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Structural Benefit of Subgrade Stabilization in Kansas

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Overview
Chemical Subgrade Soil Stabilization

- Lime
- Cement
- Fly Ash
- Other

Purpose

- Control differential swell
- Increase load carrying capacity
- Facilitate construction, working platform
- Construct economical roadways

Structural Contribution

- Unconfined compressive strength
- Resilient modulus
- Triaxial modulus
- Layer coefficient

Specification, Ks 07-302 and 303

- Application
- Mixing
- Rotting period
- Moisture content
- Re-mix
- Gradation
- Compaction and moisture
- Evolving process since 1977

Research Efforts

- Develop Test Criteria for Evaluation
- Measure Strength and Durability
- Conduct Experiments
  - Laboratory
  - Field
  - ATL

Lime Durability Laboratory Study, 1996

- Lime at optimal percent for clay soil
- Different curing conditions to capture moisture affect on strength
- Measure resilient modulus over time to access durability

Laboratory Lime Durability Study, 1996

Conclusions
Resilient Modulus - Durability

- Laboratory strength values of raw soils degrade significantly when exposed to moisture.
- Laboratory strength values of lime stabilized soils remain the same under saturated conditions.
- Lime stabilization is not reversible over time.

Construction Features Evaluated in KSU-00-06

- Application, wet or dry
- Mixing
- Mellow period
- Moisture control
- Compaction
- Equipment
- Verification of quantity

Research Findings
Evaluation of Soil Modification Mixing Procedures
KSU-00-06

- Field mixed lime reduced P.I. and increased UCS.
- Two passes of mixer are minimum, additional passes yield additional strength.
- Results more uniform when slurry used.

Research Recommendations
Evaluation of Soil Modification Mixing Procedures
KSU-00-06

- Re-instate mellowing period, 24 to 48 hours, with moisture content 8% above optimum.
- Moisture content at compaction, optimum or above.
- Use lime/pH to determine lime application rate.
- Use gradation to control mixing efficiency.
  - Preliminary, 95% < 1 ½”, 40% < #4 sieve.
  - Final, 100% <1”.

Performance of Soil Stabilizing Agents

- Lime
- Fly Ash
- Cement
- Enzymatic

Research Findings
Performance of Soil Stabilization Agents
KU-02-02

- Agents
  - Lime
  - Fly Ash
  - Cement
  - Enzymatic
- Lime caused soils to become non-plastic, while cement and fly ash retained some PI.
- Mellowing of sulfate bearing soils reduced swell

Research Findings-Continued
Performance of Soil Stabilization Agents
KU-02-02

- Cement and lime retained strength after F/T and leaching better than fly ash
- Enzymatic stabilizer did not substantially improve soil performance.
- Swell potential is reduced.

Research Recommendations Performance of Soil Stabilization Agents KU-02-02

- Basis for selecting additive
  - Control shrink/swell
  - Strength gain
  - Durability due to F/T and leaching
- Use PI reduction with caution, not complete with cement or fly ash.
- Soil stabilization can contribute to pavement section.
- Environmental conditions should dictate wet/dry or freeze/thaw testing.

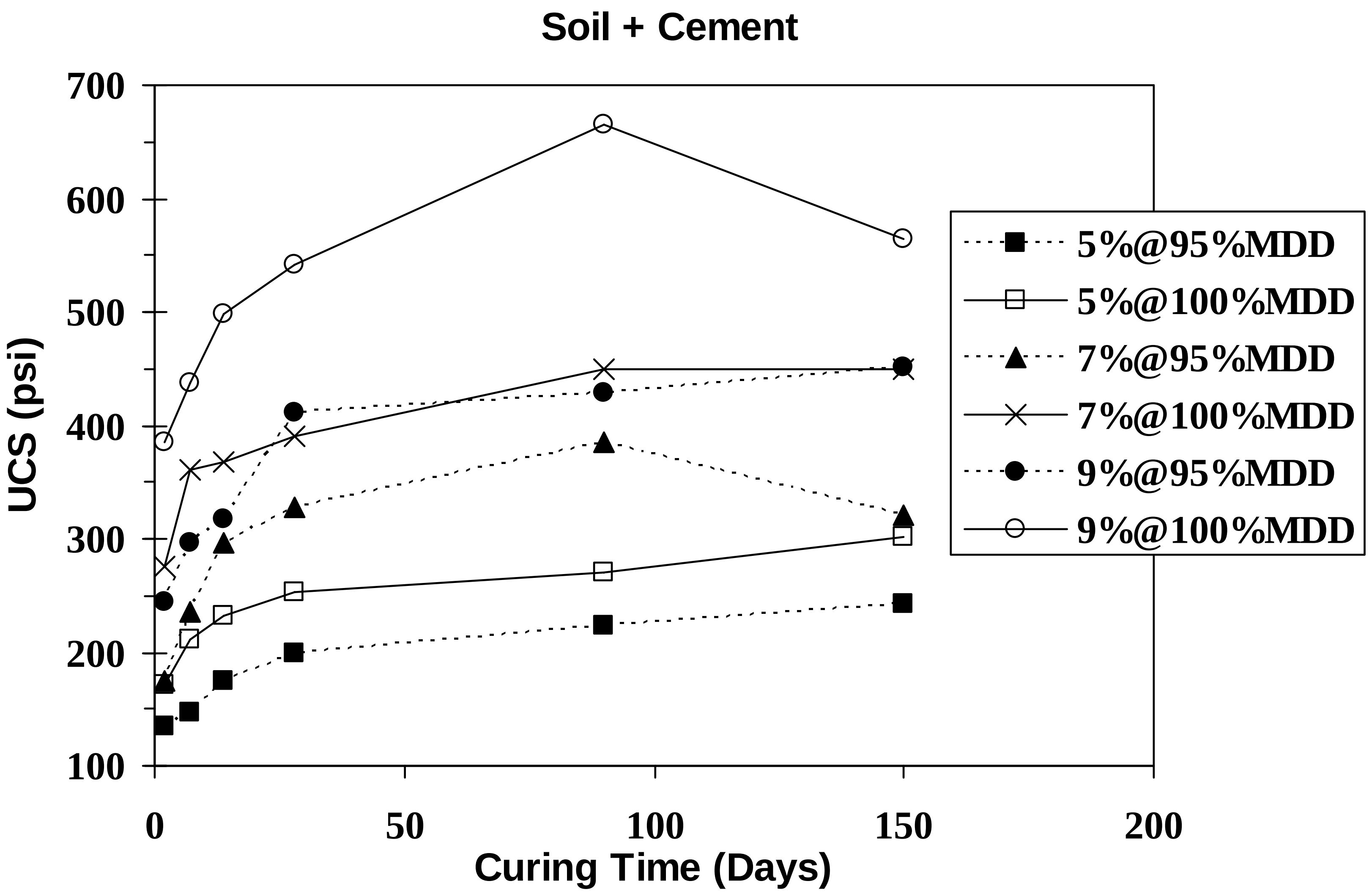
Accelerated Pavement Testing
Evaluation of Chemical Stabilized Soil
CISL #12

- Four Chemicals
  - Lime
  - Cement
  - Fly Ash
  - EMC- Square
- One Soil, moderately plastic clay.
- 3.5” HMA over 6” Stabilized Subgrade

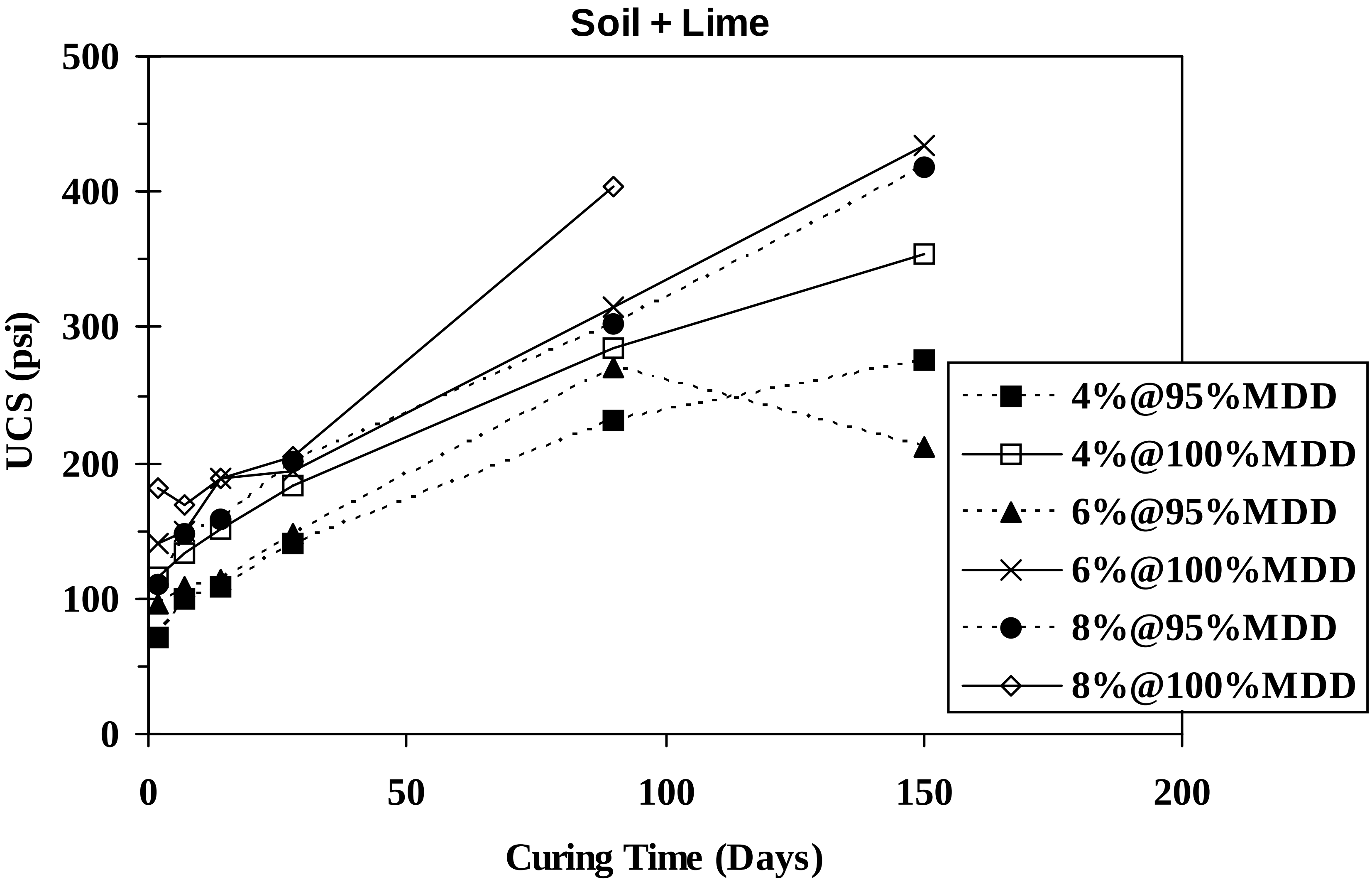
Accelerated Pavement Testing
Evaluation of Chemical Stabilized Soil
Results

- Lime most effective in reducing vertical compression at top of subgrade.
- Cement second most effective.
- Commercial stabilizer proved not effective.
- Chemical stabilizers are effective for improving engineering properties of soil.

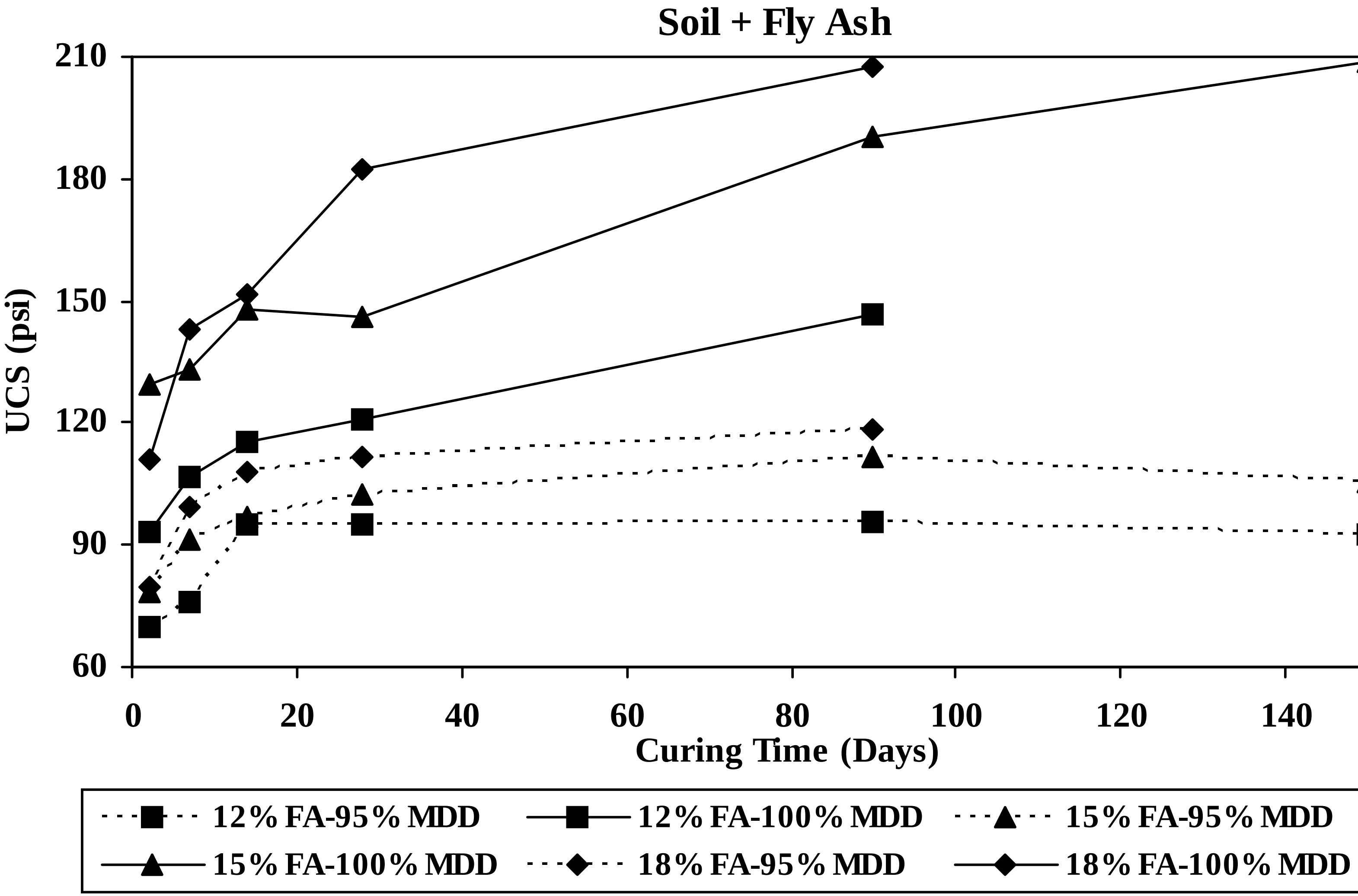
UCS Cement Stabilized Soil



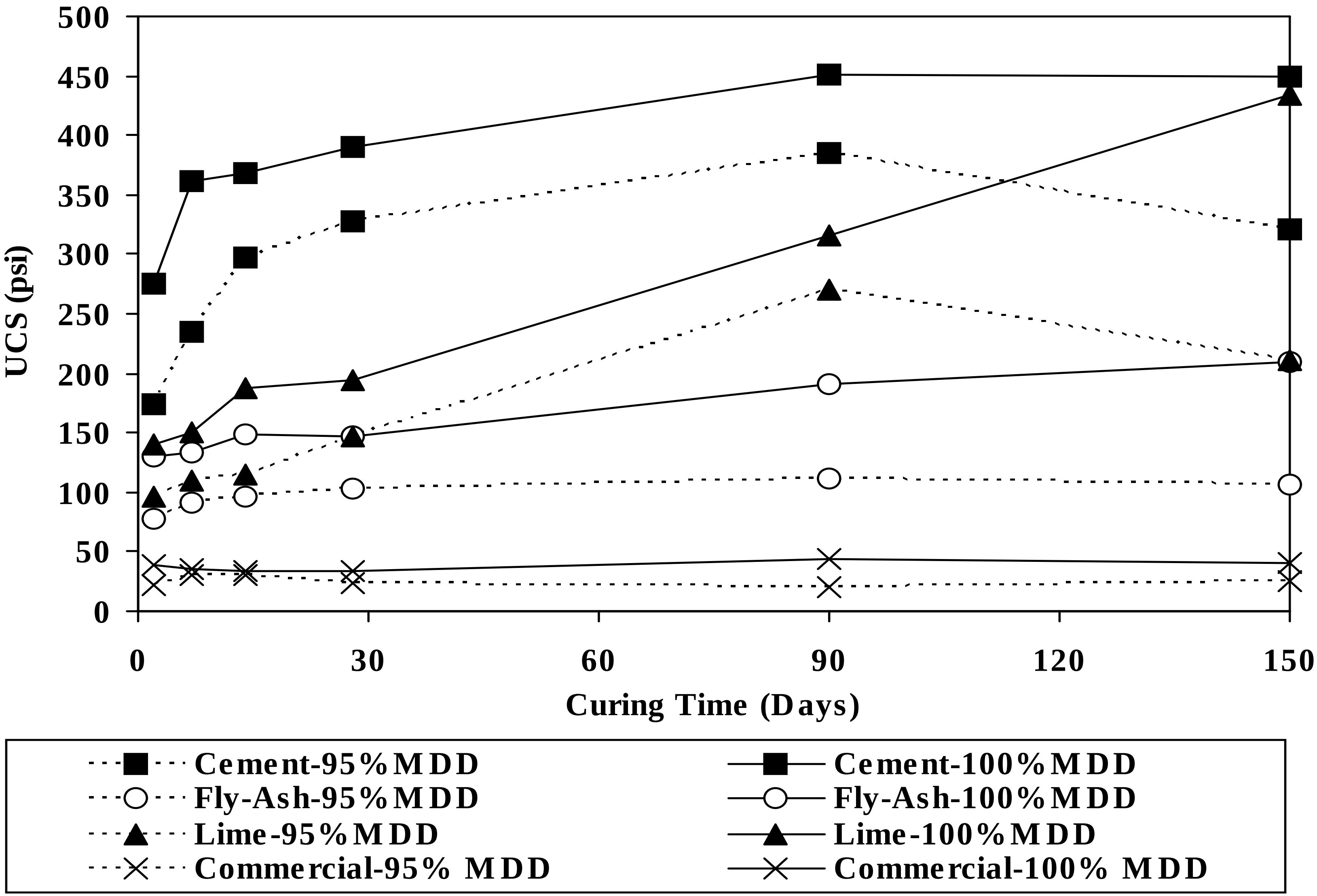
UCS Lime Stabilized Soil



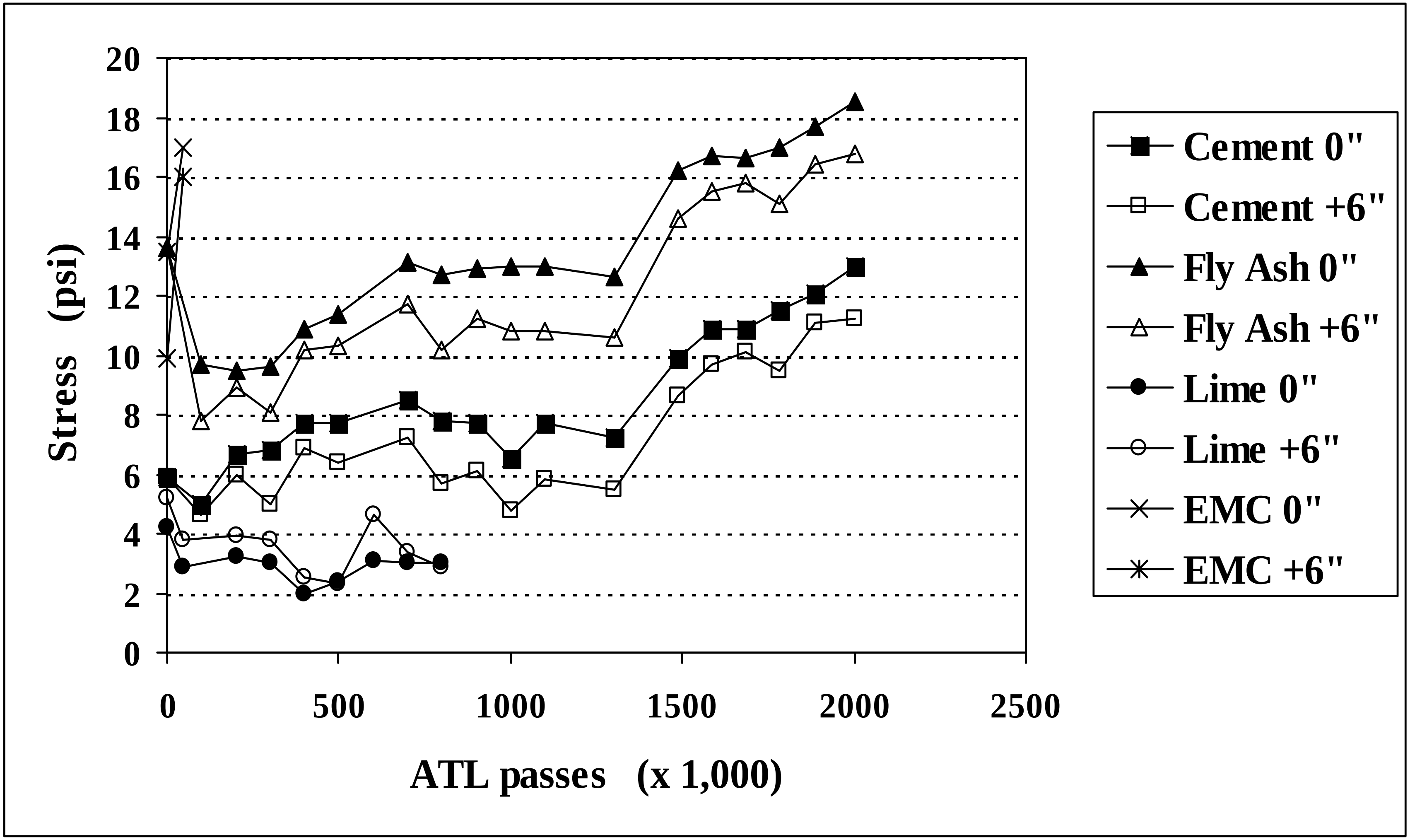
UCS Fly Ash Stabilized Soil



UCS at Optimum % Admixture



Vertical Stress at Top of Subgrade



FWD Backcalculated Moduli

Cement	HMA	Base	Subgr
Initial	538,608	35,327	13,657
Final	631,694	38,150	11,833

Fly Ash	HMA	Base	Subgr
Initial	328,894	31,444	11,636
Final	231,433	25,253	9,232

Lime	HMA	Base	Subgr
Initial	512,629	43,530	16,605
Final	445,741	44,235	13,700

EMC	HMA	Base	Subgr
Initial	171,470	38,269	7,507
Final	----	----	----

Economic Considerations of Soil Stabilization

- Stabilization increases cost
- Each feature of contract should be cost effective

Road Experiment, 1958
Cost Effectiveness, $/Sta

- Full Depth HMA
  - 2” Surface $110.35
  - 11” Base $524.91

  Total: $635.26

- PD HMA w/lime
  - 2” Surface $110.35
  - 6” Base $281.75
  - 6” LTSG $133.37

  Total: $525.48

Road Experiment, 1961, 1962
Cost Effectiveness, $/Sta

- Full Depth HMA
  - 10” HMA $483.98

  Total: $483.98

- PD HMA w/lime
  - 6” HMA
  - 6” LTSG

  Total: $411.72

Structural Equivalency
Kansas Triaxial Method

- Based on Palmer and Barber, Proceedings HRB Vol 20, 1940
- Published, “Design of Flexible Pavements Using The Triaxial Compression Test”, HRB Bulletin No. 8, 1947.
- $T = (Cp/Ct)^{0.33}$
- Cp for HMA is 20,000 psi
- Ct for LTSG is 3,000 psi
- Equivalency is 1.9 : 1.0 (2” lime for 1” HMA)

Current Practice, 1993 DARWin Layer Coefficients

■ Surface HMA-	0.40 – 0.44
■ Base HMA-	0.28 – 0.34
■ Aggregate base-	0.14
■ LTSG-	0.11

- Lime Equivalency is 2.5” : 1.0”

HMA/Stabilization Equivalency, Summary

	KS Triaxial	**FWD Moduli**	**Layer Coeff**
Surface	20,000	500,000	0.28
Base	3,000	35,000	0.11
Equiv	1.9	2.4	2.5

THE END

QUESTIONS?