"Shear Strength and Slope Stability"

Slide Show Presentation by Dr. Bob Gilbert, University of Texas at Austin,

Geosynthetic Clay Liner University, September 30, 2008

RCRA Subtitle D for Municipal Solid Waste Landfills

- Minimum Standards Set for States
- Slope Stability Addressed in Criteria for Siting
  - Avoid Unstable Areas
  - Demonstrate Stability in Seismic Impact Zones and Fault Areas

History

1978 — Love Canal Hits News

1982 — Engineered Containment Systems Required for RCRA Subtitle C Landfills

1986 — Kettleman Hills Slope Failure

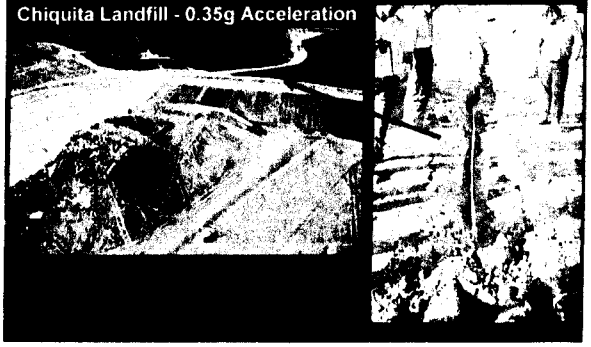
1990 — RCRA Subtitle D Promulgated

1994 — Northridge Earthquake

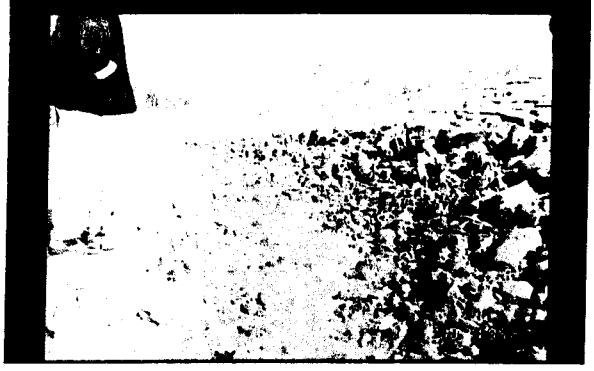
1998

Northridge Earthquake (1994)

Chiquita Landfill - 0.35g Acceleration



Cover Slope Failures

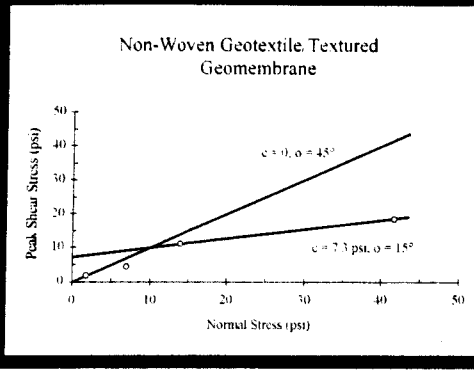


Cover Slope Failures

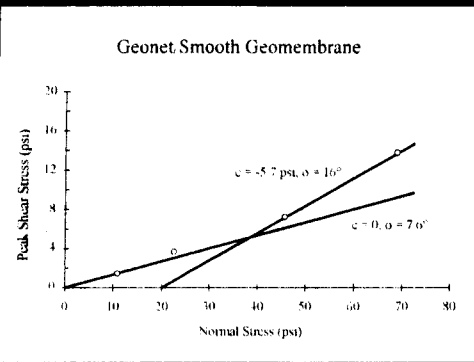
Cover Slope Failure Lessons

- A very common problem that is frequently not reported
- Seemingly small fluid pressures (water and gas) can have a LARGE effect
- Shear strengths measured at high normal stresses are not necessarily relevant at low normal stresses
- Can require long-term maintenance activities

Non-Linear Failure Envelopes



Non-Linear Failure Envelopes



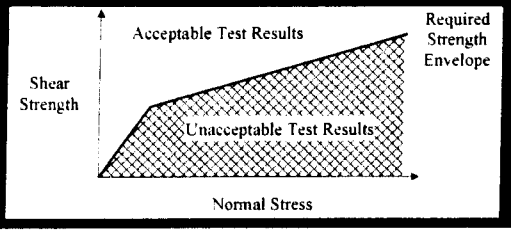
Comments on c and ϕ

$$\tau_f = c + \sigma_n \tan(\phi)$$

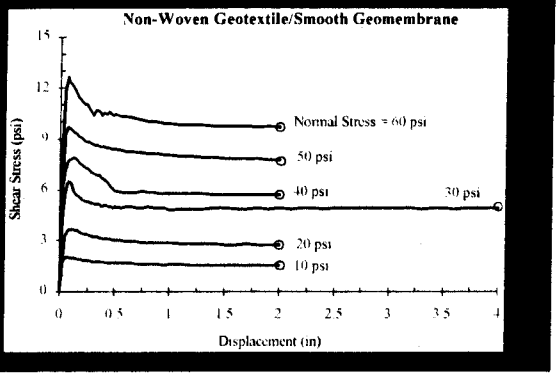
- c and tan(ϕ) are linear regression coefficients
- Envelopes are non-linear, so c and ϕ are different for different ranges of normal stress
- Be VERY careful specifying allowable c and ϕ values

Specifying Allowable c and ϕ

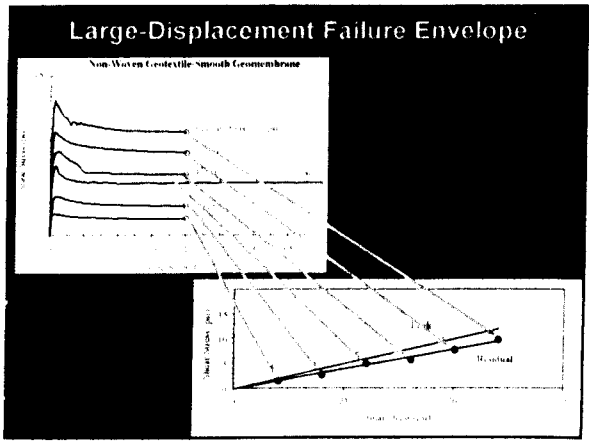
1. **Strength is a COMBINATION of c and ϕ, so specify allowable combinations of c and ϕ**
2. **c and ϕ depend on the range of normal stresses**



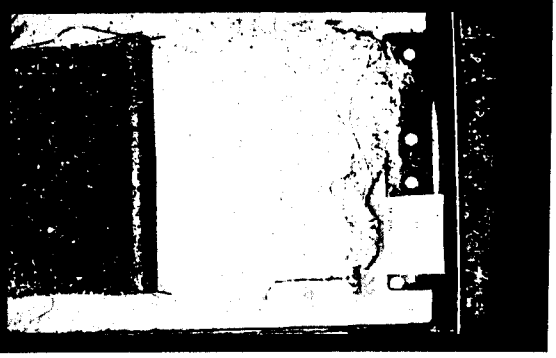
Large-Displacement Failure Envelope



Large-Displacement Failure Envelope



Reinforced GCL

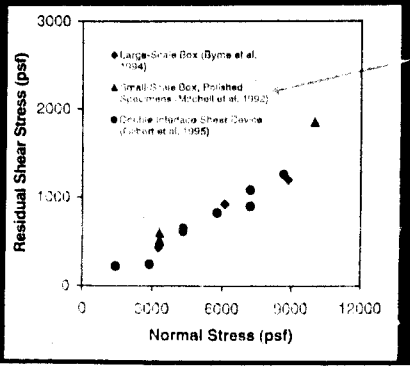


Post-Peak Reductions in Shear Strength

- Post-peak reductions in strength with displacement are common for geosynthetic interfaces
- Several inches of displacement in the laboratory is significant
- Several inches of displacement in the field is insignificant and commonplace
- The Kettleman Hills Landfill would not have failed when it did if peak strengths had been available along the entire interface

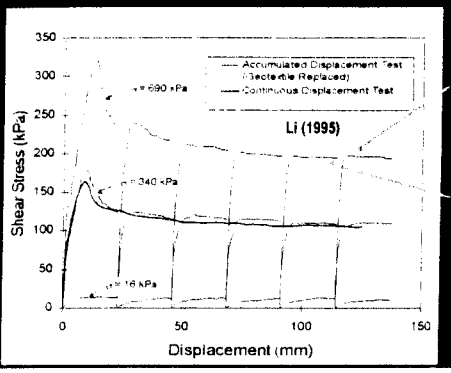
Estimating Residual Strengths

Nonwoven Geotextile/Smooth HDPE



Estimating Residual Strengths

Nonwoven Geotextile/Textured HDPE

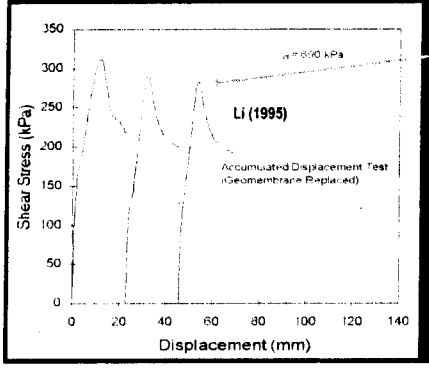


Small-Scale Direct Shear Box

Reduction due to Surface Polishing

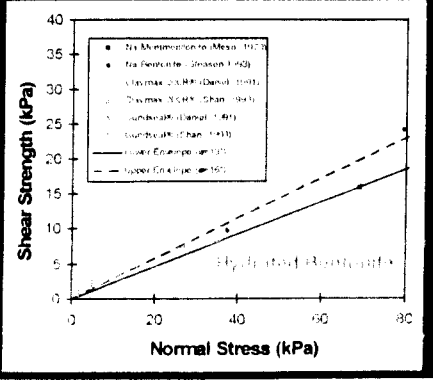
Estimating Residual Strengths

Nonwoven Geotextile/Textured HDPE



Reduction due to Geotextile Failure

Lower-Bound Shear Strength for GCLs



PIERCE CHANDLER

Geosynthetic Clay Liner University

You and your associates are invited to attend an educational opportunity sponsored by

CETCO®

GCLU Date and Location:

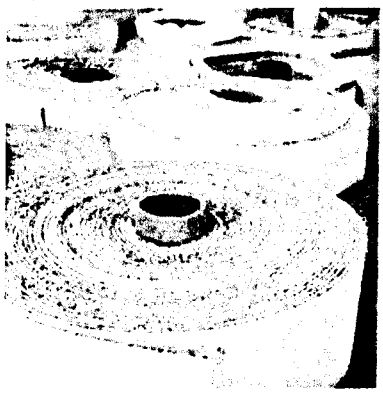
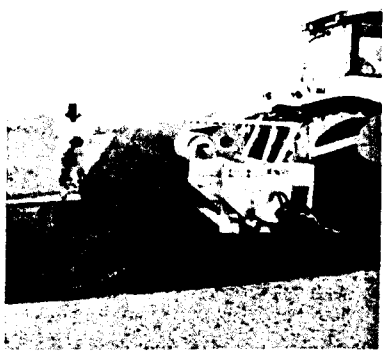
Tuesday, September 30, 2008
9am-5pm
Houston Marriott North at Greenspoint
225 N Sam Houston Parkway East
Houston, TX 77060
(lunch will be served)

This seminar will teach basic methodologies for the practical inclusion of "GCLs-geosynthetic clay liners" in the design of landfill cells and caps, liquid containment, and general use as a hydraulic barrier in municipal and industrial applications.

Geosynthetic Clay Liner University (GCLU) is a comprehensive training course with a cirriculum intended for design professionals including civil and geotechnical engineers and regulatory personnel. Practical applications and basic engineering principles will be our focus. The seminar will present real world design examples which include case studies on both successes and failures.

GCL topics that will be covered include: Hydraulic Properties, Certified Properties and Test Methods, Shear Strength and Slope Stability Design Considerations, and GCL Installation and Chemical Compatibility.

Geosynthetic Clay Liner University


2008 Curriculum
Houston, TX

9:00 - 9:30 **Introduction (Rod Kirch)**
- Introduction and Overview of CETCO
- Bentonite basics
- GCL definition and our product line

9:30 - 10:45 **Hydraulic Properties (Chris Athanassopoulos)**
- Darcy's Law
- Permeability, flux, and application of these values for design purposes
- Hydraulic equivalency with clay liners and composite systems
- Water balance models (HELP)
- Seam performance
- Contaminant transport
- Water containment with GCLs

10:45 - 11:00 **Break**

11:00 - 12:00 **Chemical Compatibility (Jim Olsta)**
- Bentonite structure, hydration, and swelling
- Contaminant effects
- Compatibility tests
- Lab and field research related to landfill bottom liners and caps

12:00 - 1:00 **Lunch**

1:00 - 3:00 **Shear Strength and Slope Stability (Dr. Bob Gilbert- University of Texas)**
- Shear testing methods
- Specimen preparation and test conditions
- Data interpretation
- Methods of stability analysis
- GCL internal shear strength
- Interface shear strength
- Peak vs residual, definition and application

3:00 - 3:15 **Break**

3:15-4:30 **Certified Properties and Test Methods (John Allen- TRI)**
- Physical properties
- Hydraulic properties
- Direct shear strength
- GCL specification issues and guidelines
- MQC methods and practices

4:30 - 5:00 **GCL Installation (Jim Olsta)**
- Standard recommended practices
- Construction survivability
- Panel Separation