust from NAVD 1988, 1991 Adjustment to NAVD 1988, 2001 Adjustment
  - National Geodetic Survey
  - TSARP Flood Plain Reference Mark System
  - IAH Survey Manual Update

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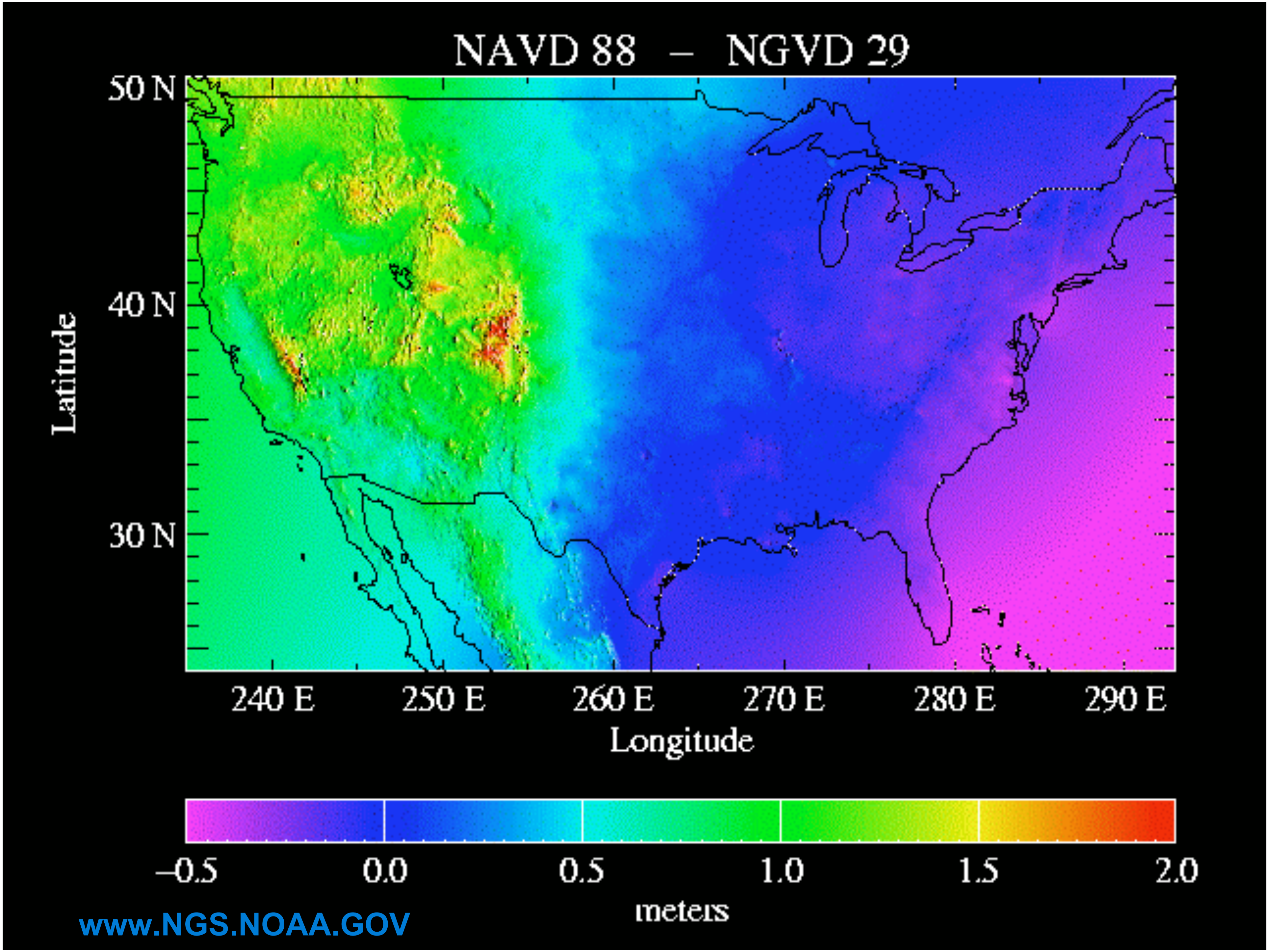
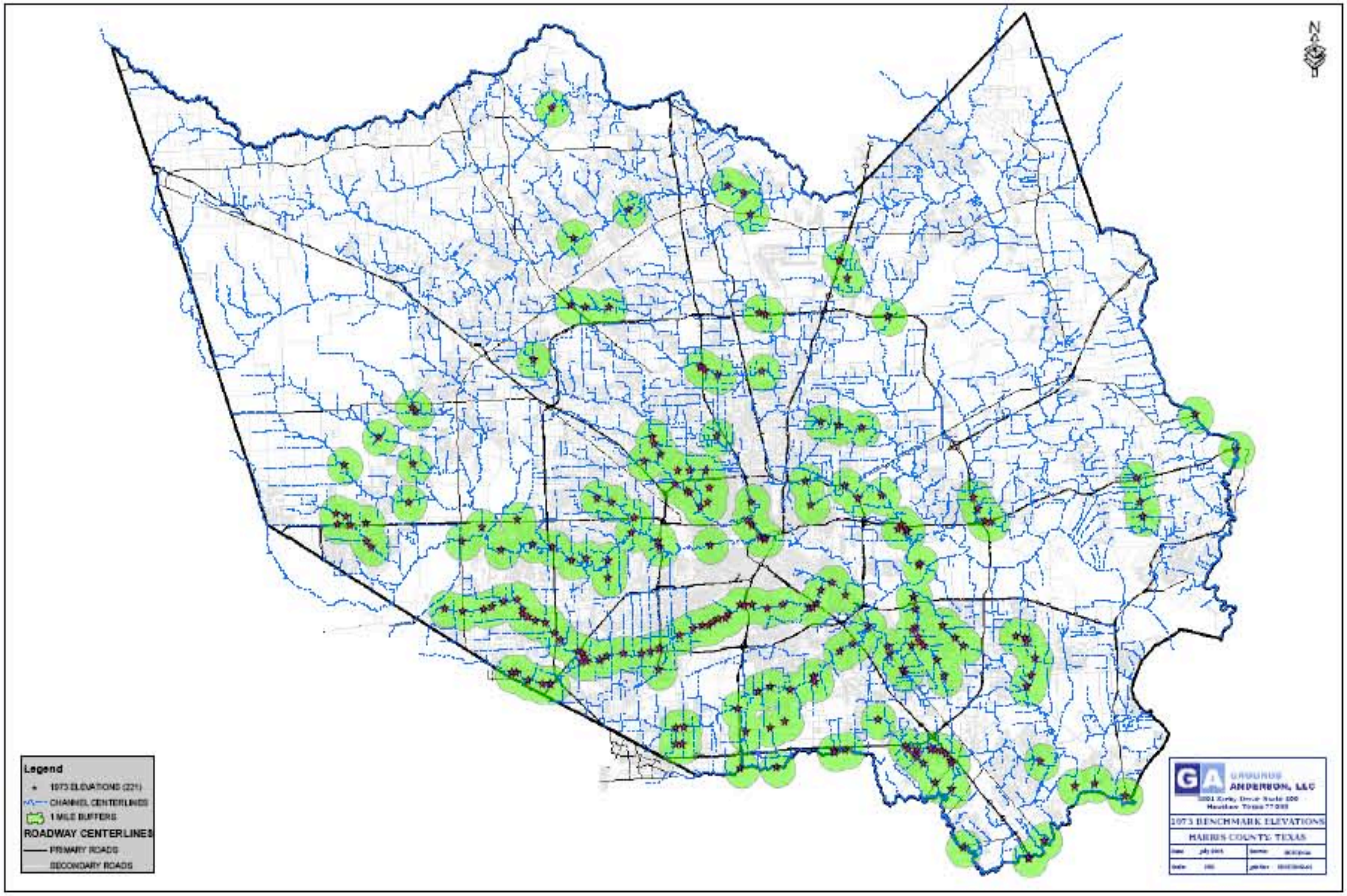


NAVD 88 – NGVD 29
50 N
40 N
30 N
Latitude
240 E
250 E
260 E
270 E
280 E
290 E
Longitude
–0.5
0.0
0.5
1.0
1.5
2.0
meters
www.NGS.NOAA.GOV

Benchmarks with 1973 Elevations



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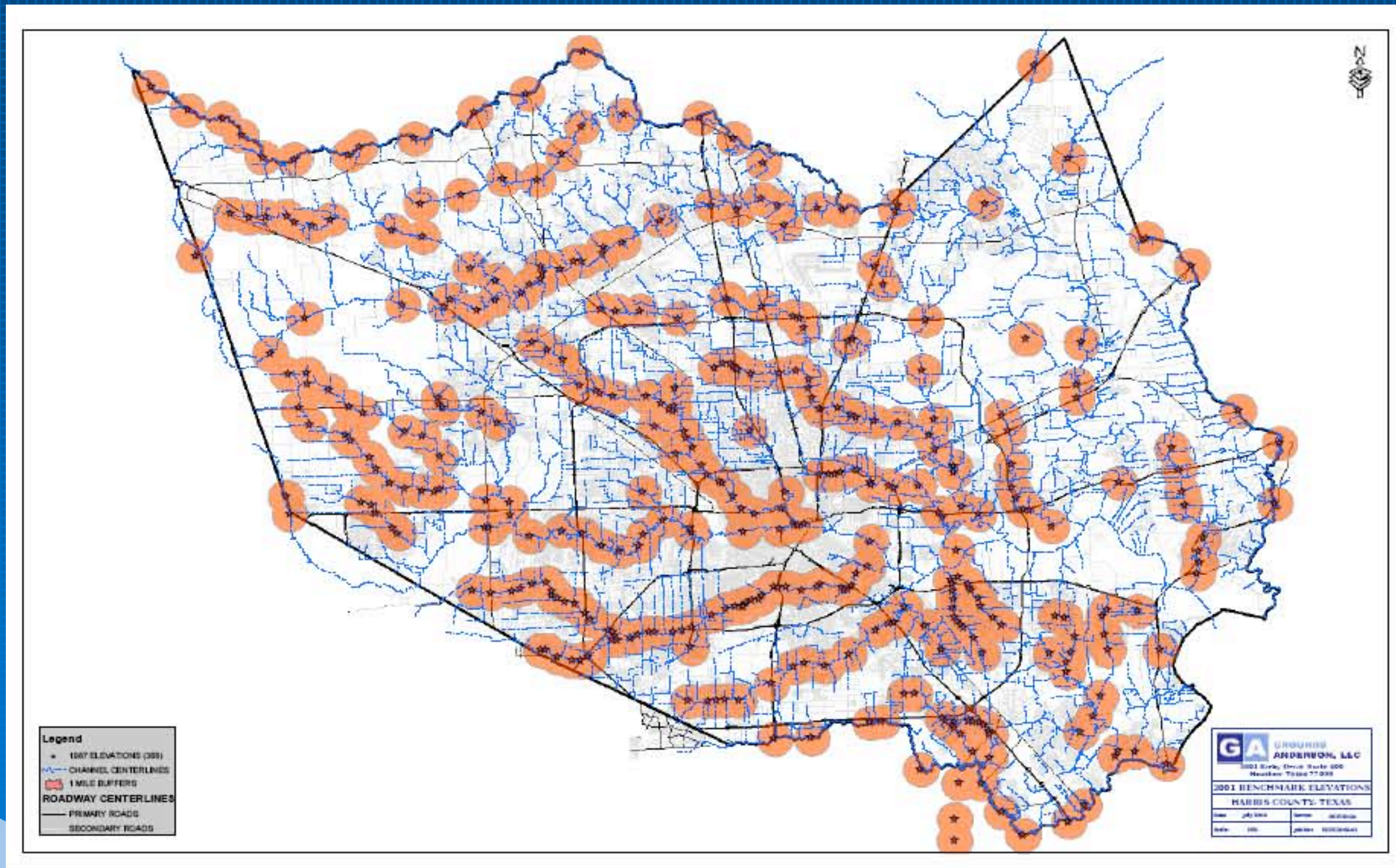
Benchmarks with 2001 Elevations



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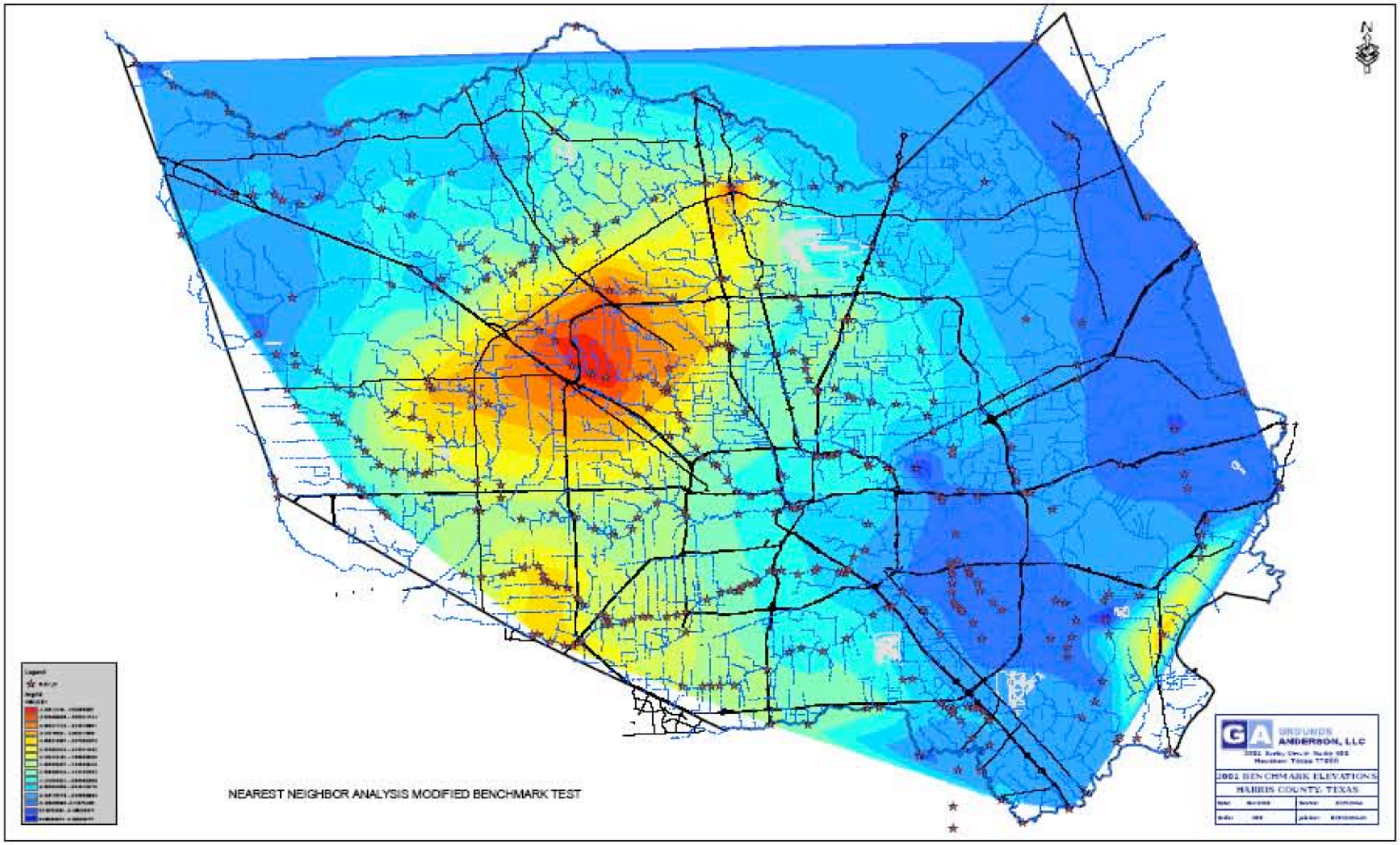
1978-2001 Adjustment Map



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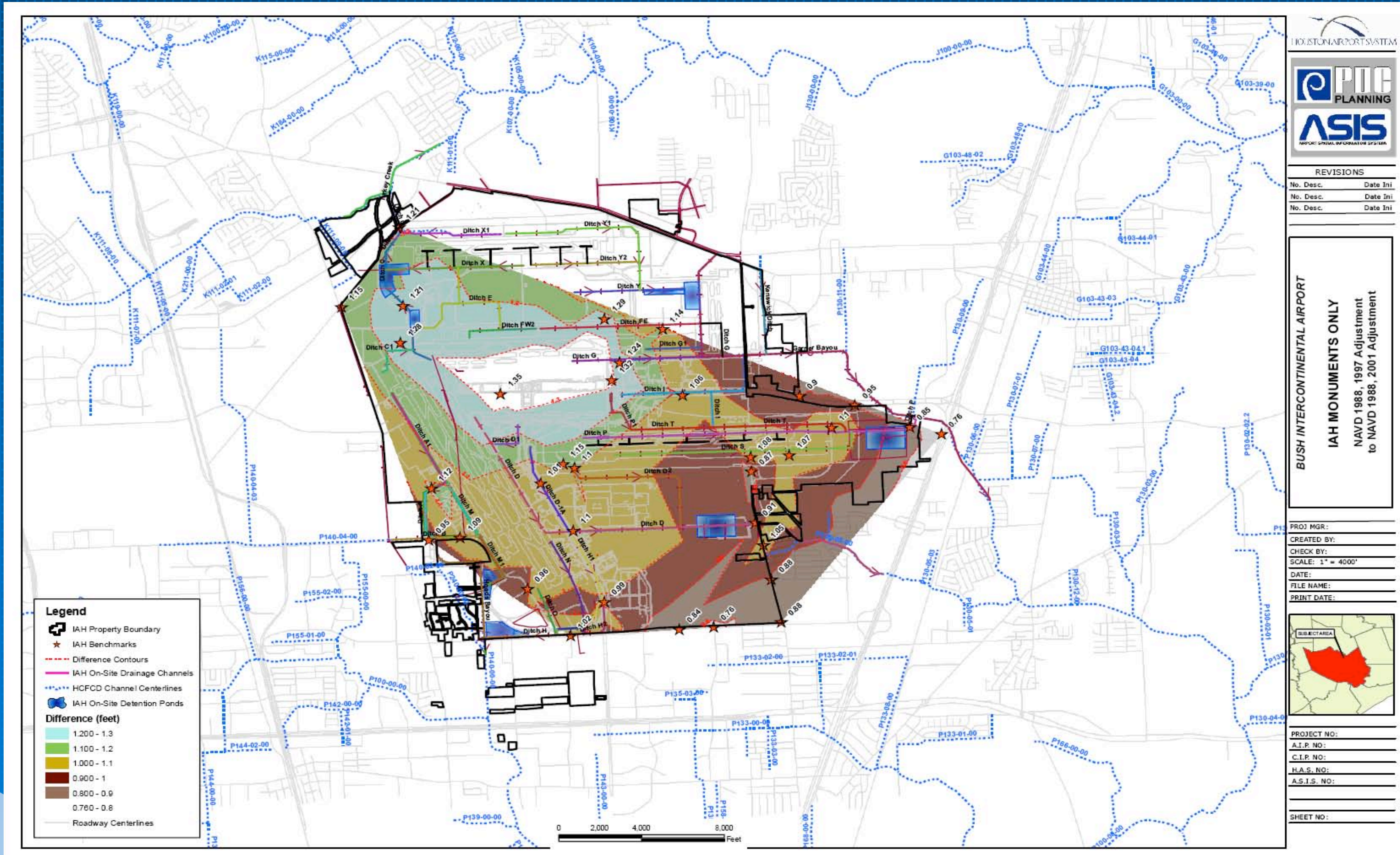
GBIAH ADJUSTMENT MAP



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PRESENTATION OUTLINE

Objective

- Subgrade Characterization
- Evaluation of Subgrade Stabilization on Pavement Performance
- Research in progress

HOUSTON AIRPORT SYSTEM

TERMINAL & RUNWAY

- $1.6B program
  - 35 miles of runways, taxiways
  - 2.2M cu yds of PCC
  - 29M cu yds of earthwork
- Modern, parallel runway configuration
- Massive earthmoving, construction, hydraulic, environmental impact challenges

SUBGRADE STABILIZATION

Definition

The improvement of pertinent soil engineering properties by the addition of additives so that the soil can effectively serve its function in the construction and life of a pavement

TECHNICAL OBJECTIVES

Some recognized direct causes of subgrade/subbase non-uniformity include

- **(1) Expansive soil**
- **(2) Non-uniform strength and stiffness due to variable soil type, moisture content and density**
- **(3) Pumping and rutting**
- **(4) Cut/fill transitions**
- **(5) Poor grading.**

REASONS TO STABILIZE

- **IMPROVE ENGINEERING PROPERTIES OF IN-SITU SOILS (STRENGTH WATERPROOF)**
- **RECYCLE EXISTING PAVEMENTS/BASES**
- **IMPROVE DURABILITY**
- **REDUCE THICKNESS OF PAVEMENT**
- **FACILITATE CONSTRUCTION**

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FAA COMPARATIVE ANALYSIS

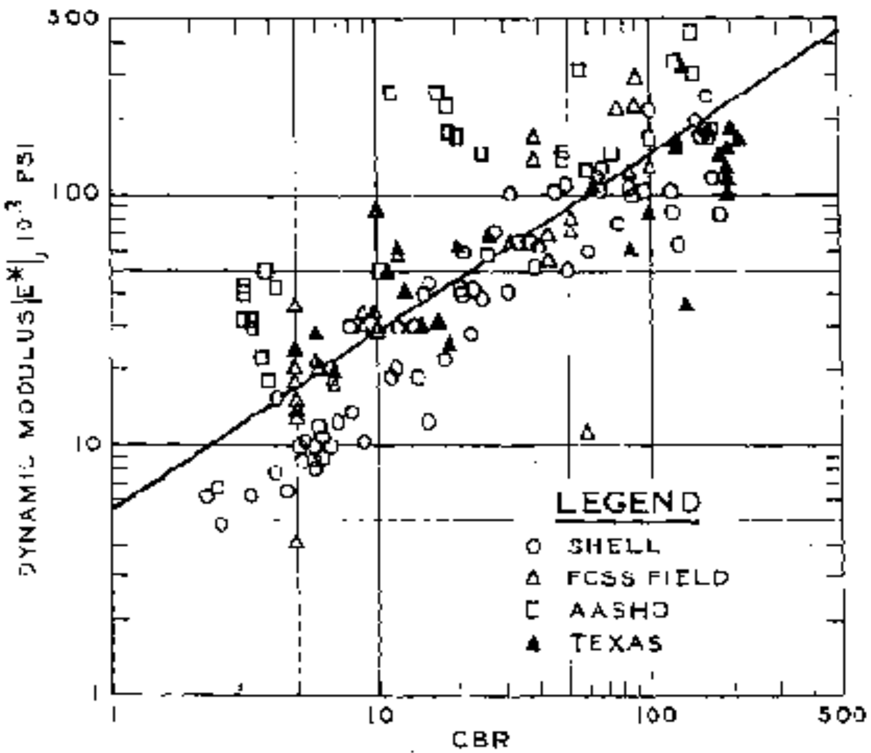

Figure 15. Relationship between dynamic modulus and CBR; WES correlation (after Green and Hall37)

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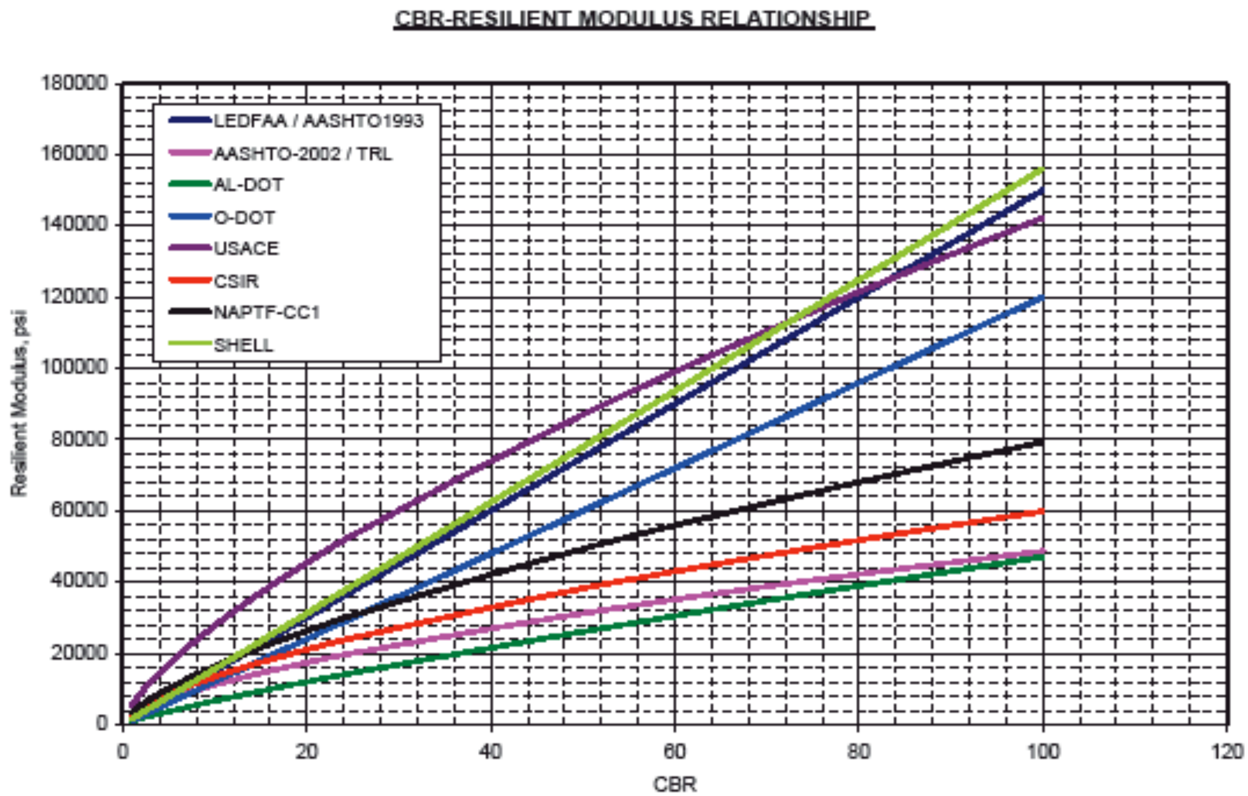
SUBGRADE and SUBBASE CHARACTERIZATION

- FAA thickness design procedure based on subgrade CBR.
- Current FAA thickness design procedure (based on Layered Elastic Analysis) uses CBR or modulus (estimated from CBR)
- E = 1500 * CBR (for CBR 2 to 200)

Subgrade and Subbase Characterization



Subgrade and Subbase Characterization

- E –CBR relationship
- Strong trend
- Lot of scatter
- Generally recognized that
- For weak soils, CBR dependent on shear strength;
- For strong soils, CBR dependent on bulk modulus

Subgrade and Subbase Characterization

The manner of the scatter in the modulus versus CBR correlation indicates that a strong combination of multiple underlying characteristics determines the CBR of materials at any given CBR value.

- From new FAA thickness design procedures, the capability for measuring resilient modulus of soils will become more common.
- Resilient modulus, in combination with a measure of strength such as shear strength, could well displace CBR as a means of characterizing subgrade soils.

Subgrade and Subbase Characterization

- Emphasis is placed on subgrade/subbase stiffness (i.e., modulus of subgrade reaction, *ks*) for designing PCC pavement thickness
- Performance monitoring suggests that uniformity of stiffness is the key for ensuring long-term performance.
- The subgrade/subbase should be uniform, with no abrupt changes in “degree of support” .
- Stabilization has a significant influence on the “stress intensity” and “deflection” of the pavement support.

Subgrade and Subbase Characterization

- **Laboratory Testing** –
- Atterberg Limit (LL, PL, PI of soils)
- Grain size analysis (hydrometer tests and sieve analysis)
- Modified Proctor Tests (moisture-density relationship)
- Unconfined compressive strength tests (shear strength of cohesive soils)
- Triaxial shear tests (shear strength parameters for cohesionless soils)
- Dynamic Triaxial Tests (resilient modulus and permanent deformation behavior)

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DESIGN FOR DIFFERENTIAL SETTLEMENT

RUNWAY 8L - 26R

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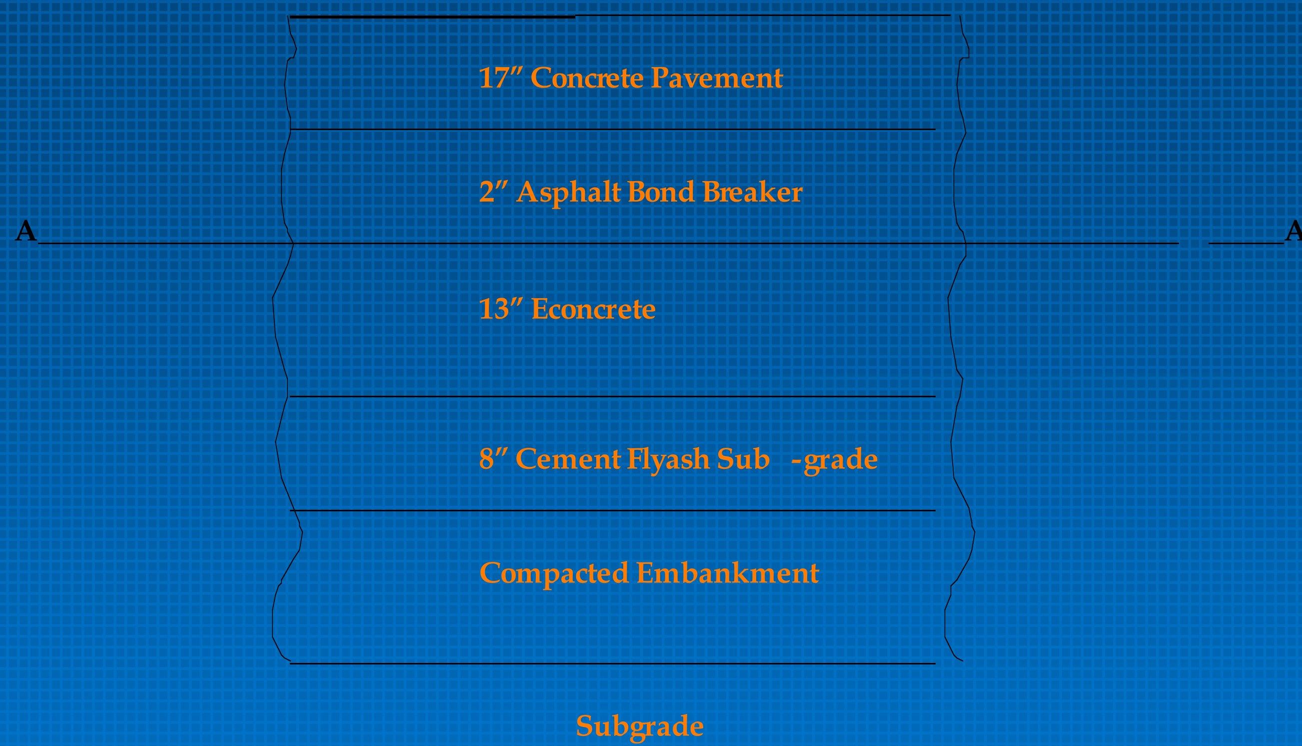
RUNWAY 8L -26R



At Layer A -A (Elevation)

Normal Stress = 20.70 psi; Normal Strain = 0.0000067

Shear Stress = 8.2 psi; Shear Strain = 0.0000049

Principal Stress = 22 psi; Principal Strain = 0.0000072

Displacement (Deflection) = 0.05 ”

DESIGN FOR DIFFERENTIAL SETTLEMENT

- To design for differential settlement in the areas where consolidation of the backfilled soil were yet to take place
- Dr. Dallas Little of Texas Transportation Institute
- Did some finite element analysis.
- This was done by modeling an abrupt (transition between the various pits undergoing settlement. The finite element analysis showed that the effect of the settlement discontinuity is significant.

- It was decided to use a Stress Absorbing Membrane Interlayer (SAMI) to absorb some of the energy due to the differential settlements. SAMI was added to the asphalt bond breaker in these areas.

- In addition two layers of reinforcing steel in the concrete pavement. This extra layer of steel at the bottom of the concrete pavement would help mitigate and arrest the cracks due to excessive tensile stresses in the event of differential settlement.

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Reasons to Stabilize

Improve Durability
Reduce Thickness of Pavement
Facilitate Construction

SUBGRADE PROPERTIES

Soil Type

- – Heavy Clay
- – Lean clay
- – Silt
- **Soil Condition**
- – Wet
- – Optimum
- – Dry
- **Stabilization Agents**
- – Cement
- – Lime
- – Lime/Fly Ash
- – Cement/Fly Ash

Stabilizer Selection

- Soil stabilization index system
- Developed by jon epps for the corps of engineers

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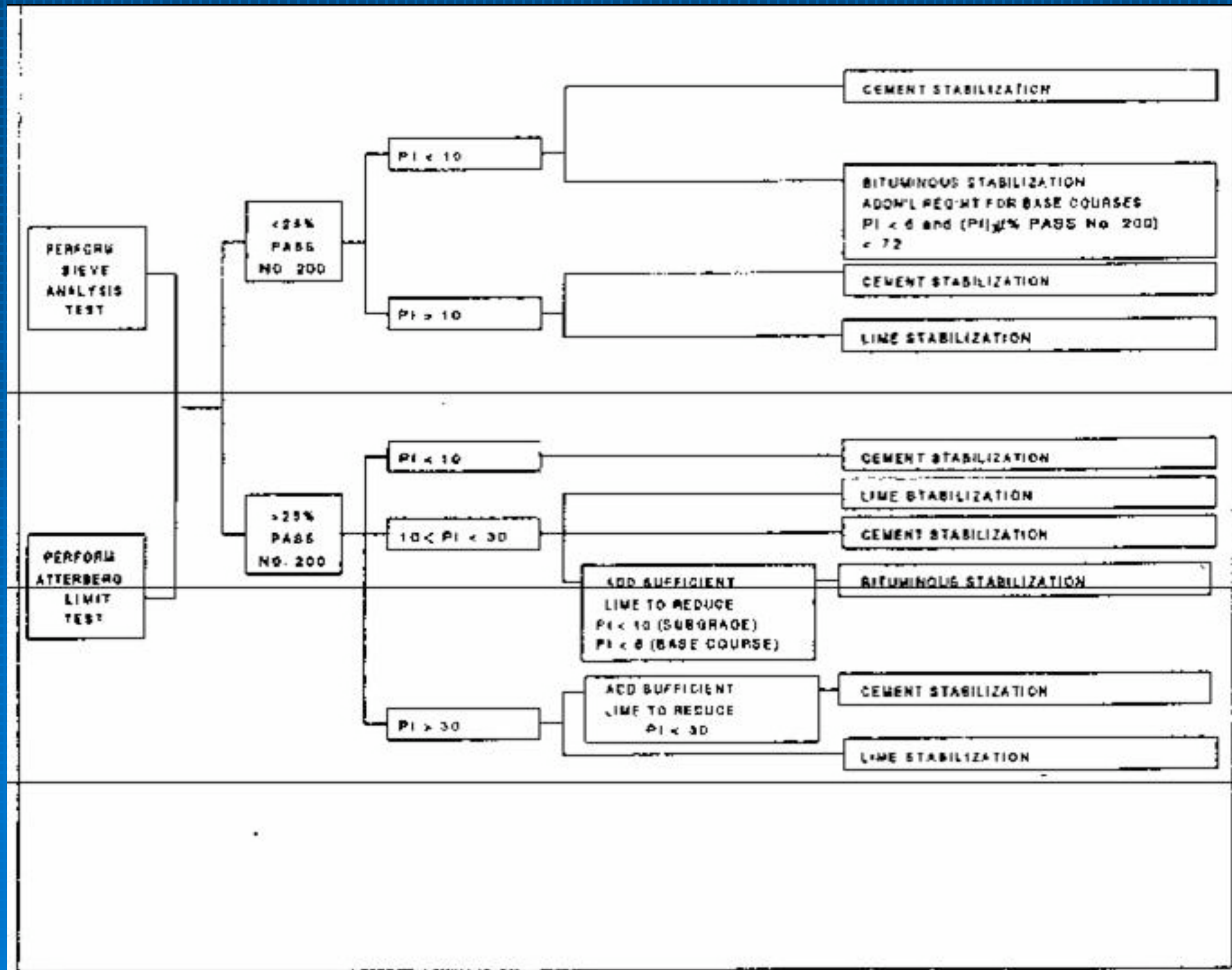
PERFORM SIEVE ANALYSIS TEST
PERFORM ATTERBERG LIMIT TEST
<25% PASS NO. 200
>25% PASS NO. 200
PI < 10
PI > 10
PI < 10
10 < PI < 30
PI > 30
CEMENT STABILIZATION
BITUMINOUS STABILIZATION ADDN'L REQ'MT FOR BASE COURSES PI < 6 and (PI)(% PASS No. 200) < 72
CEMENT STABILIZATION
LIME STABILIZATION
CEMENT STABILIZATION
LIME STABILIZATION
CEMENT STABILIZATION
ADD SUFFICIENT LIME TO REDUCE PI < 10 (SUBGRADE) PI < 6 (BASE COURSE)
BITUMINOUS STABILIZATION
ADD SUFFICIENT LIME TO REDUCE PI < 30
CEMENT STABILIZATION
LIME STABILIZATION

Flyash

- Most commonly used w/lime on silts
- Pozzolanic
- High quantities normally required

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General Use

- lime
  - high pi soils (usually >10)
- Portland cement
  -pi 10-30
- Asphalt
  -pi < 10 (sands)
- Flyash – fine grained silts

Lime

Percent by weight
- 2% for modification
- 3-6% for stabilization

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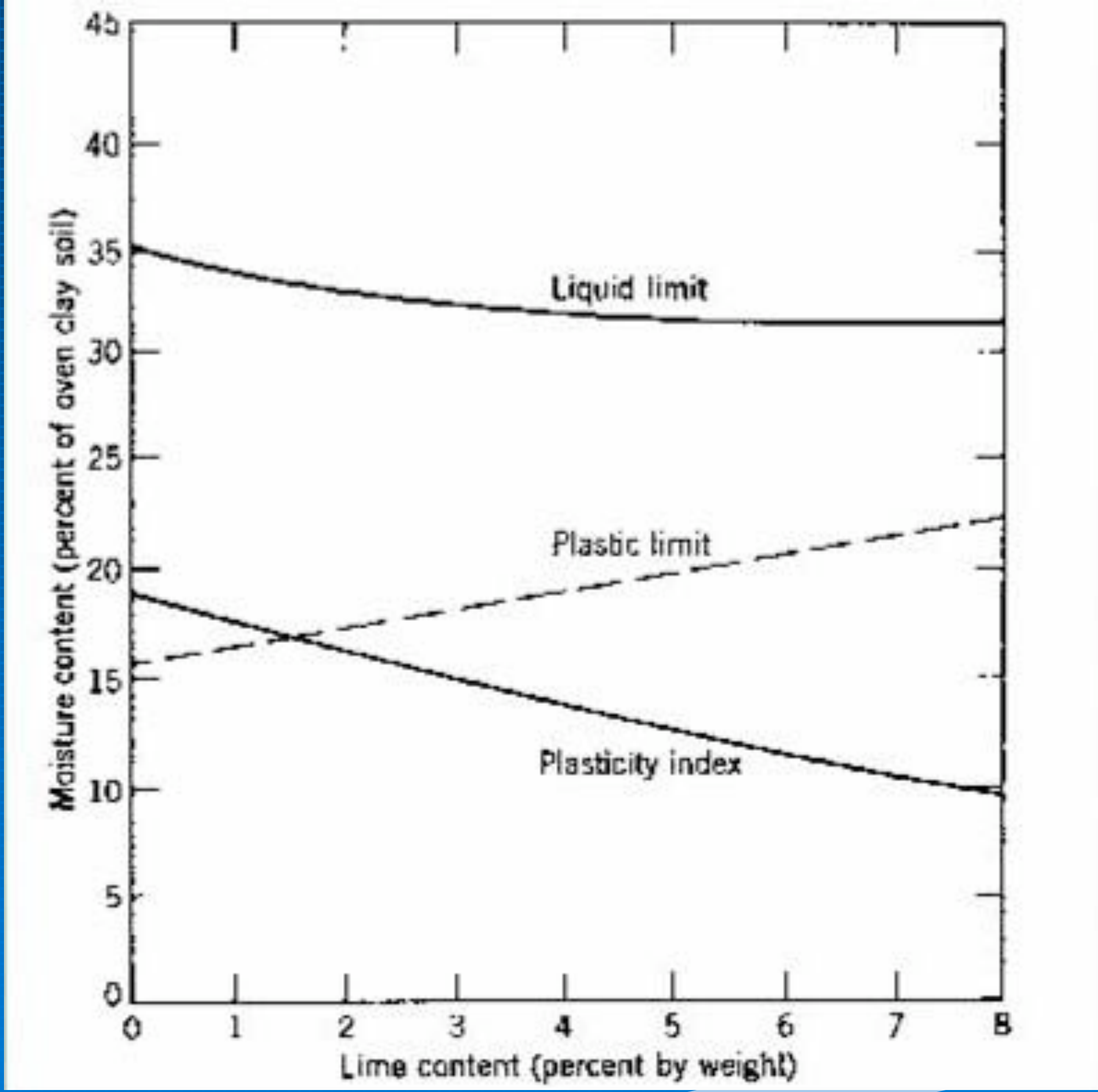

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Cement

Percent by weight

- 3-7% for coarse grained material
- 6-15% for fine grained material

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Cement Requirements

AASHTO Soil Classification	Unified Soil Classification[a]	Usual Range in Cement Requirement[b] (%/vol.)	Usual Range in Cement Requirement[b] (%/wt.)	Estimated Cement Content and That Used in Moisture-Density Test (%/wt.)	Cement Contents for Wet-Dry and Freeze-Thaw Tests (%/wt.)
A-1-a	GW, GP, GM, SW, SP, SM	5–7	3–5	5	3–5–7
A-1-b	GM, GP, SM, SP	7–9	5–8	6	4–6–8
A-2	GM, GC, SM, SC	7 10	5 9	7	5–7–9
A-3	SP	8–12	7–11	9	7–9–11
A-4	CL, ML	8 12	7-12	10	8–10–12
A-5	ML, MH, CH	8–12	8–13	10	8-10–12
A-6	CL, CH,	10–14	9–15	12	10–12–14
A-7	OH, MH, CH	10 14	10–16	13	11–13–15

[a]Based on correlation presented by the Air Force.

[b]For most A horizon soils, the cement should be increased 4 percentage points if the soil is dark grey to grey and 6 percentage points if the soil is black.

Source: Adapted from *Soil Cement Inspector's Manual*, Portland Cement Association, Skokie, Ill., 1963.

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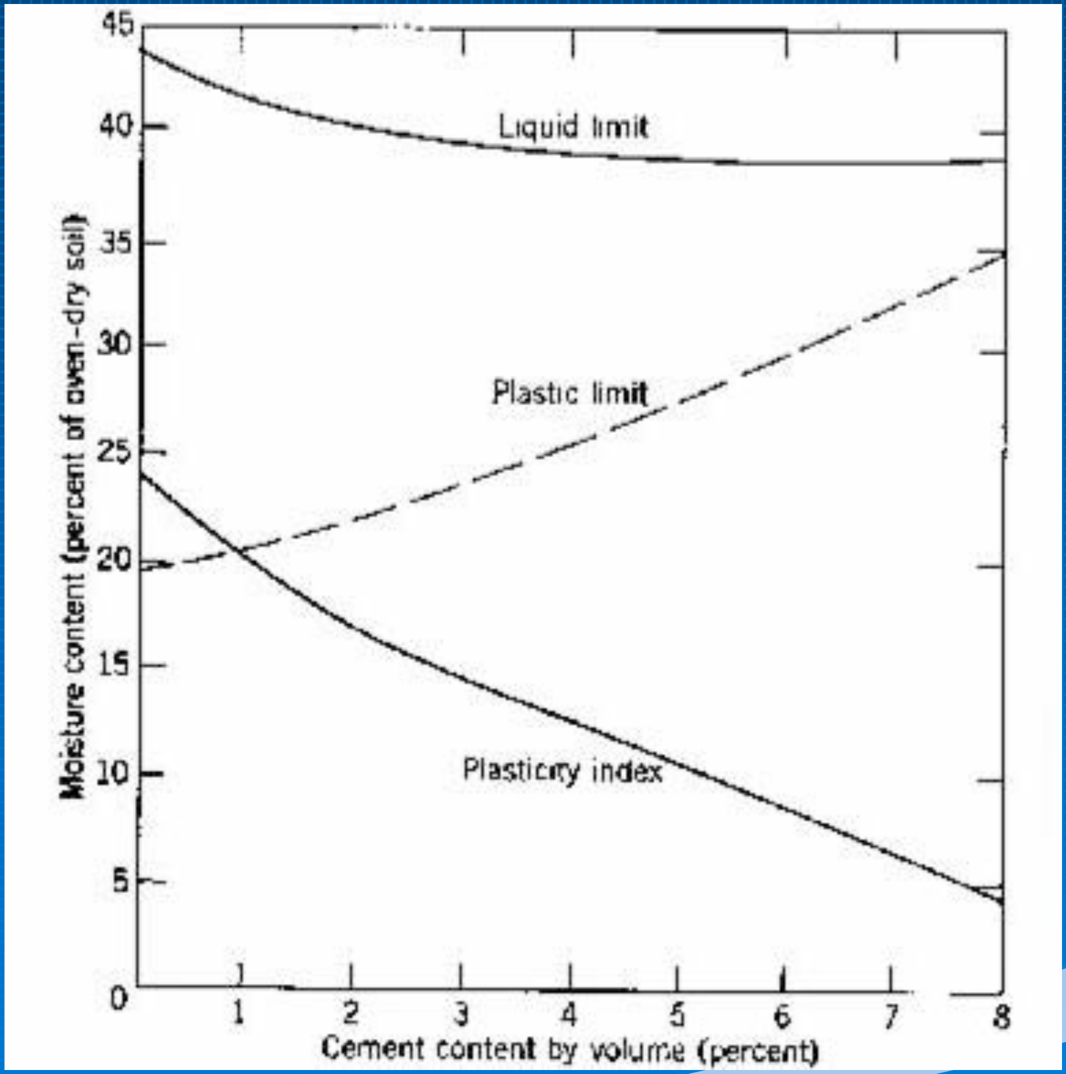
Percent Cement



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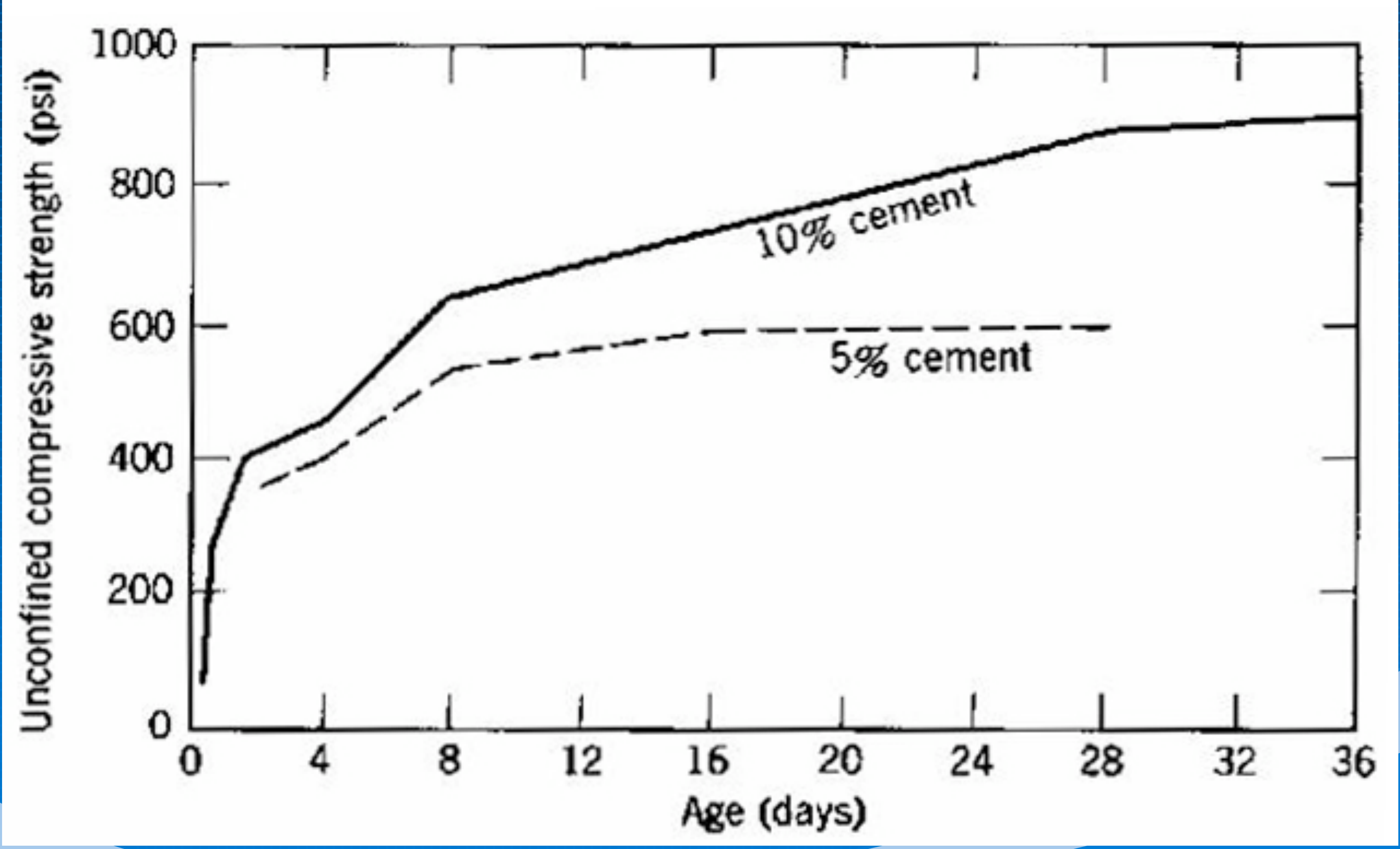
Cement Curing Time



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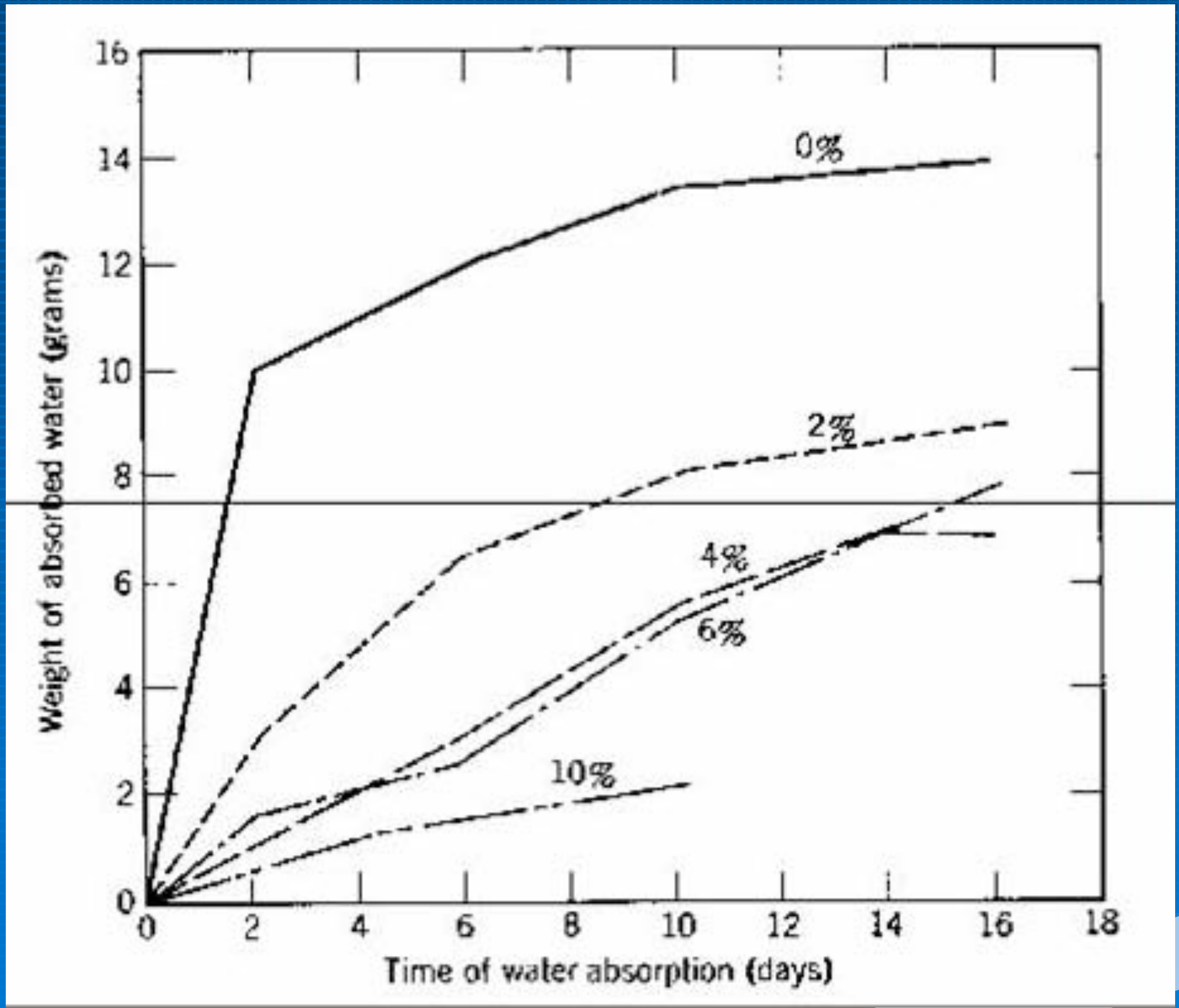
Water Absorption



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Asphalt Requirements

Material Type	Maximum Values for Adequate Stabilization	Bitumen Types and Grades	Approximate Amount of Bitumen (%)
Fine-grained soils	Max LL = 40% Max PI = 18%	MC & SC Emulsions RT 3–6	4–8
Sands	Max pass No. 200 sieve = 25% Max PI = 12%	AC Pen 85–100 & 120–150 RC 1–3 Emulsions RT 6–10	4–10
Gravel and sand gravel	Max pass No. 200 sieve = 15% Max PI = 12%	RC 1–3 RT 4, 5 AC	2–6

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Mix Designs

Perform Detailed Mix Design

Consider

- Workability
- Strength
- Durability
- Volume Sensitivity

• Swelling, Shrinkage

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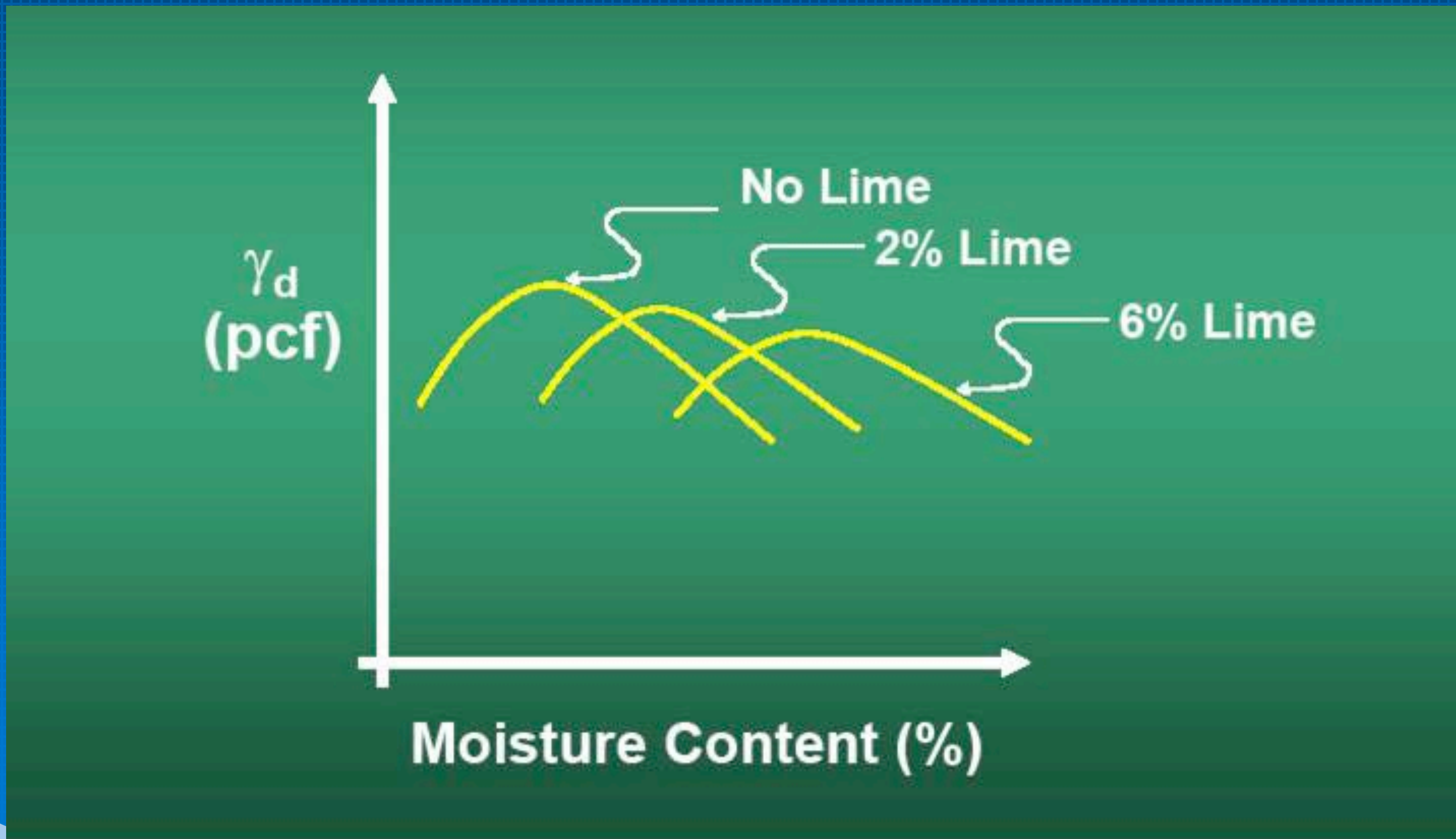
Field Control

- In – Place Density Usually Employed for QC.QA Purpose

- Density/ Moisture Relationship of Stabilized Materials
Changes with Curing Time and Stabilizer Content

Field Control



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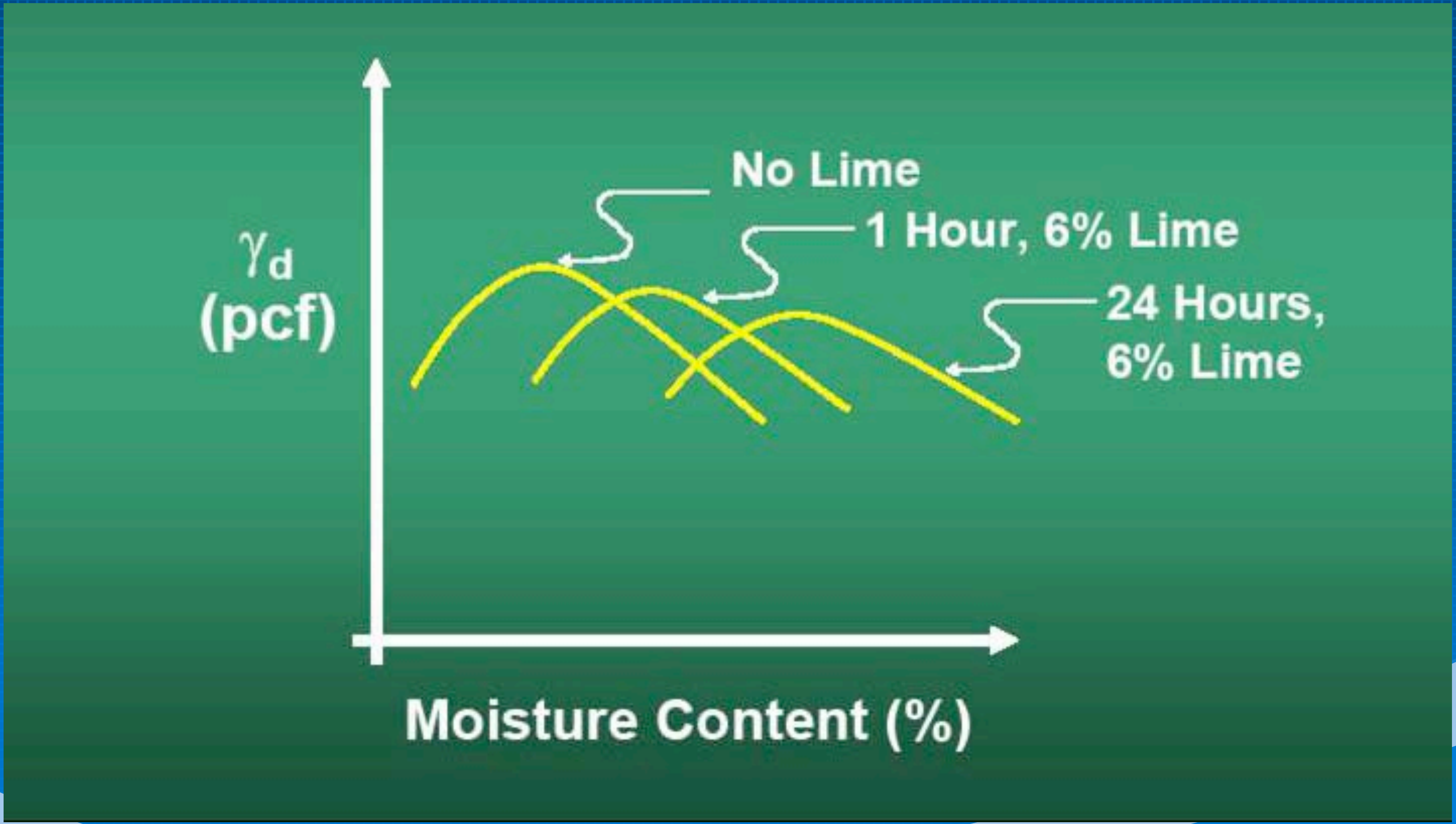
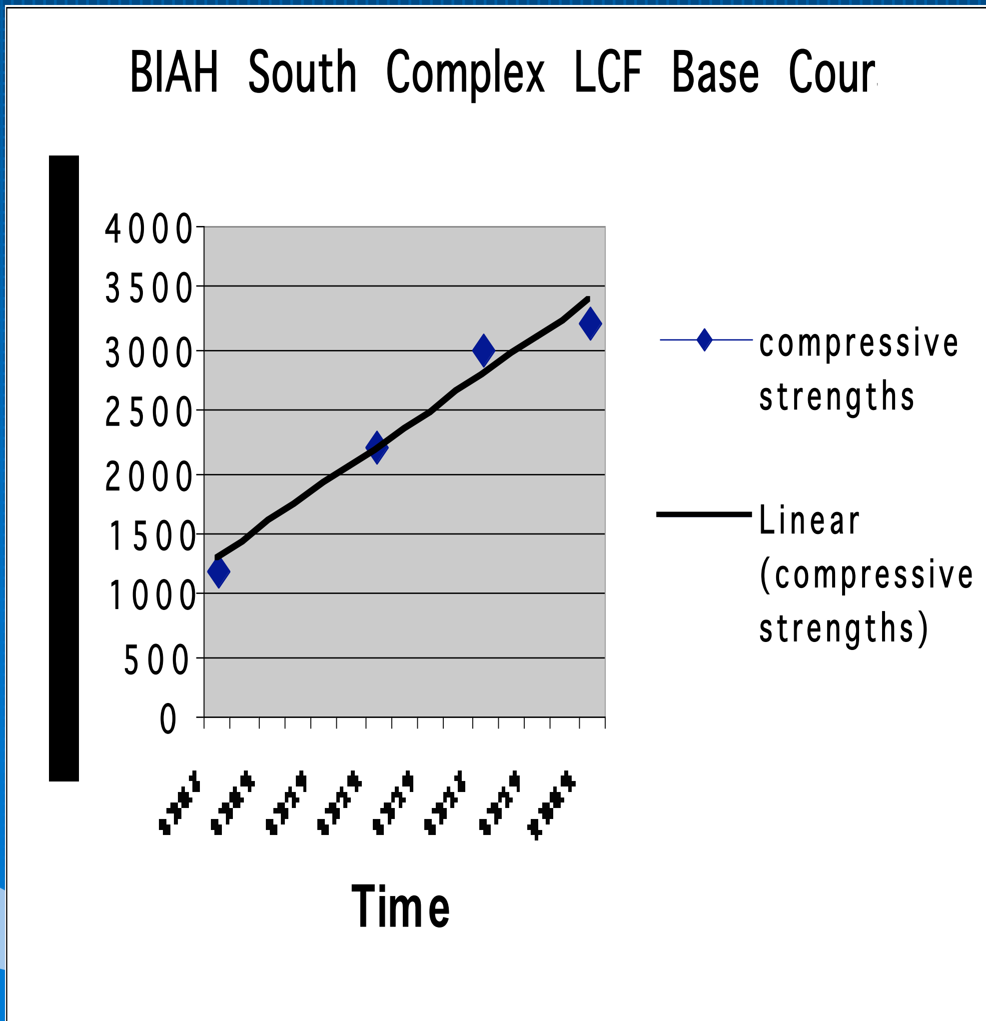
Field Control



Asphalt

Percent by weight
- 2-4% for coarse grained material
- 4-6% for fine grained material

SOUTH COMPLEX—
RUNWAY 9-27 AND ASSOCIATED TAXIWAYS



987 1,200 psi 8,280 KPa

993 2,200 psi 15,180 KPa

997 3,000 psi 20,700 KPa

001 3,200 psi 22,080 KPa

ong-term strength gain

Research in progress

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LCF TECHNOLOGY

LCF Technology developed by Nai Yang

Pozzolanic base stabilization

4 Airports used LCF base stabilization

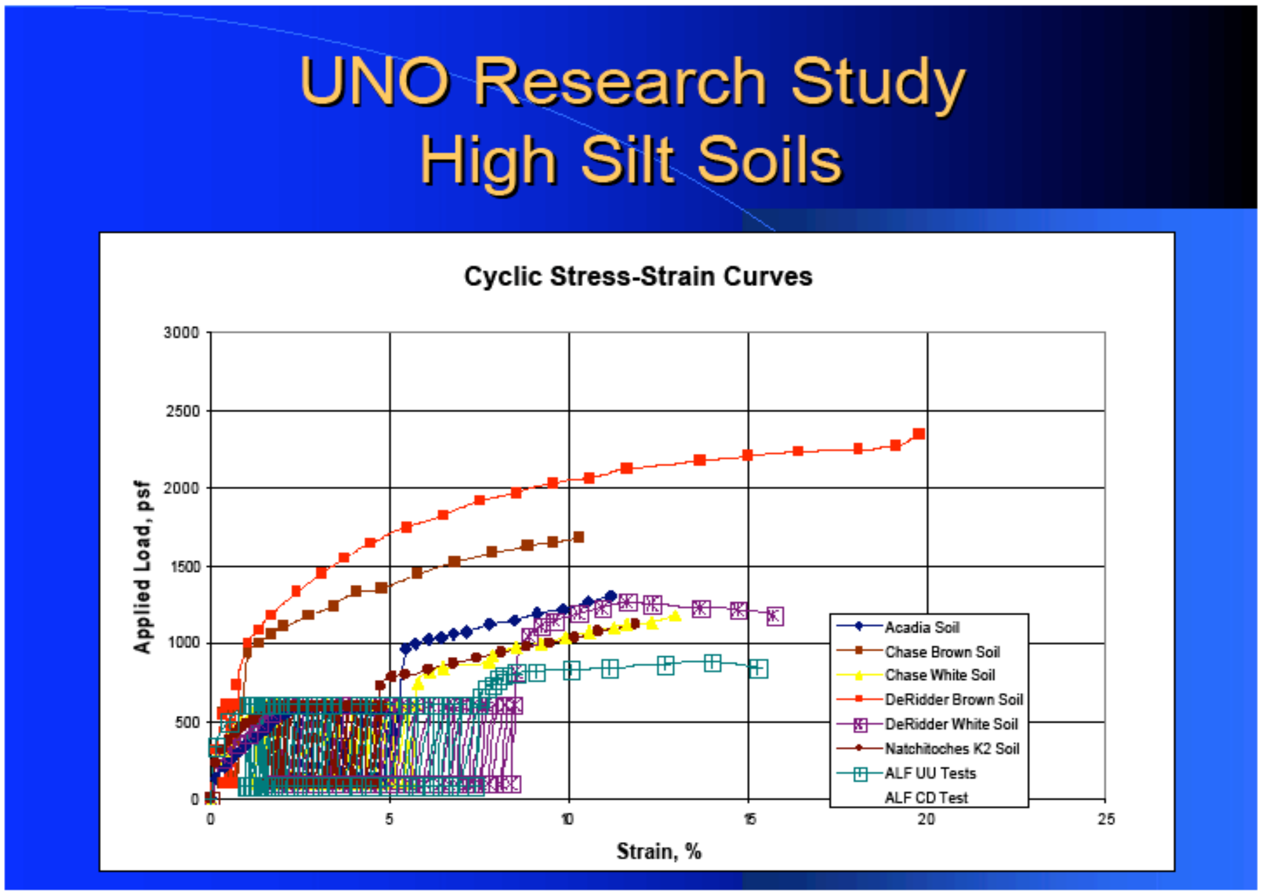
Newark International Airport 1969

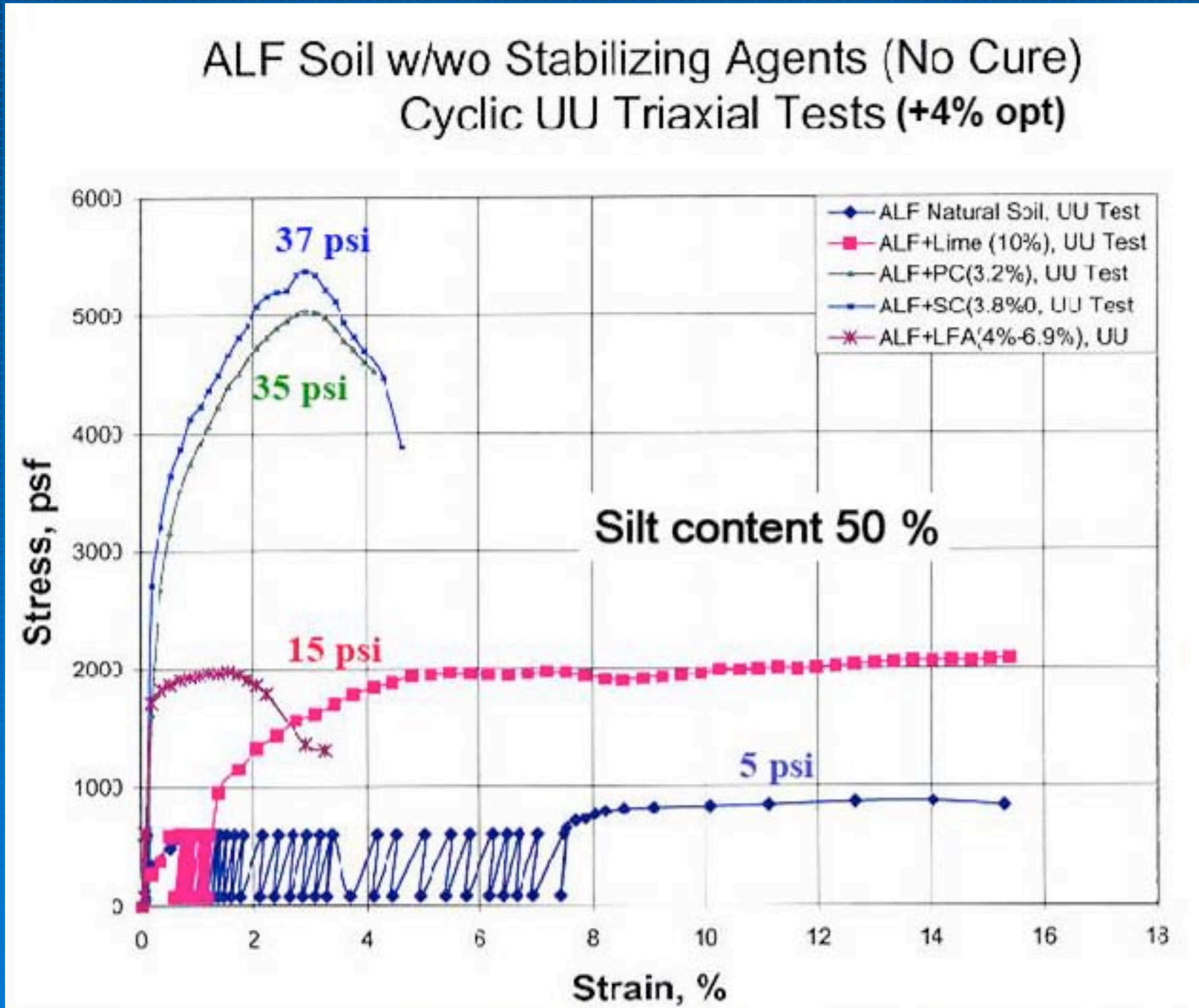
Portland International Airport 1974 Zurich, Switzerland, International Airport 1979

Bush Intercontinental Airport 1986

Adil Godiwalla

Stabilization Methods for Problematic Silt Soils





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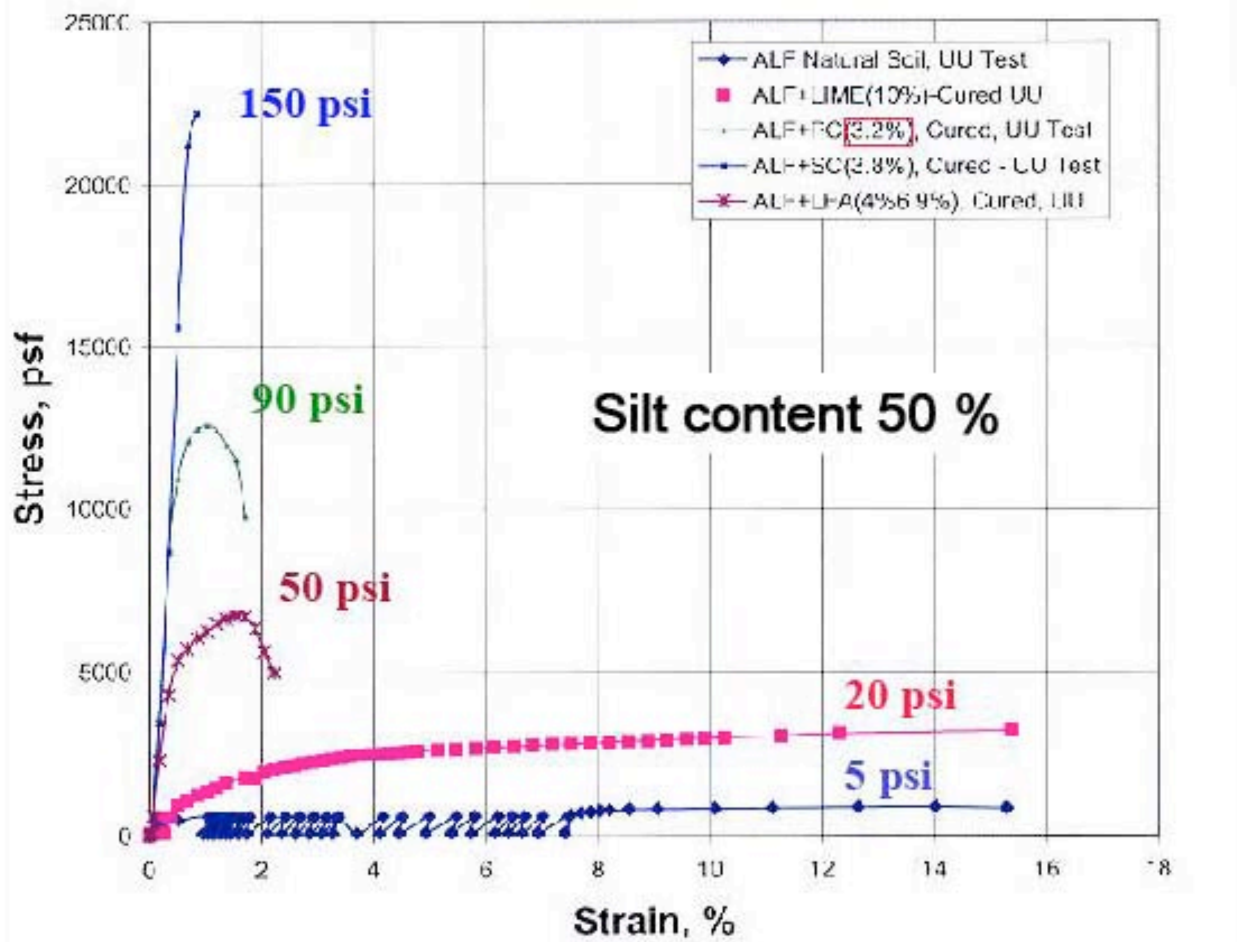
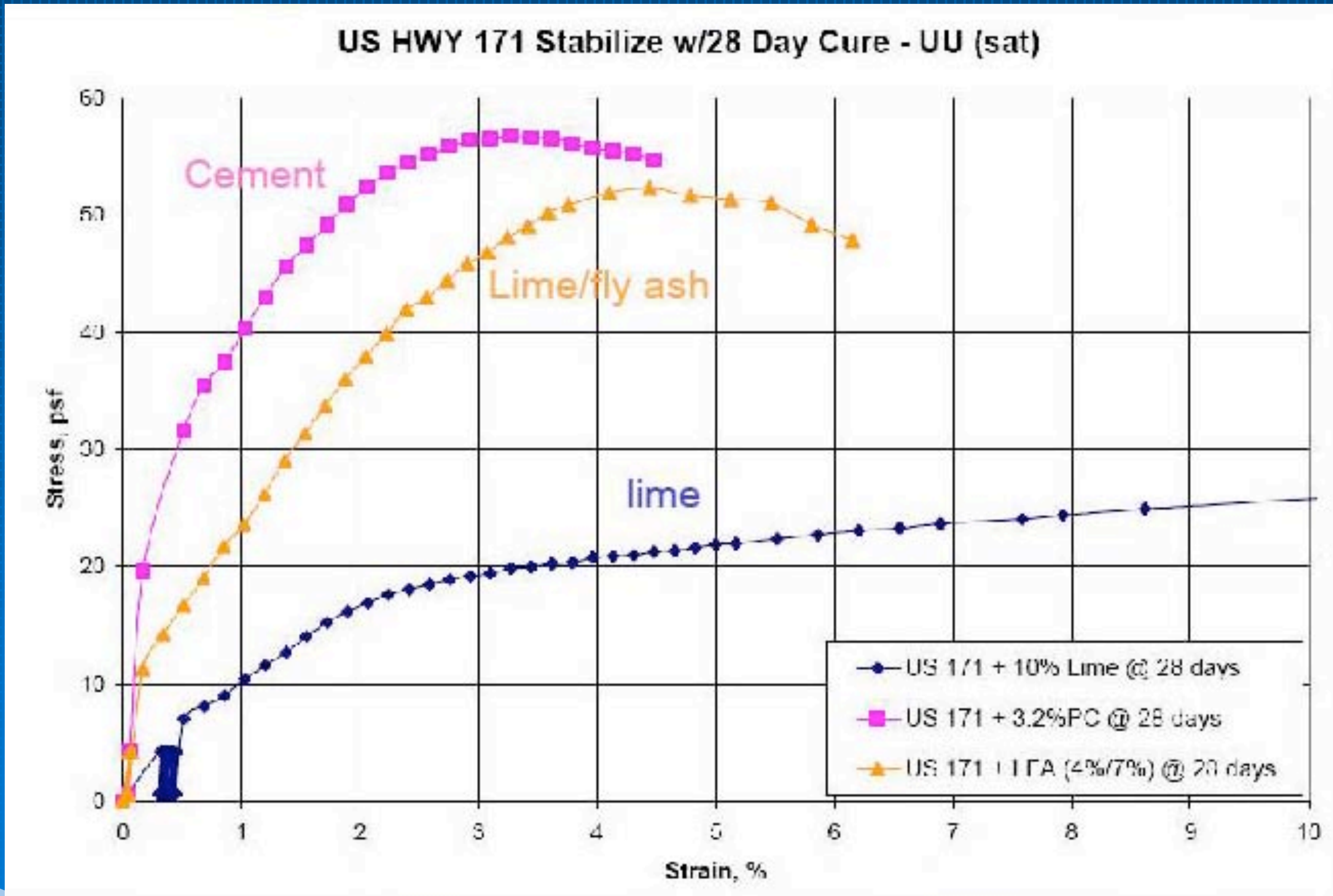
ALF Soil w/o Stabilizing Agents (28-Day Cure)
Cyclic UU Triaxial Tests (+4% opt)





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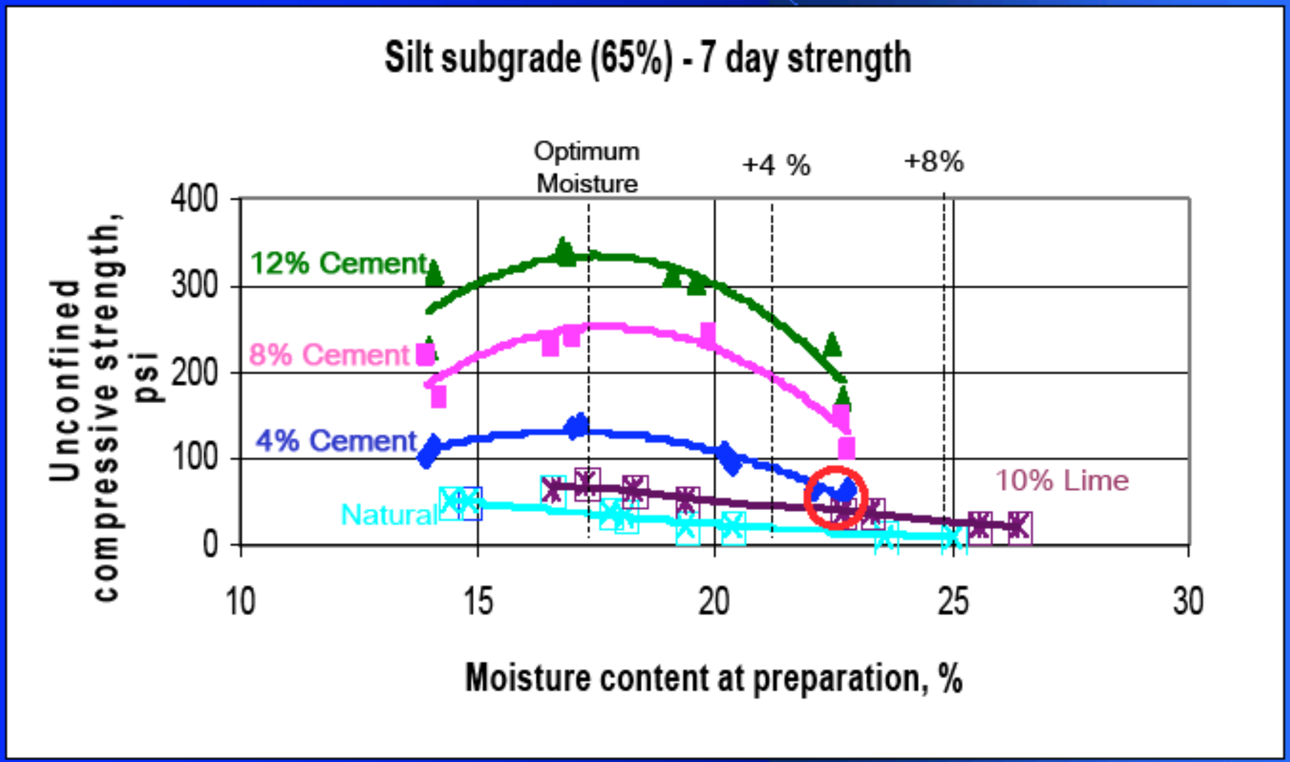
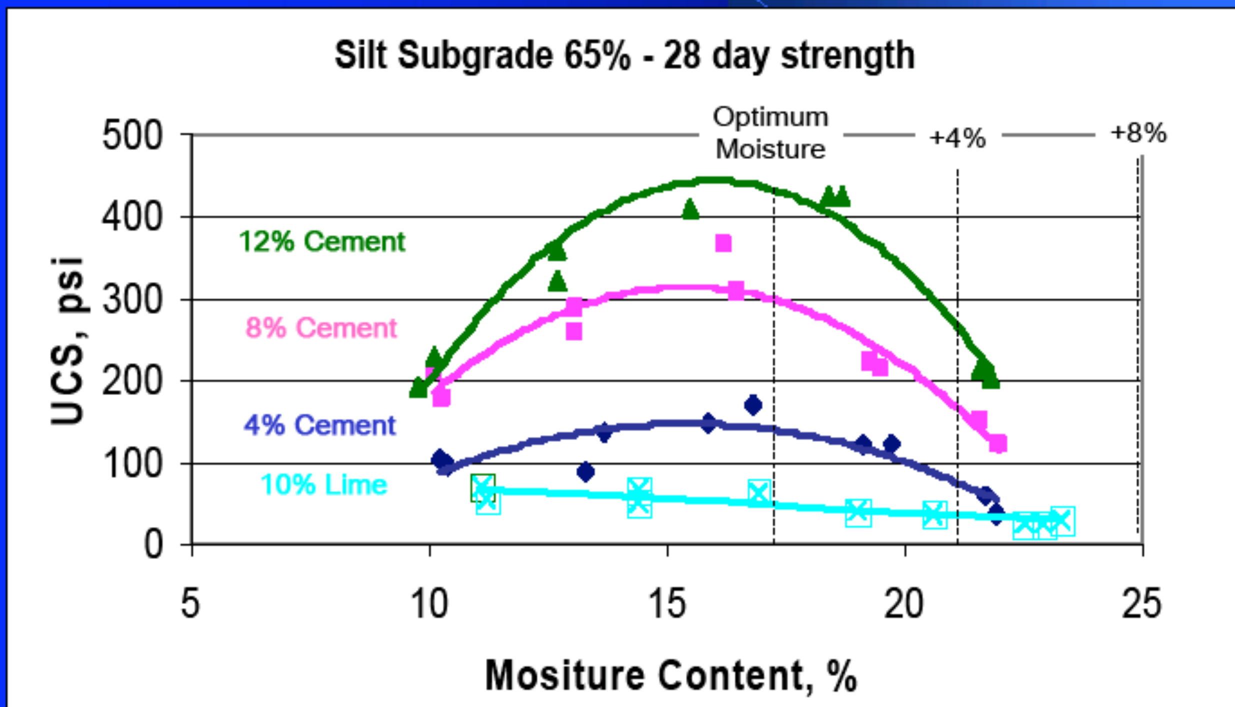
Subgrade Treatment vs. Subgrade Stabilization

- Subgrade Treatment
  - Construction Aid
  - Standardized Design
  - Quality not as important
  - Temporary Performance
  - Less costs
  - Faster to construct
- Subgrade Stabilization
  - Enhances pavement performance
  - Requires laboratory design
  - Construction Quality important
  - More expensive
  - May require more time to construct

High Silt Subgrades Laboratory Results



Laboratory Results
High Silt Soils



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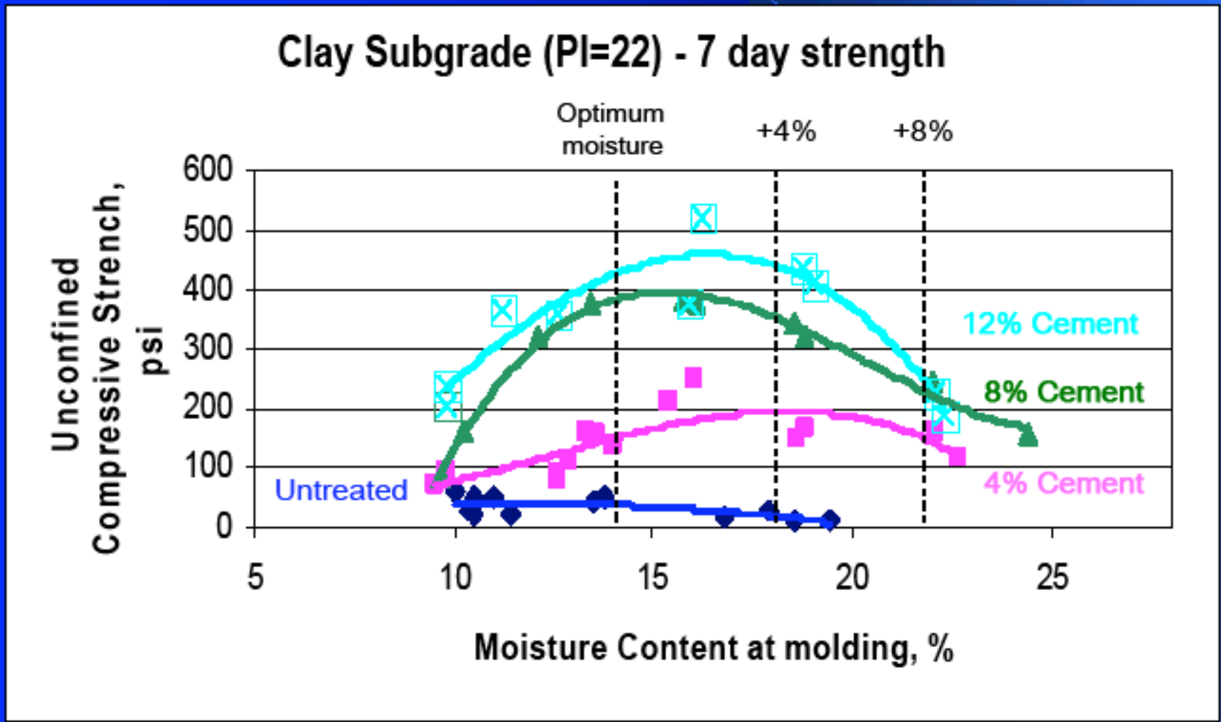
Silty Clay
Laboratory Results



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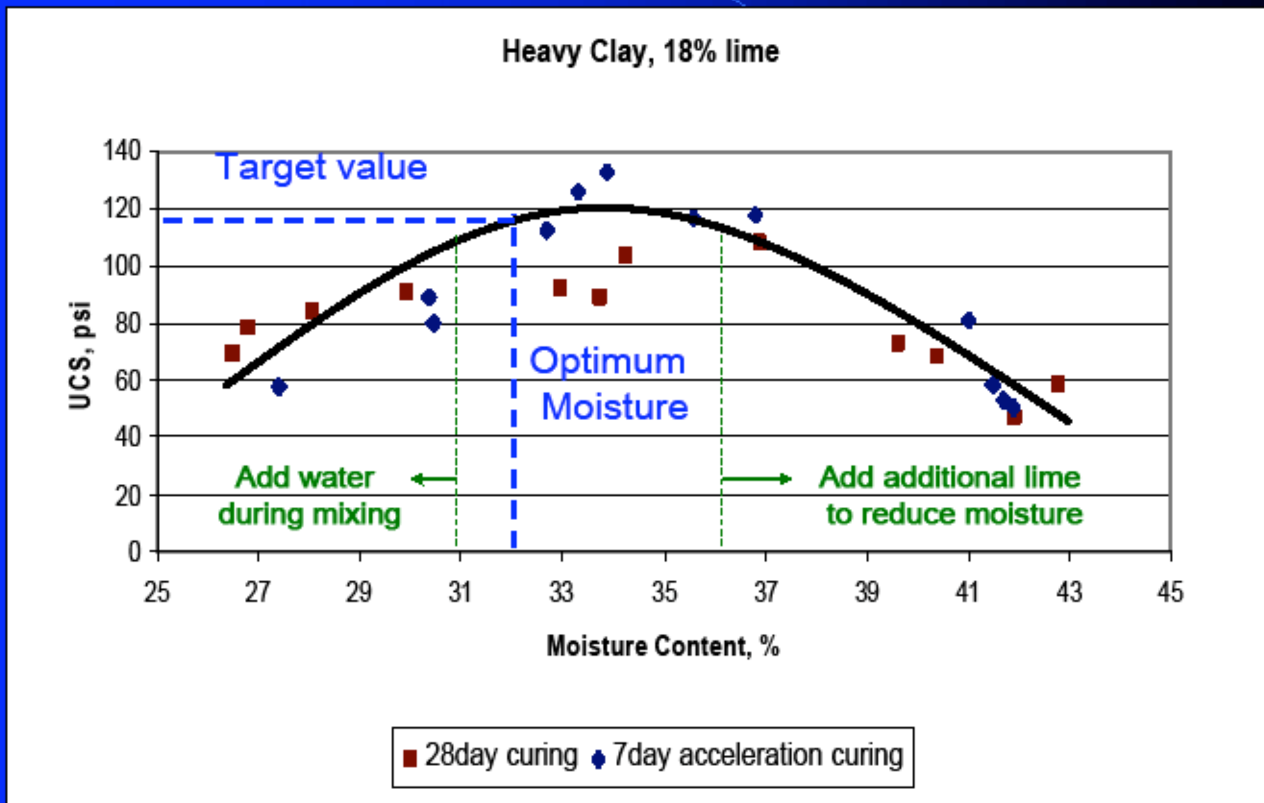
Lime Treated Heavy Clay Accelerated Cure vs Natural Cure



Heavy Clay Subgrade Lime Stabilization Preliminary Recommendations

- pH Test for full lime reaction
  - Eades & Grimes Test
- Unconfined compression test for minimum strength
  - Target value 100 psi – 125 psi
  - Minimum 50 psi increase from untreated
- Specifications for maximum performance
  - Mellowing period
  - Additional lime based on in situ moisture
  - Double application if necessary

REFERENCES

- LOUISIANA TRANSPORTATION RESEARCH CENTER
- FEDERAL AVIATION ADMINISTRATION
- HOUSTON AIRPORT SYSTEM (MASTER PLAN)
- AMERICAN CONCRETE PAVEMENT ASSOCIATION

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Thank You.
Questions and Comments