Emergence of Intelligent Compaction in U.S. Practice

Start: August 2005 End: February 2006

Report Available: February 2007

- Student: Michael McGuire
- Supervisors: George Filz and Tom Brandon
- Sponsors: Virginia Tech CGPR

Objective: Compile and summarize comprehensive reference materials on intelligent compaction and continuous compaction control.

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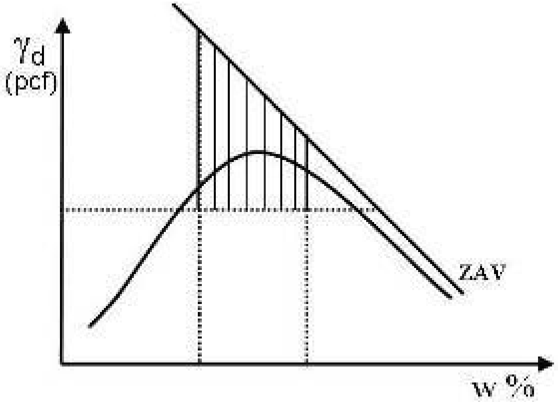
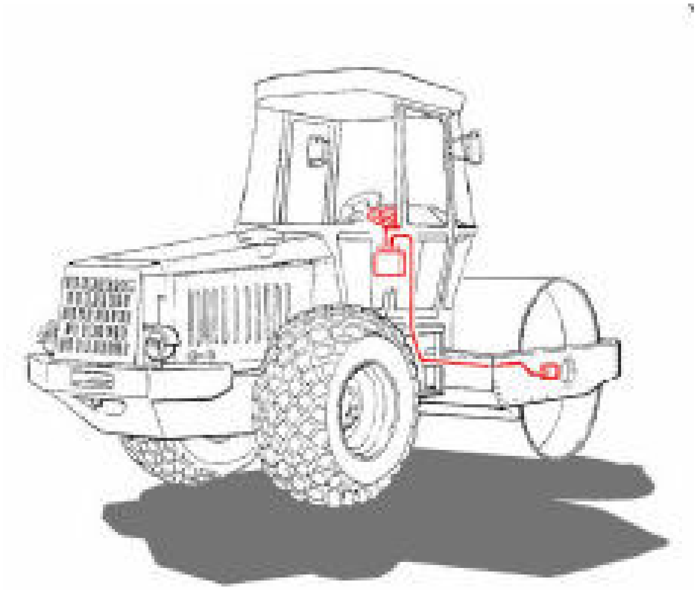
Problems With Traditional Method of Assessing Compaction Quality



- Very low testing frequency
- Even with high testing frequency, only very small percentage of total compacted volume tested
- Sampling bias

- Inspection budgets strained under rising labor and benefits costs.
- Many experienced inspectors are retiring.
- Visual inspection of compaction is often undervalued.

IC/CCC Technology



www.geodynamik.com

Continuous Compaction Control (CCC): compactor integrated technology that collects data in real time over the entire compacted area regarding the state of soil compaction.

Intelligent Compaction (IC): refers to the capability of a compactor to automatically adjust its operation based on data from the CCC system.

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Overview of IC/CCC Technology

- Depending on the system, compactor-derived compaction measurements can be:
  - Unit less values that reflect the stiffness of the compacted material in a relative sense.
  - Calculated values of the actual stiffness or modulus of the compacted material (sands and gravels only).

- CCC output values can be correlated to other soil parameter values (e.g. density for a particular water content) or be used directly for acceptance.

- CCC output values are stored along with GPS coordinates in on-board *Compaction Documentation Systems (CDS)* to create a permanent record of the compaction process.

Using IC/CCC Technology for Assessment of Compaction

A contractor QC program can benefit from IC/CCC technology.

- Continuous and instantaneous measurements of compaction over the entire roller pattern provides documentation of compaction and eliminates unnecessary roller passes.
- Correlation with traditional field tests increases the effectiveness of infrequent spot-testing.
- Statistical analysis (min, max, mean, std. dev.) of CCC output values can evaluate the uniformity of the compacted area and identify localized soft/weak zones.
- IC equipment adjusts the compactor operation to maximize compaction efficiency to reduce the number of roller passes, prevent aggregate crushing, and increase equipment life .

Probabilistic Procedures for Post-Liquefaction Stability Analysis of Embankment Dams and Foundations

Start: April 2004 End: February 2007

- Student: Morgan Eddy
- Supervisor: Dr. Marte Gutierrez
- Sponsors: USBR

<u>Objectives</u>

- Re-evaluate and expand available databases
- Develop reliability-based back-analysis procedures
- Produce probabilistic liquefied shear strength criteria
- Demonstrate new procedures within USBR seismic risk scheme

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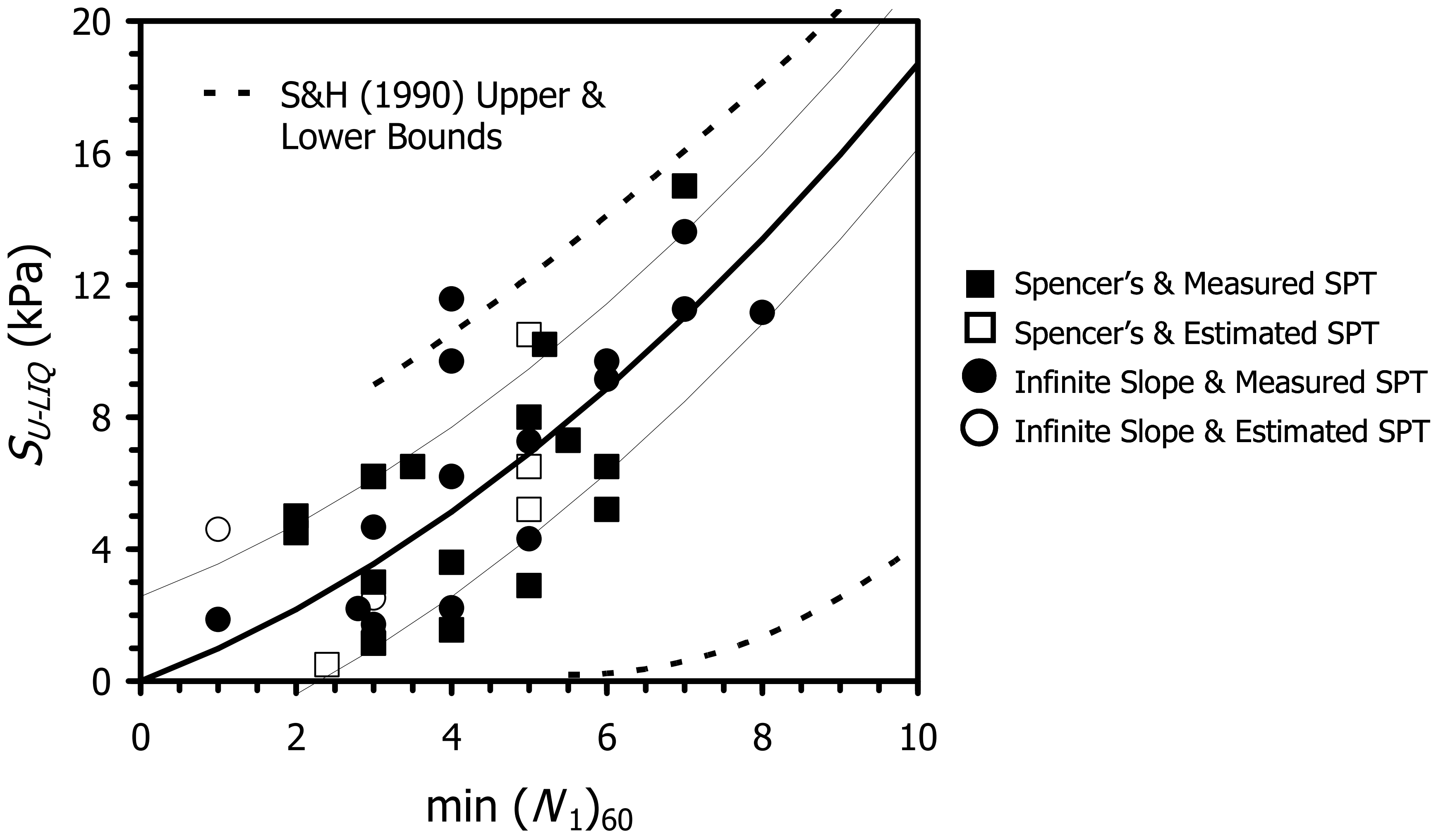
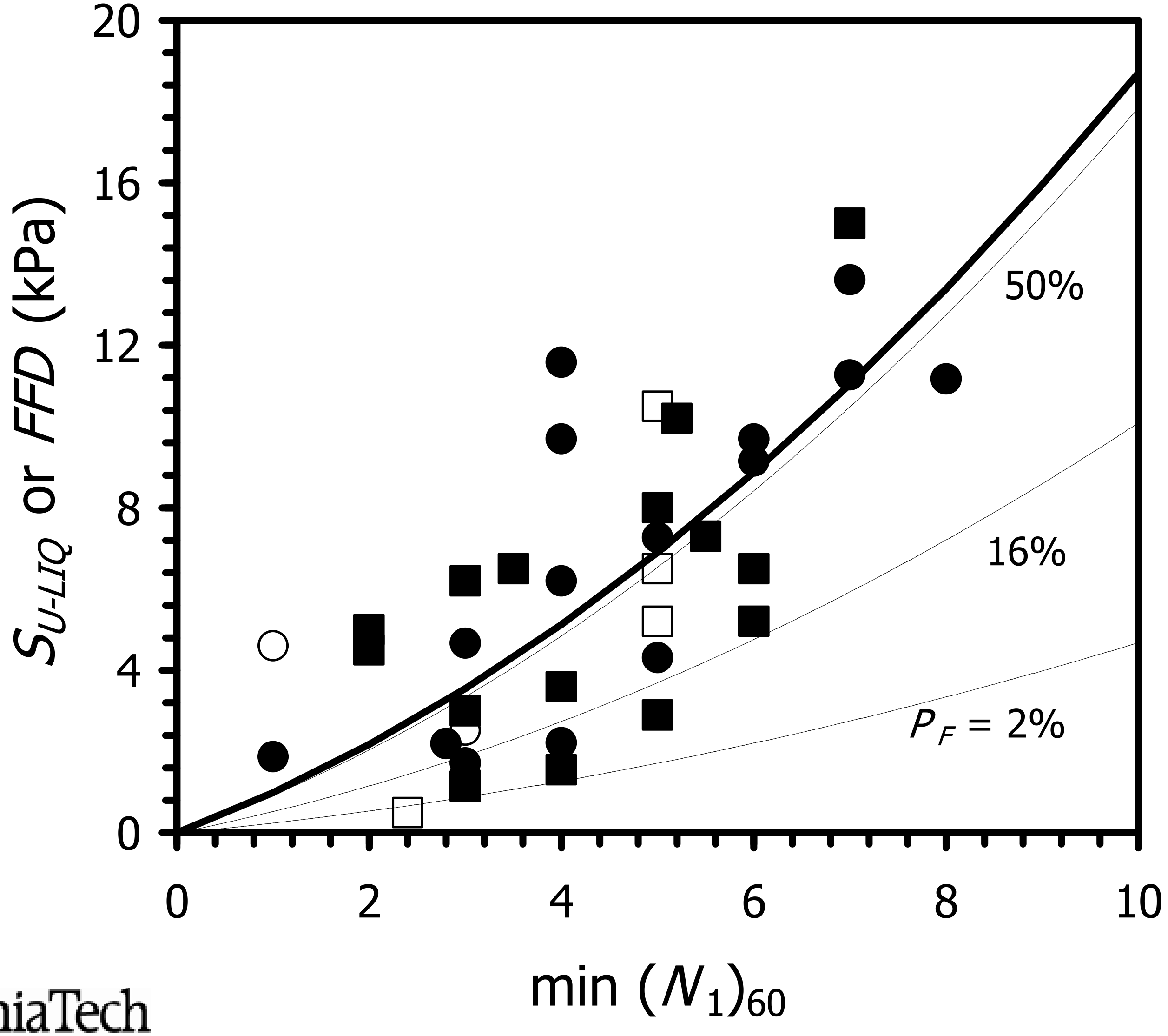
(a)
(b)
(c)
N
(d)

Liquefied Shear Strength Relationship



Probabilistic Criteria



Conclusions

- Additional cases from recent earthquakes have been added to the existing database of failures
- Monte Carlo Simulations and the First-Order Reliability Method are used to analyze the failures
- Simplified charts have been developed using Bayesian Mapping to provide relations between SPT blowcount, liquefied shear strength (or *FFD*), and probability of failure

SOIL AND SITE CHARACTERIZATION USING ELECTROMAGNETIC WAVES

Start: November 2004 End: May 2007

- Student: Ning Liu
- Supervisor: James K. Mitchell
- Sponsor: Charles Edward Via. Fellowship

  NSF IGERT Program

Objectives – use electromagnetic waves to evaluate:

- Water content, specific surface area, pore water chemistry
- Strength, compressibility, hydraulic conductivity

Soil Components and Structure

Theoretical equations and empirical correlations

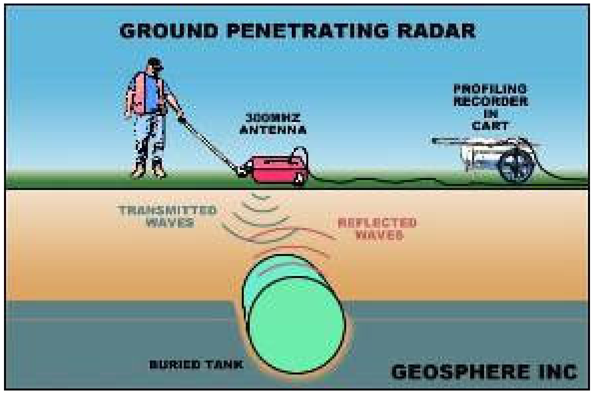
Soil Engineering Properties

- Strength
- Fluid flow properties
- Stress-deformation properties

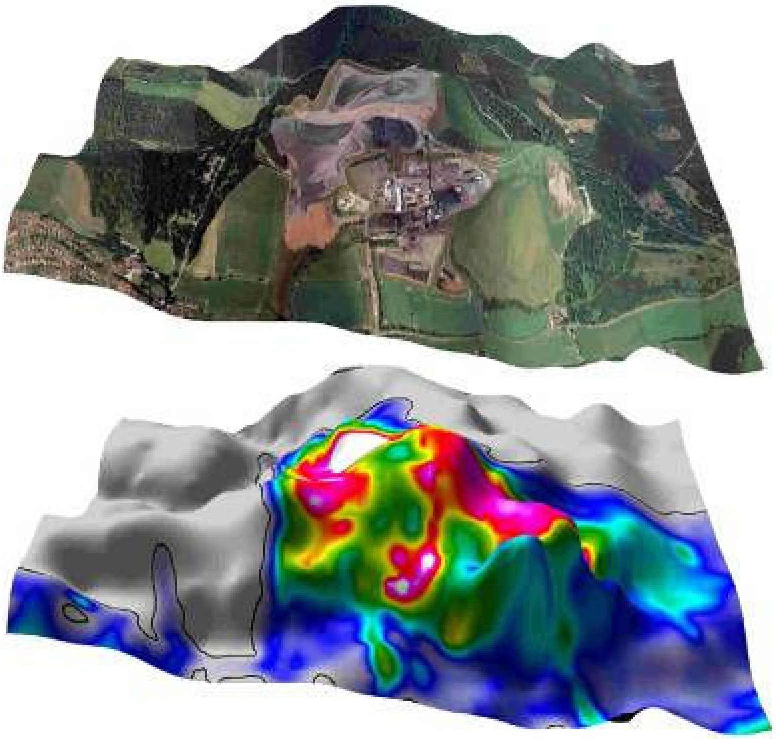
?

Soil Electromagnetic Properties

- Non-destructive
- Suitable for remote sensing
- Suitable for automation



Ground Penetration Radar



Air-borne electromagnetic survey

Electromagnetic Measurements - From Theory to Practice

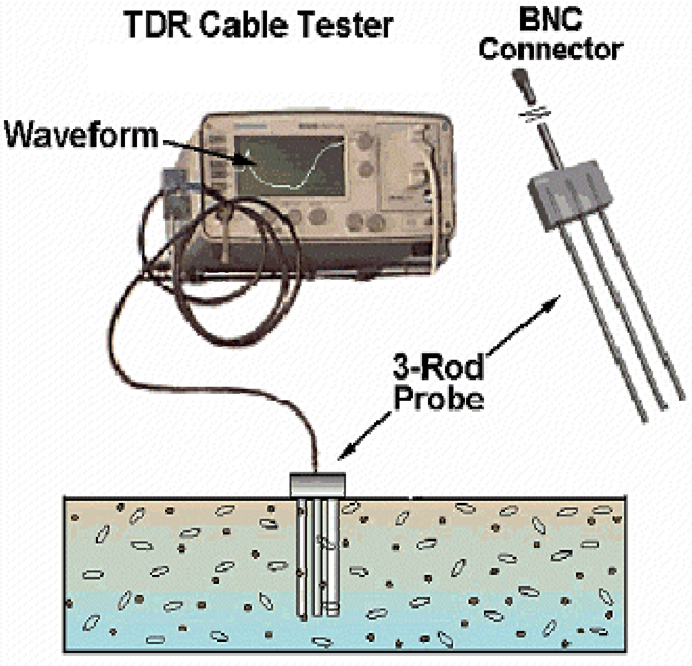
- A model to relate the EM property of a soil to:
  - Porosity, clay percentage, clay mineralogy, anisotropy, flocculation
  - Pore fluid chemistry, temperature

- A simple method to determine:
  - Volumetric water content
  - Total specific surface area
  - Pore fluid salt concentration

- An economical and convenient tool for in-situ EM property measurements
  - Time domain reflectometry (TDR)

- Relationships between soil EM properties and Engineering properties :
  - Residual shear strength
  - Compressibility
  - Hydraulic conductivity

A method to determine total specific surface area and water content from dielectric spectrum

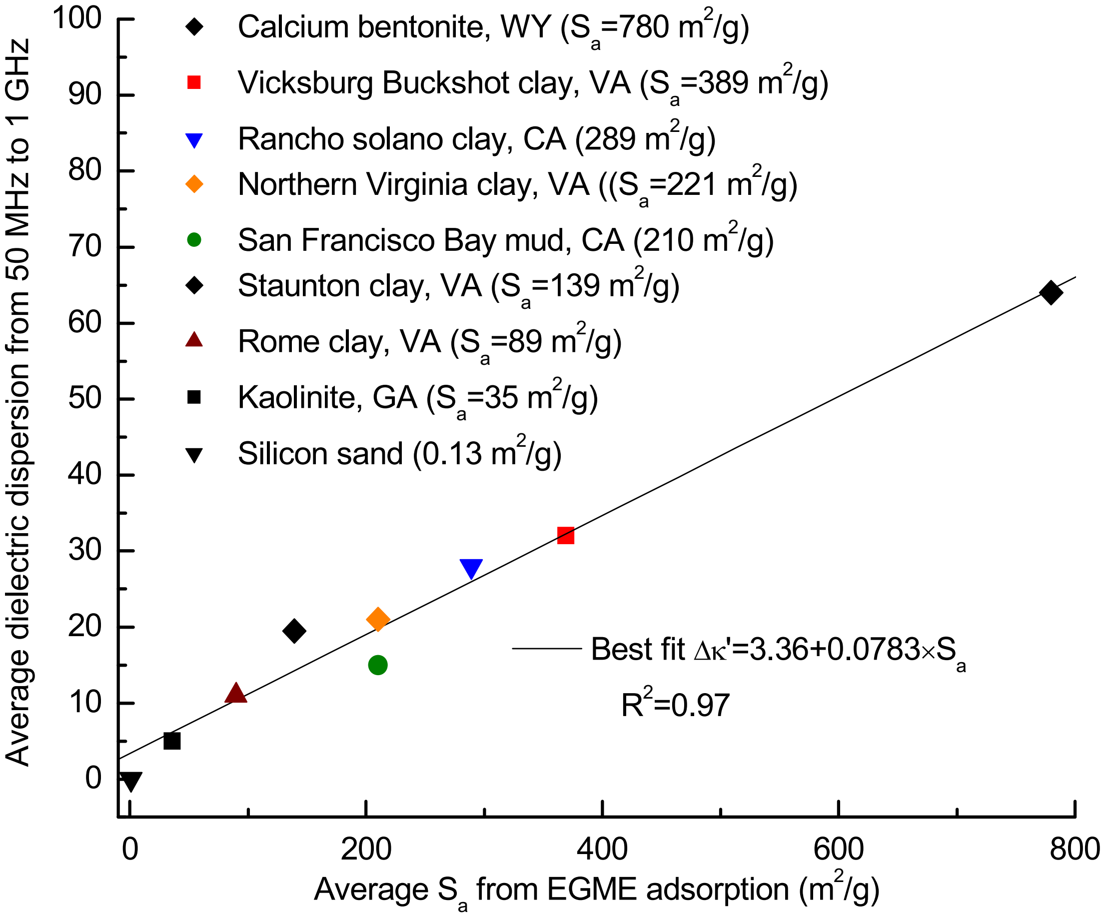


TDR100 System:

Cost: $3.6 K

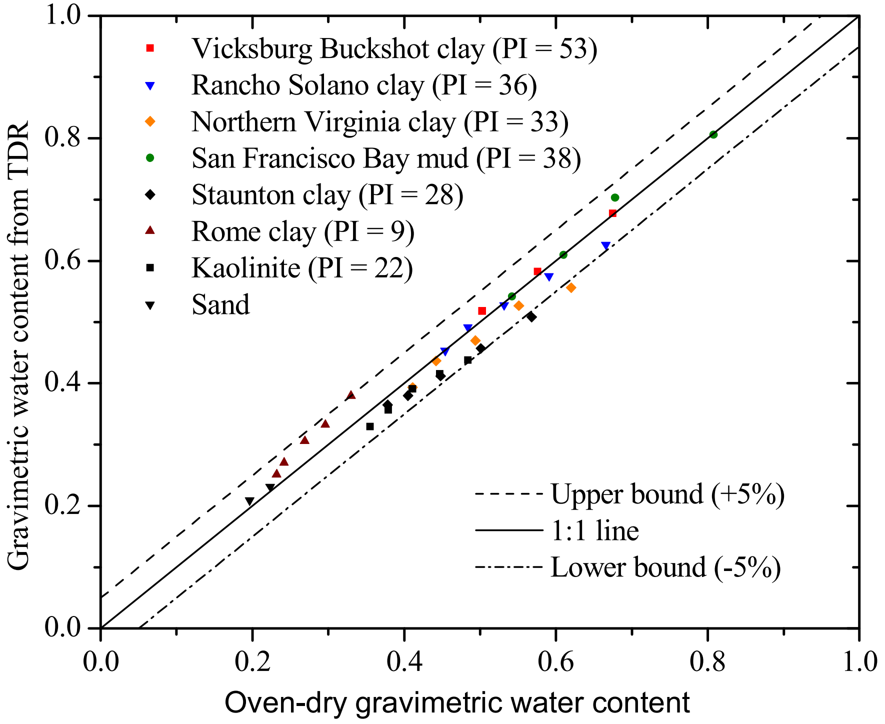
Weight: 2 Pounds

Power: Rechargeable battery

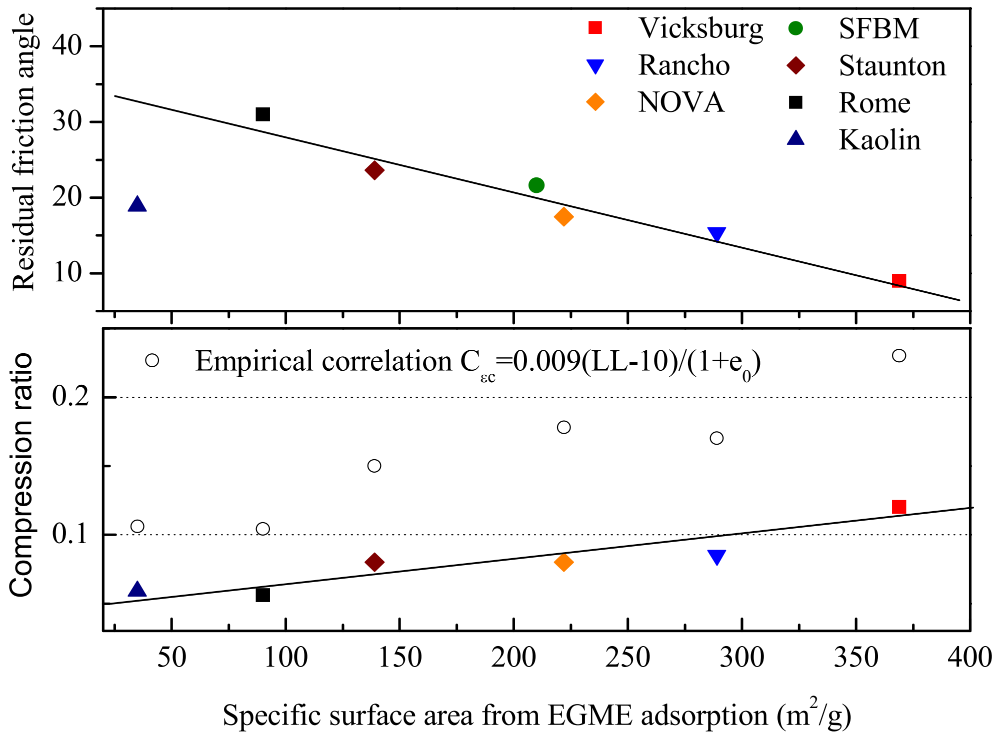


EM Property Measurement – Specific Surface Area, water content – Engineering Properties

Water content determination



Residual shear strength and compressibility



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Rapid Stabilization of Soft Clay Soils

Start: March 2003 End: May 2009

- Students: Susan Rafalko & Liselle Vega
- Supervisors: Thomas L. Brandon, George M. Filz, & James K. Mitchell
- Sponsors: Air Force Research Laboratory

<u>Purpose</u> – To increase the strength of a soft clay soil (CBR = 2) to support C-17s & C-130s within 72 hours

C-17: Globemaster III (Photo from AFCESA/CES "ETL 97-9")

Objectives

- Evaluate effectiveness of stabilizers using:
  - UCS tests
  - Toughness
- Evaluate dosage rates using:
  - UCS tests
  - CBR tests
- Develop guidance for pavement design

Stabilizers Tested

- Single Treatment
  - Portland cement
    - Type I/II
    - Type III
  - Quicklime
  - Microfine cement
  - Calcium carbide
  - Sodium silicate
  - Fibers
    - Fibrillated polypropylene
    - Nylon
    - Poly(vinyl) alcohol

- Combination Treatments
  - Fibers
    - Type I/II cement
    - Type III cement
    - Calcium carbide
  - Sodium silicate
    - Quicklime
    - Calcium carbide
  - Super absorbent polymers & calcium carbide
  - Accelerators & Type III cement
  - Superplasticizers
    - Microfine cement
    - Type III cement

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Key Findings: Laboratory Testing

- Stabilizer effectiveness
  - –Traditional stabilizers were most effective
  - –Calcium carbide performed similar to quicklime
  - –Other stabilizers were relatively ineffective
  - –Fibers increased toughness
  - –Fiber shape influenced strength
- CBR vs. UCS correlation
  - –Approximate linear relationship
  - –Relationship not dependent on treatment type

Key Findings: Pavement Design

- Layer strength
  - –Base layer: minimum CBR value of 80
    - •Achieved with 3% pelletized quicklime, 11% Type III cement, & 1% PVA fibers
  - –Subbase layer: up to a CBR value of 30
    - •Achieved with 2% to 4% pelletized quicklime
- Layer thickness
  - –Base layer: minimum of 6 inches
  - –Subbase layer: between 0 to 65 inches

Levee Underseepage, Filter Design and Installation, and Seepage Monitoring

Start: January 2006 End: August 2007

- Student: Matthew Sleep, Chris Meehan, Emily Navin
- Supervisor: Dr. J. Michael Duncan
- Sponsor: U. S. Army Corps of Engineers

<u>Objectives</u>

- Update Corps EM 1110-2-1913 Design and Construction of Levees
- Update CGPR Filter Design Workbook and filter installation guidelines
- Develop draft seepage monitoring guidelines for FEMA

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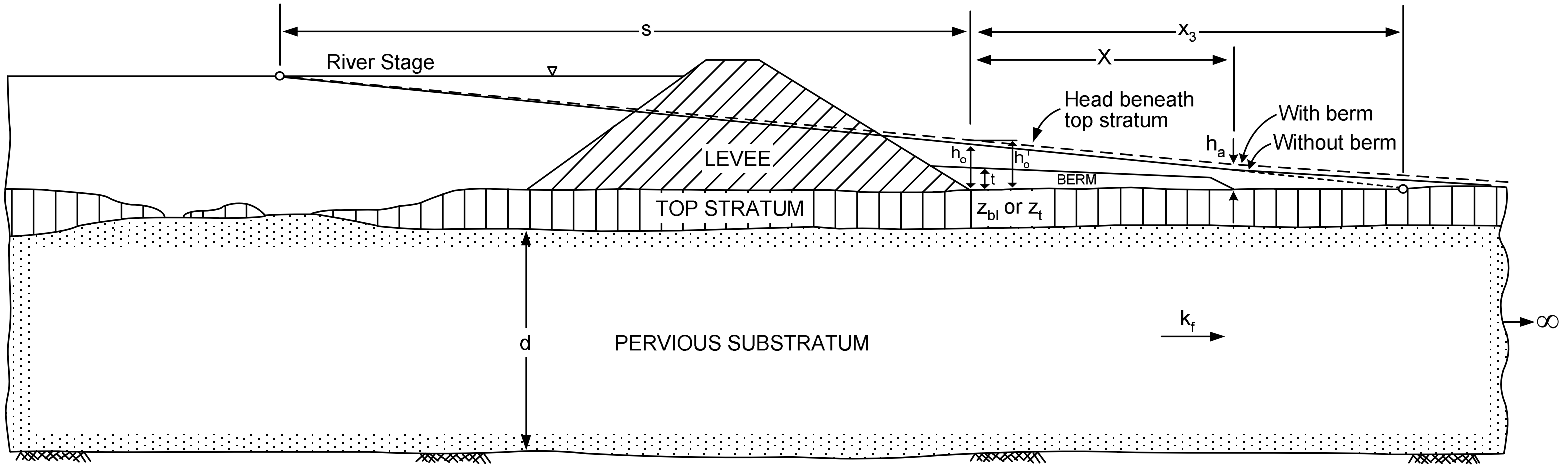
Update Corps EM 1110-2-1913 – “Design and Construction of Levees”

- Incorporate changes reflected in Corps ETL 1110-2-569
- Update guidance on seepage berm design
- Incorporate new factors of safety criteria



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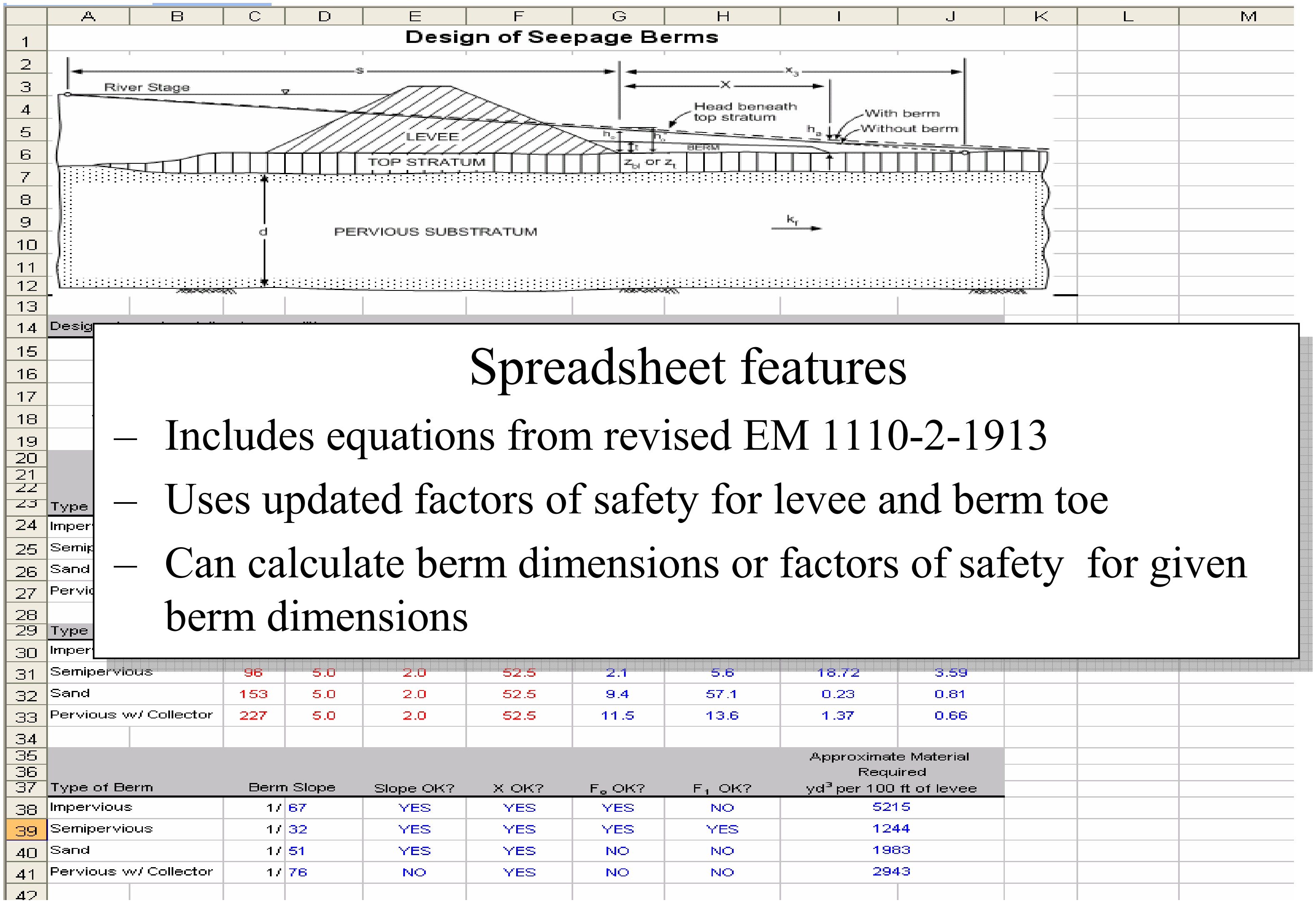
Seepage Berm Design Spreadsheet for Corps



Desig

Type
Imper
Semip
Sand
Pervic

Type
Imper

Semipervious	96	5.0	2.0	52.5	2.1	5.6	18.72	3.59
Sand	153	5.0	2.0	52.5	9.4	57.1	0.23	0.81
Pervious w/ Collector	227	5.0	2.0	52.5	11.5	13.6	1.37	0.66

Type of Berm	Berm Slope		Slope OK?	X OK?	F_o OK?	F_1 OK?	Approximate Material Required yd^3 per 100 ft of levee
Impervious	1 /	67	YES	YES	YES	NO	5215
Semipervious	1 /	32	YES	YES	YES	YES	1244
Sand	1 /	51	YES	YES	NO	NO	1983
Pervious w/ Collector	1 /	76	NO	YES	NO	NO	2943

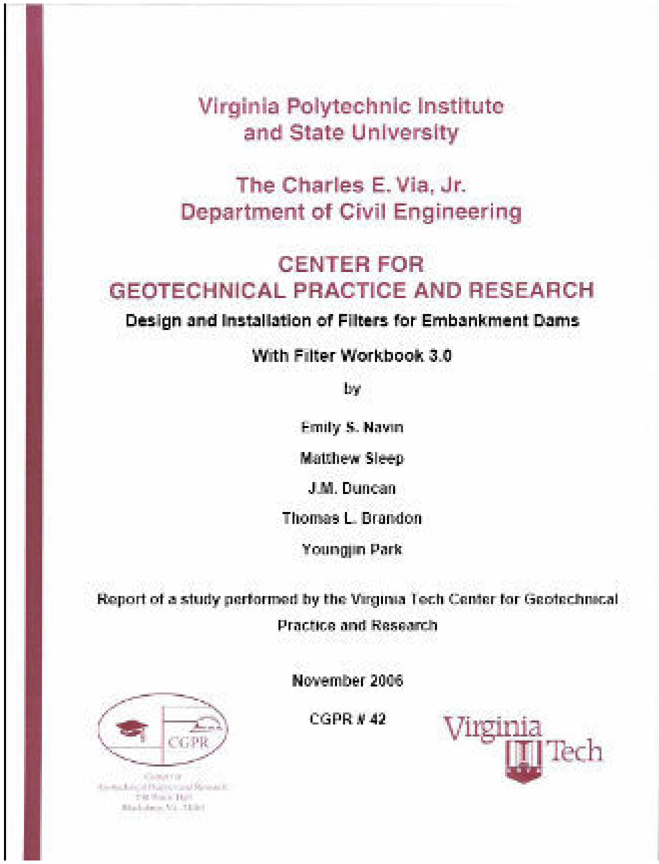
Spreadsheet features

- Includes equations from revised EM 1110-2-1913
- Uses updated factors of safety for levee and berm toe
- Can calculate berm dimensions or factors of safety for given berm dimensions

Update CGPR Filter Design Manual

- Add NRCS criteria to filter workbook
- Add guidance for filter installation

1. Segregation
2. Compaction
3. Cementation
4. Durability
5. Width
6. Contamination



Virginia Polytechnic Institute
and State University

The Charles E. Via, Jr.
Department of Civil Engineering

CENTER FOR
GEOTECHNICAL PRACTICE AND RESEARCH

Design and Installation of Filters for Embankment Dams

With Filter Workbook 3.0

by

Emily S. Navin

Matthew Sleep

J.M. Duncan

Thomas L. Brandon

Youngjin Park

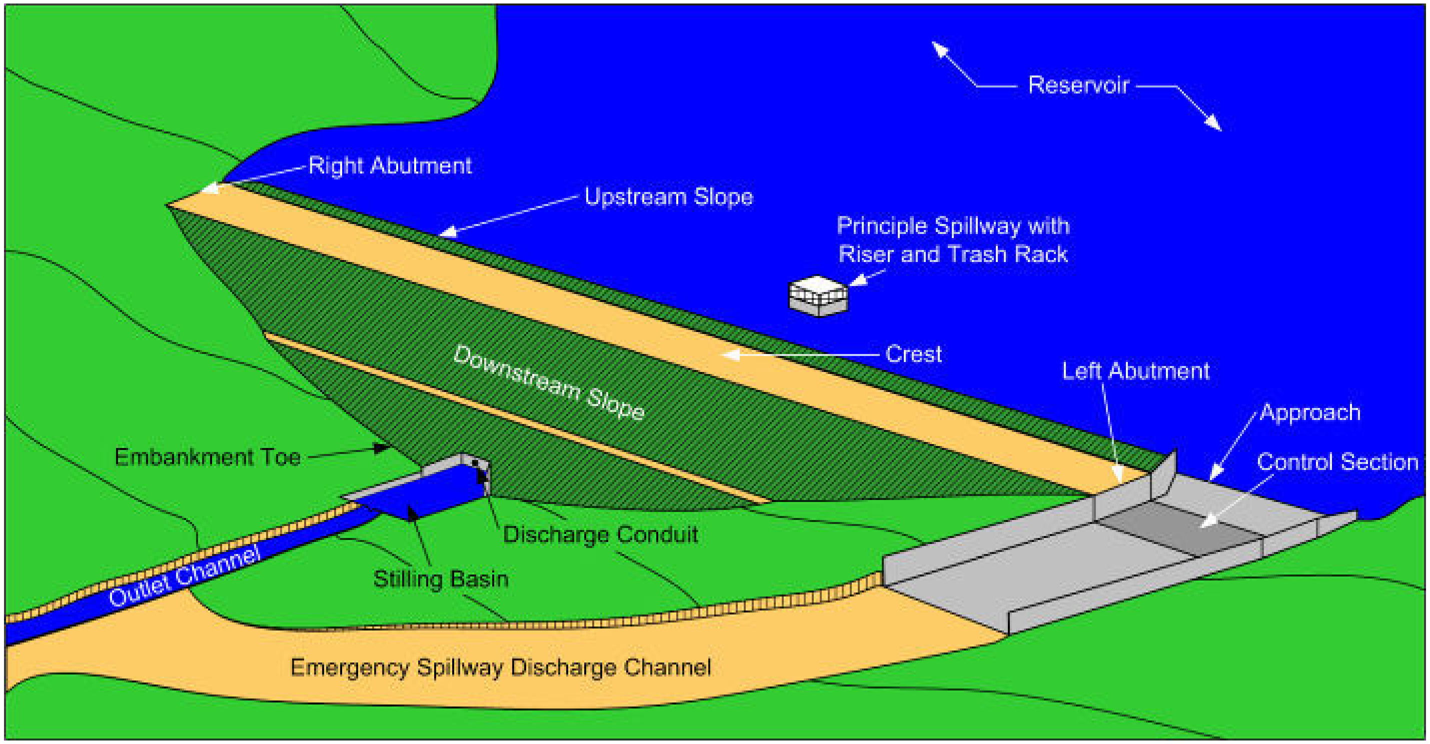
Report of a study performed by the Virginia Tech Center for Geotechnical Practice and Research

November 2006

CGPR # 42

Seepage Monitoring Guidelines for FEMA

- Visual Inspection
- Instrumentation
- Assessment of Consequences



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Levee Stability on Deep-Mixed Foundations

Start: May 2006 End: Jan 2009

- Student: Tiffany Adams
- Supervisor: Dr. George Filz
- Sponsors: National Science Foundation/
  U.S. Army Corps of Engineers

Objectives

– Provide recommendations for design of levee structures on shear walls constructed using deep-mixing methods.

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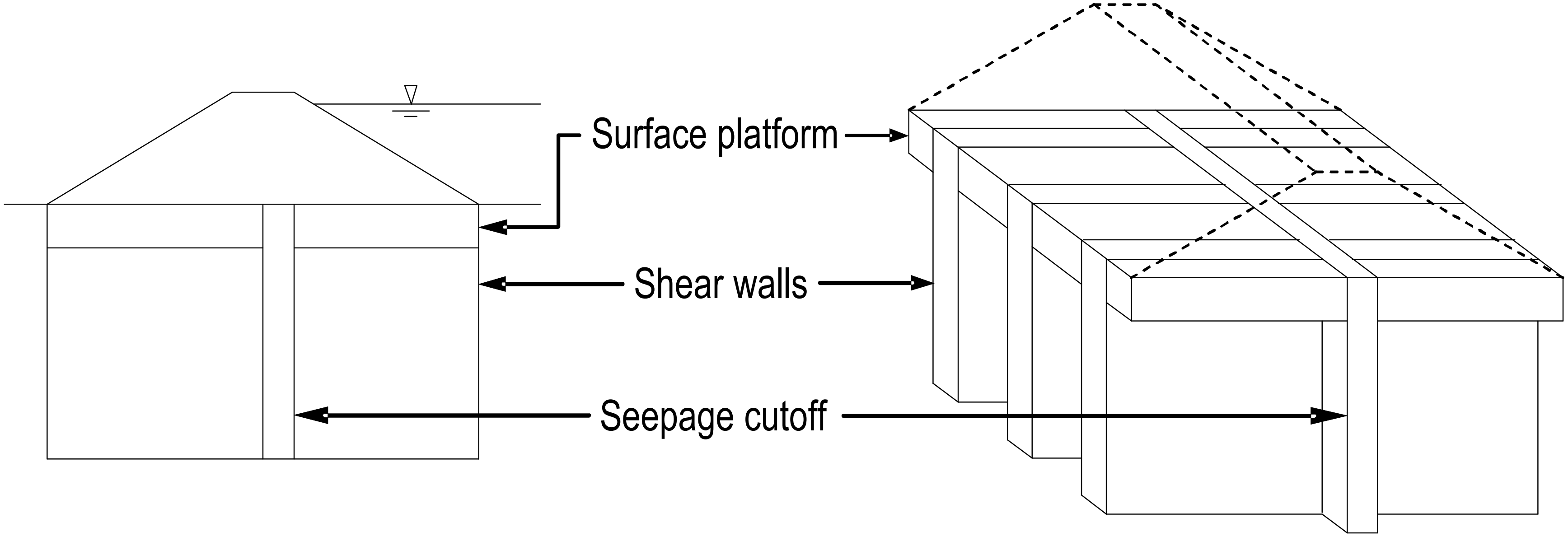
Levees Built on DMM Shear Walls

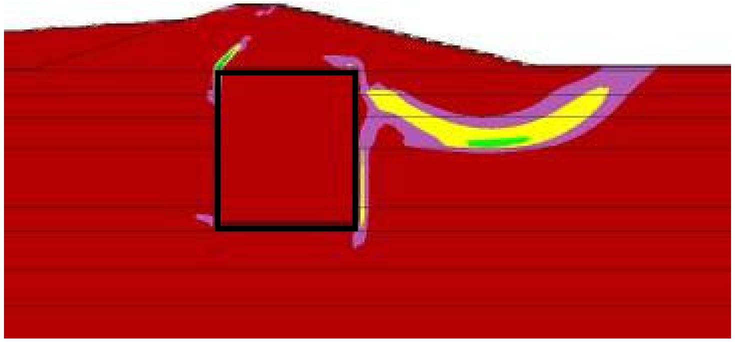


Surface platform

Shear walls

Seepage cutoff

Full Overlap at all Locations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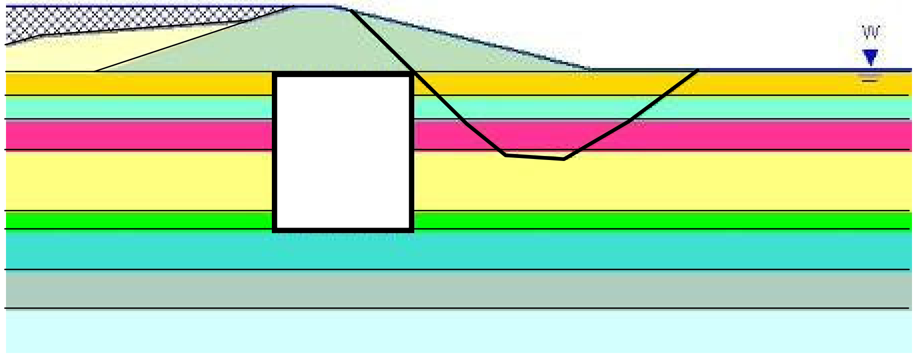
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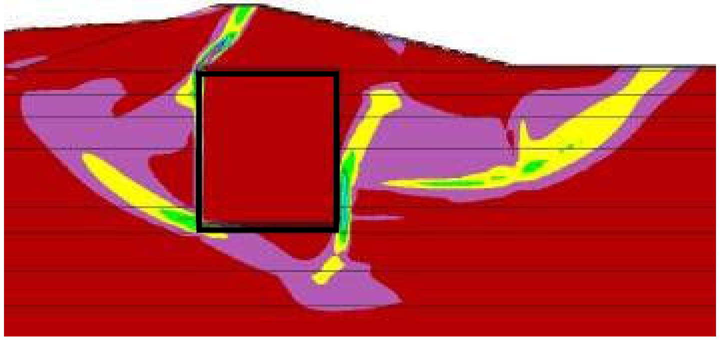
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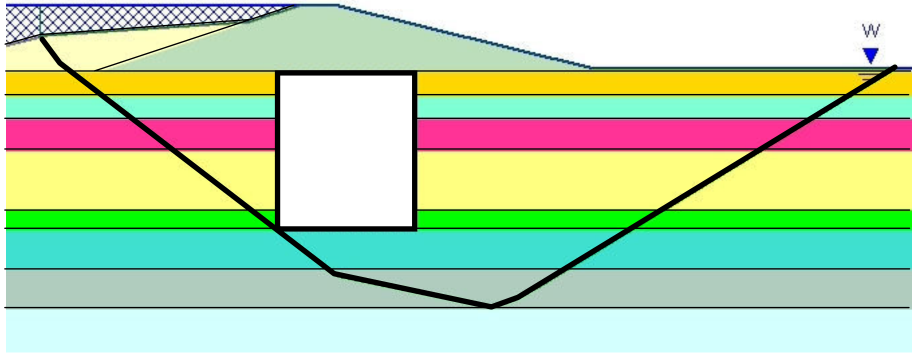
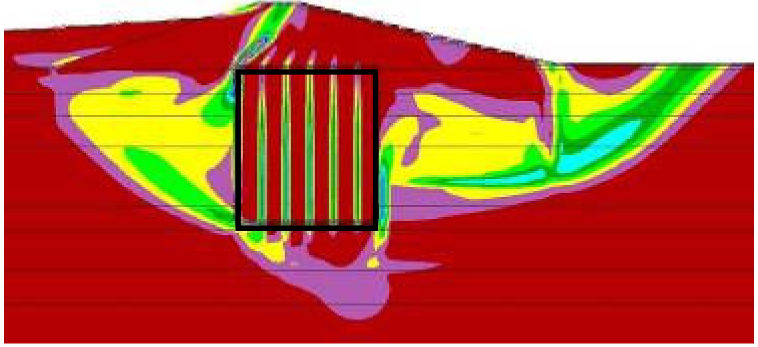

FS = 1.53

No Overlap at 5 Locations

FS = 1.37



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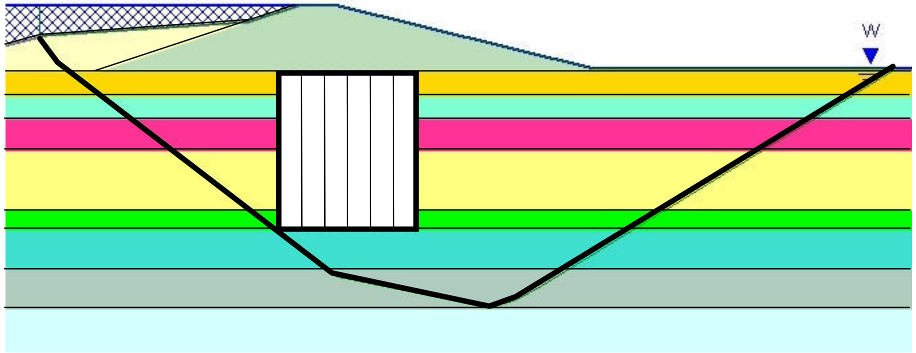

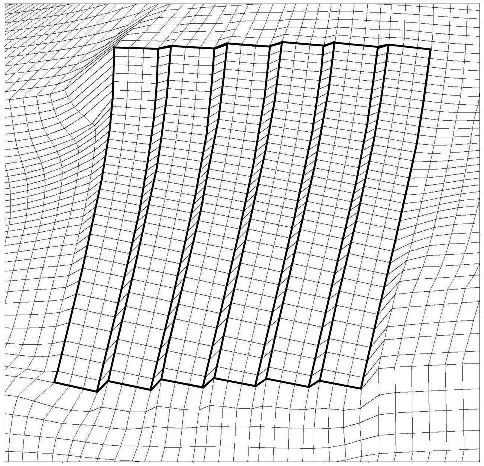

Column Deformations
(Magnified 5x)

No Overlap at all Locations

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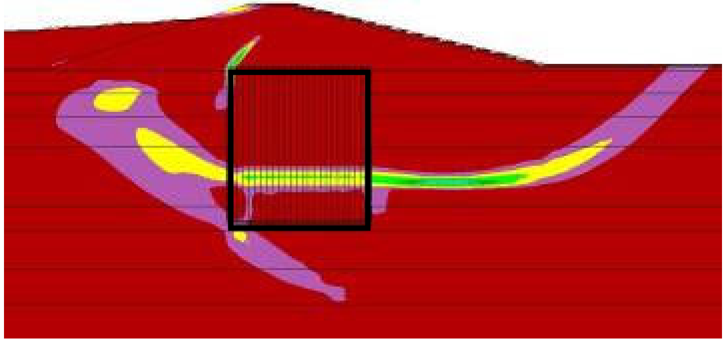

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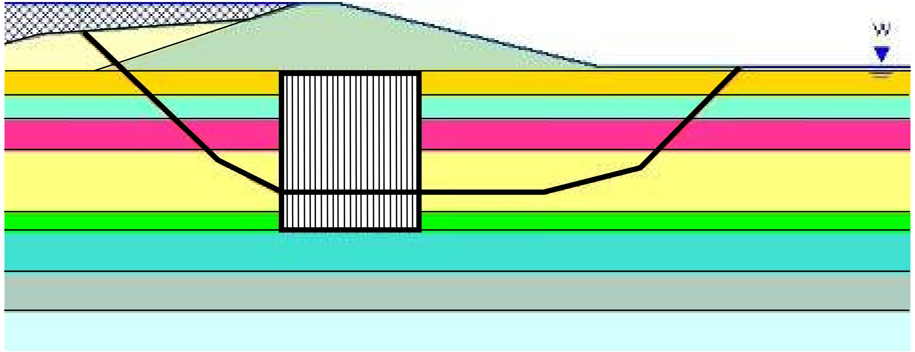
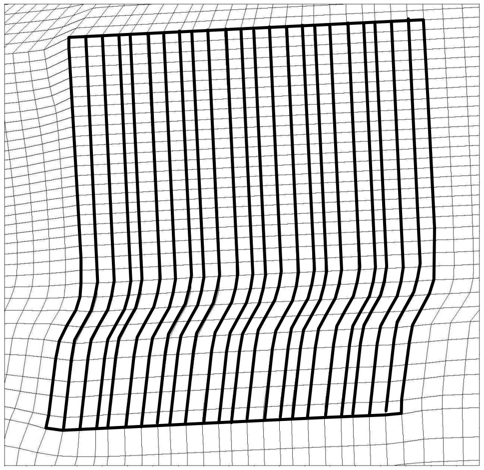




Column Deformations
(Magnified 5x)

Drained Triaxial Compression test on 21b and #57 Gravels

- Start: January 2005 End: March 2007
- Post-Doctoral staff: Wenxing Jian and Youngjin Park
- Students: Genevieve Smith, Todd Griffith, Jessa Corton, and Esther Ryan
- Supervisors: Mike Duncan and Tom Brandon
- Sponsor: CGPR and Hayward Baker

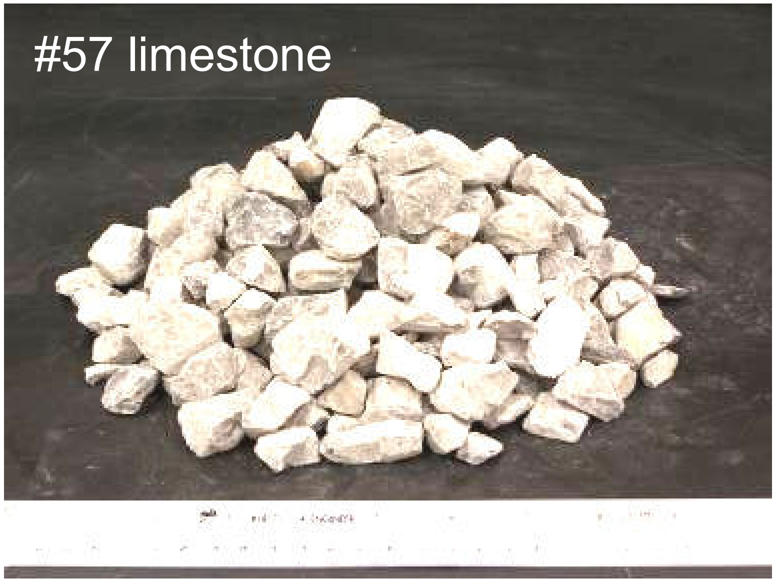
Objective

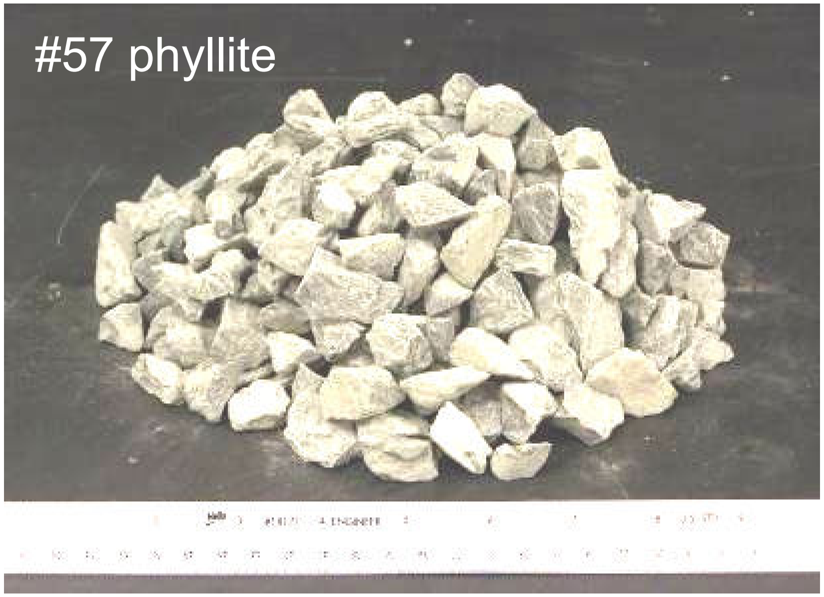
- Measure values of ϕ for

  21b gravels – limestone and granite

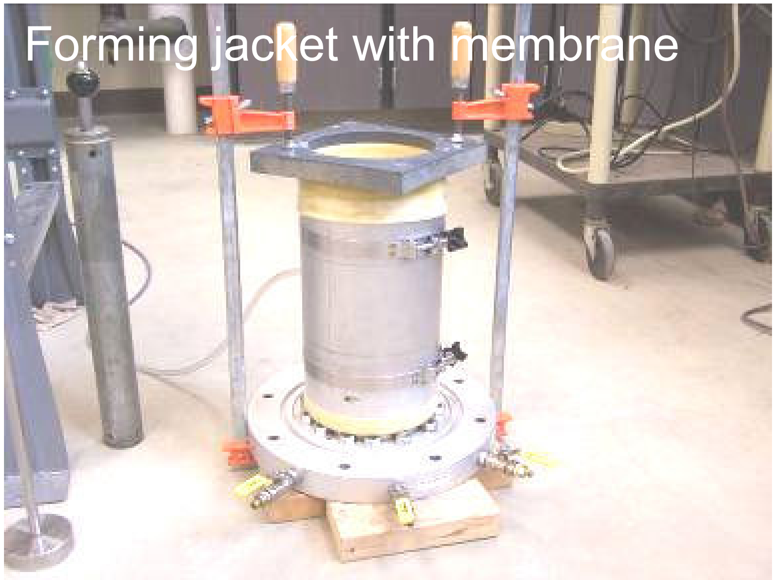
  #57 gravels – Limestone and phyllite

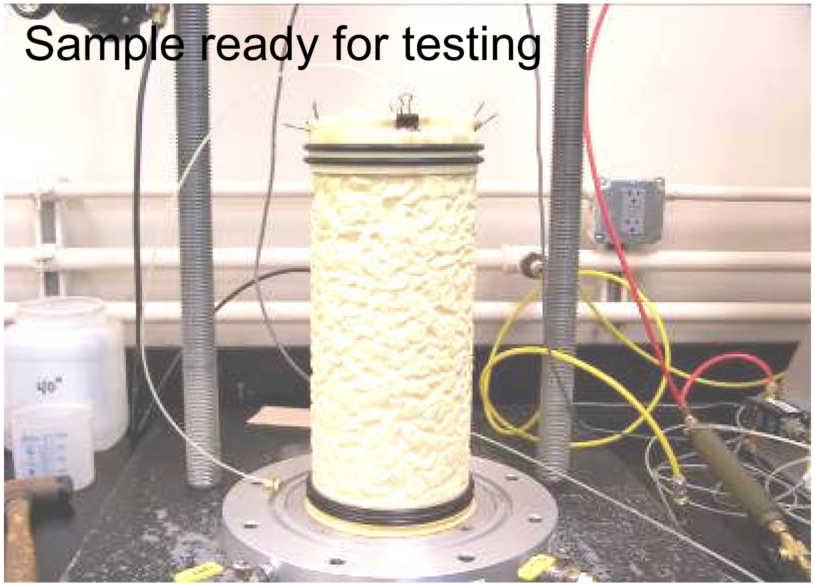
Tested Materials

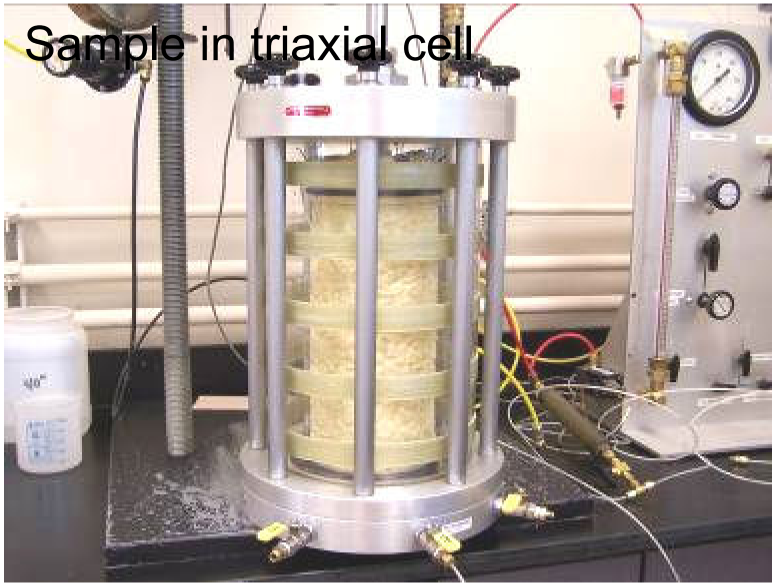


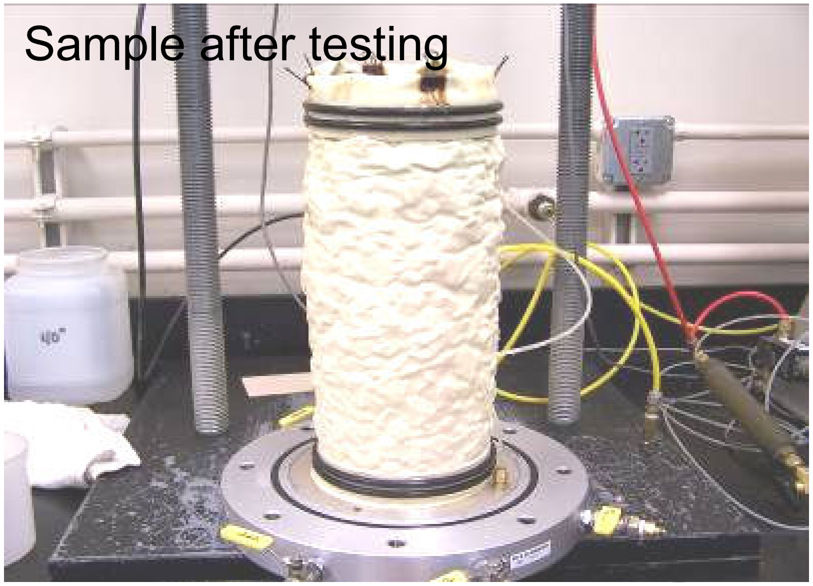


Test Procedures

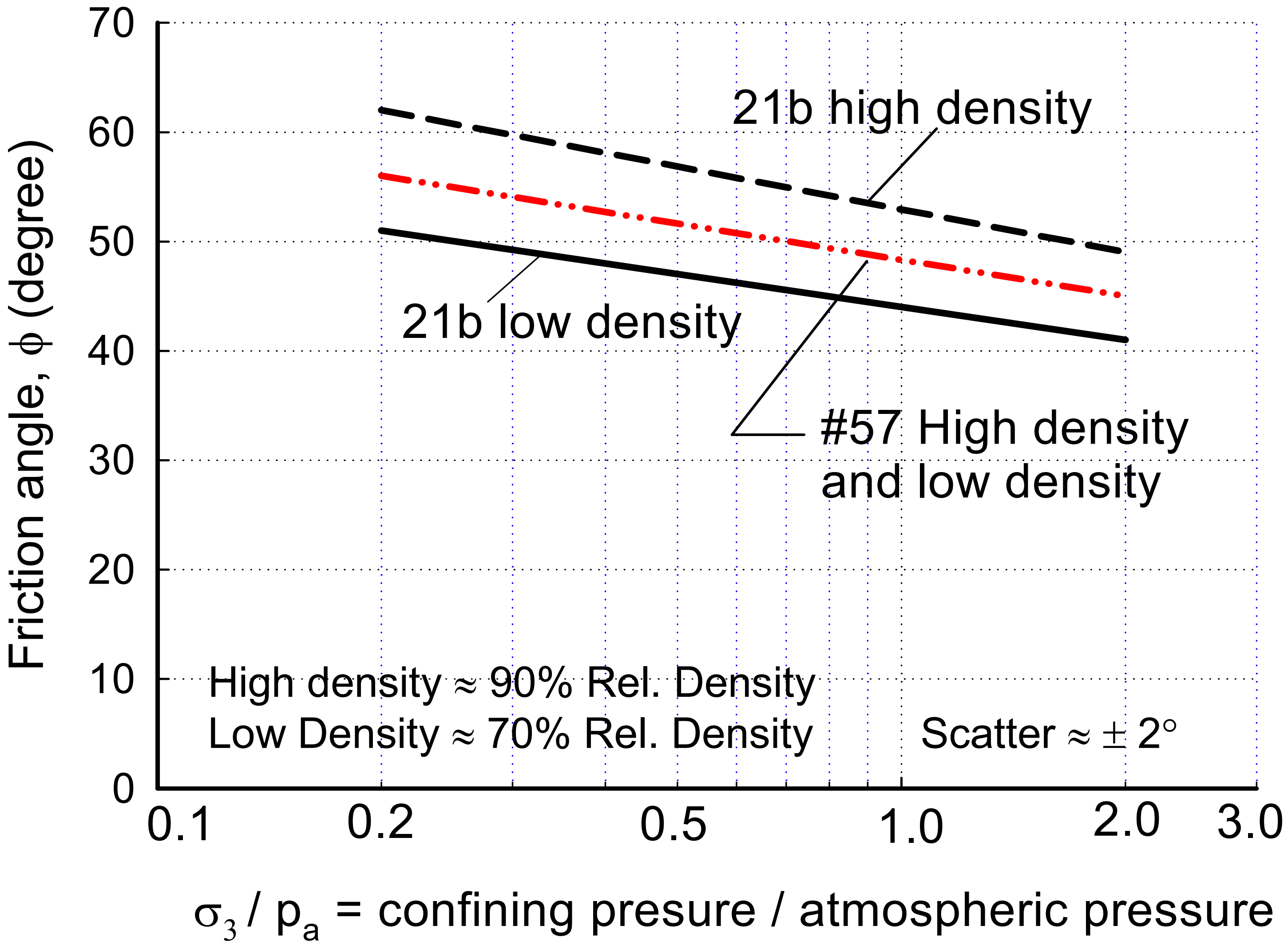

Forming jacket with membrane


Sample ready for testing


Sample in triaxial cell


Sample after testing

Results



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Remote Measurement of Fracture Data

Start: August 2003 End: May 2007

- Student: Jeramy Decker, Brian Badillo, Justin Sommerville
- Supervisors: Joseph Dove, Matthew Mauldon, Marte Gutierrez
- Sponsors: National Science Foundation

Objective

- Develop methods and tools to collect, analyze and utilize imaging data during tunnel excavation

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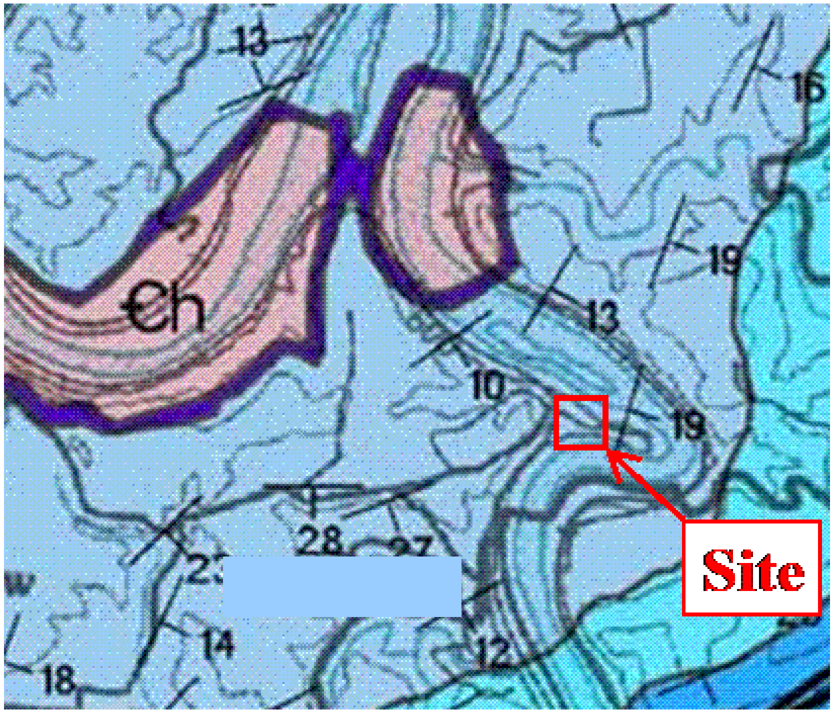
Field study: Abandoned Railroad Tunnel.

Outline:

- Site geology
- Technologies
- Results

Copper Ridge Formation (Cambrian): Dolomite €cr



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Field measurements, LiDAR and digital stereo photography used to obtain data

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3D visualization of imaging data

Tunnel

CAVE at VT

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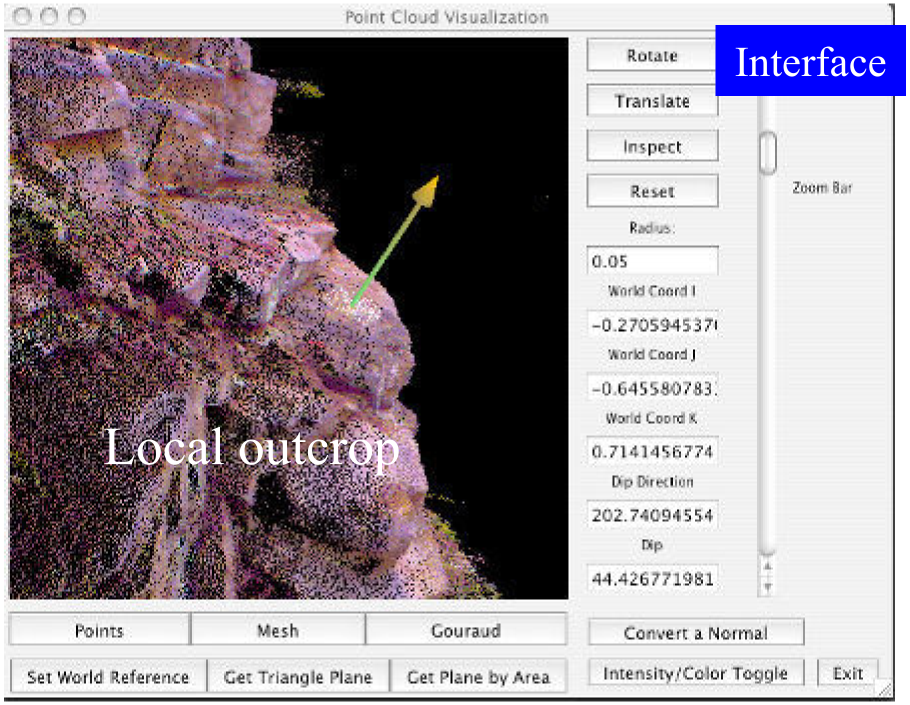
gVT– geotechnical Visualization Tools

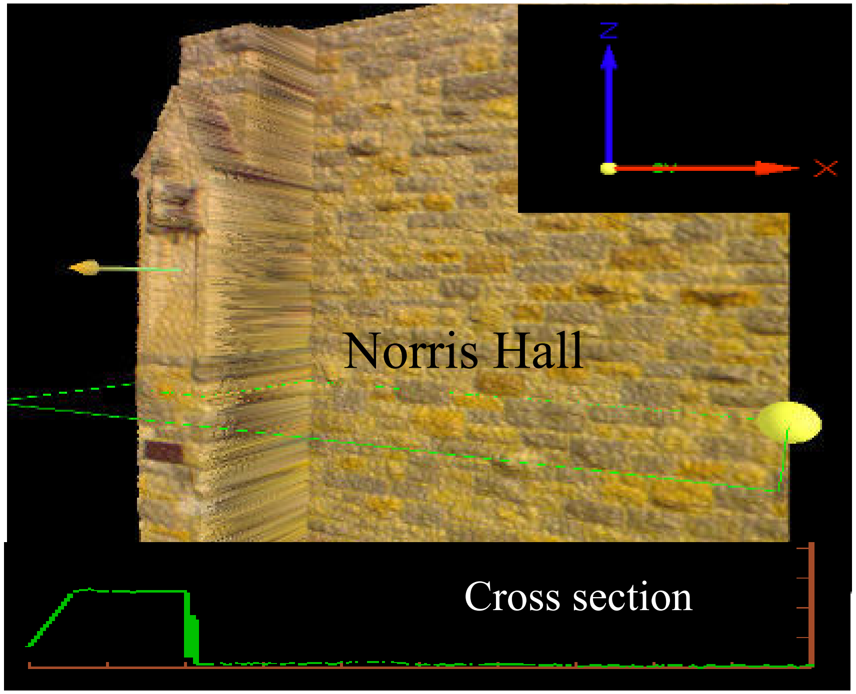
– new software for visualizing and using LiDAR-based data



Interface

Local outcrop

Radius: 0.05
World Coord I: -0.270594537
World Coord J: -0.645580783.
World Coord K: 0.7141456774
Dip Direction: 202.74094554
Dip: 44.426771981

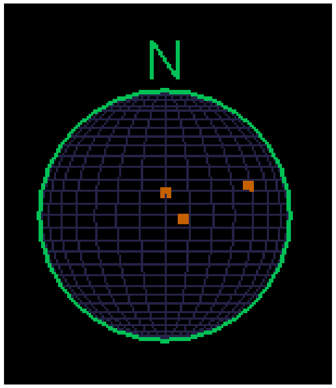


Norris Hall

Cross section

Potential Industry Benefits

- Improved field personnel safety
- Project cost savings by digitally recording site conditions for later use in the office.
- Supplement to site investigation data



Stereonet

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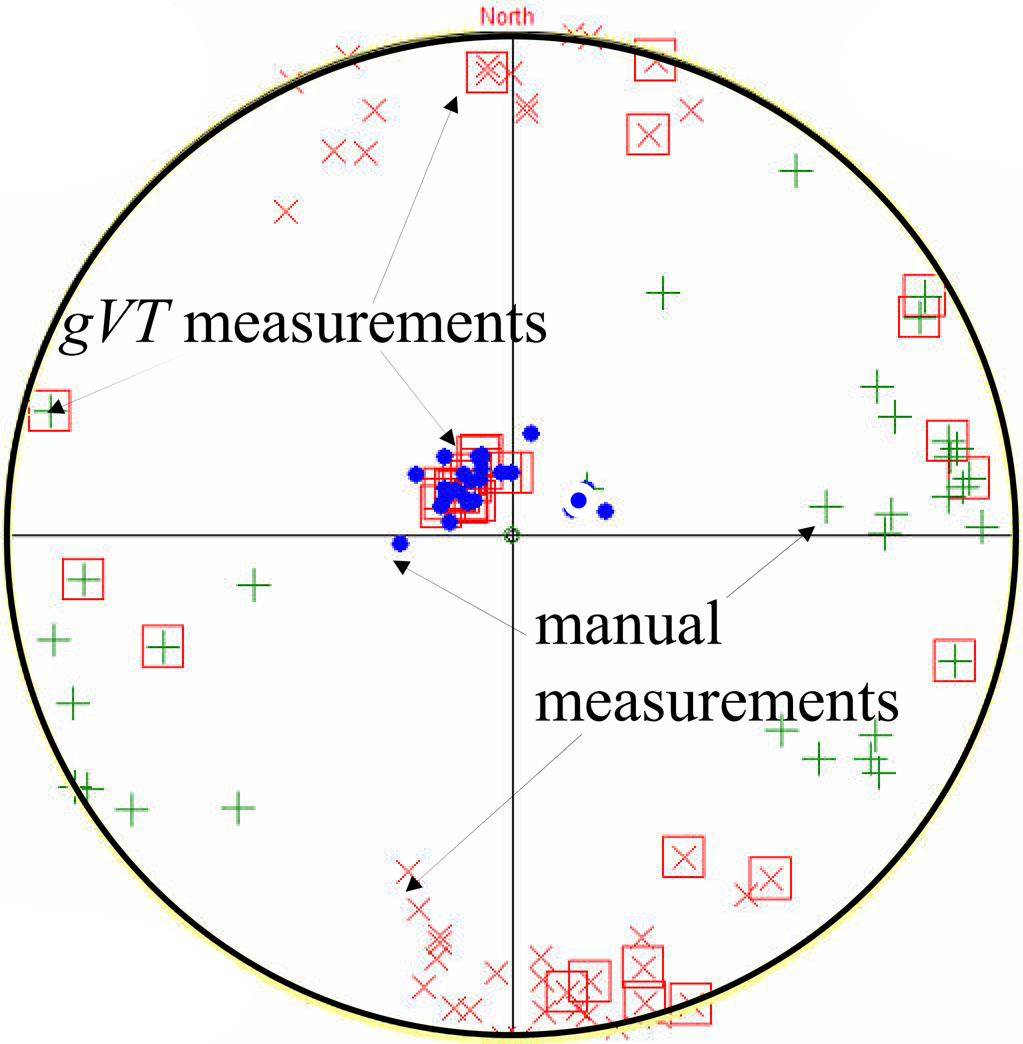
Results from *gVT* agree well with hand measurements



gVT measurements

manual measurements

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Development of Simplified Laboratory Filter Test

Start: December 2005 End: December 2007

- Students: Andrew Bolton, Manuel Ochoa, Binod Tiwari
- Supervisor: Dr. Thomas L. Brandon, Dr. J. Michael Duncan, Dr. James K. Mitchell
- Sponsors: USBR

Objectives

- Study the performance of filters that have developed cracks
- Develop a simplified and less expensive filter test method.

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Background Information

- The performance of filters during steady state seepage has been studied extensively
- The ability of filters to collapse and fill cracks has been studied less
- Available test methods are difficult and expensive
- A simpler test method is needed to assess filter performance

Research Approach (Completed Items)

- Desk study summarizing the gradation and mineralogy of the embankment materials at the existing USBR dams (Completed Spring 2006)
- Literature review of the depth and causes of cracking that has occurred in dams worldwide (Completed Spring 2006)
- Literature review of chemical and biological causes of cementation of granular soil, and case histories on the cementation in granular filters (Completed Spring 2006)

Research Approach (Present Status)

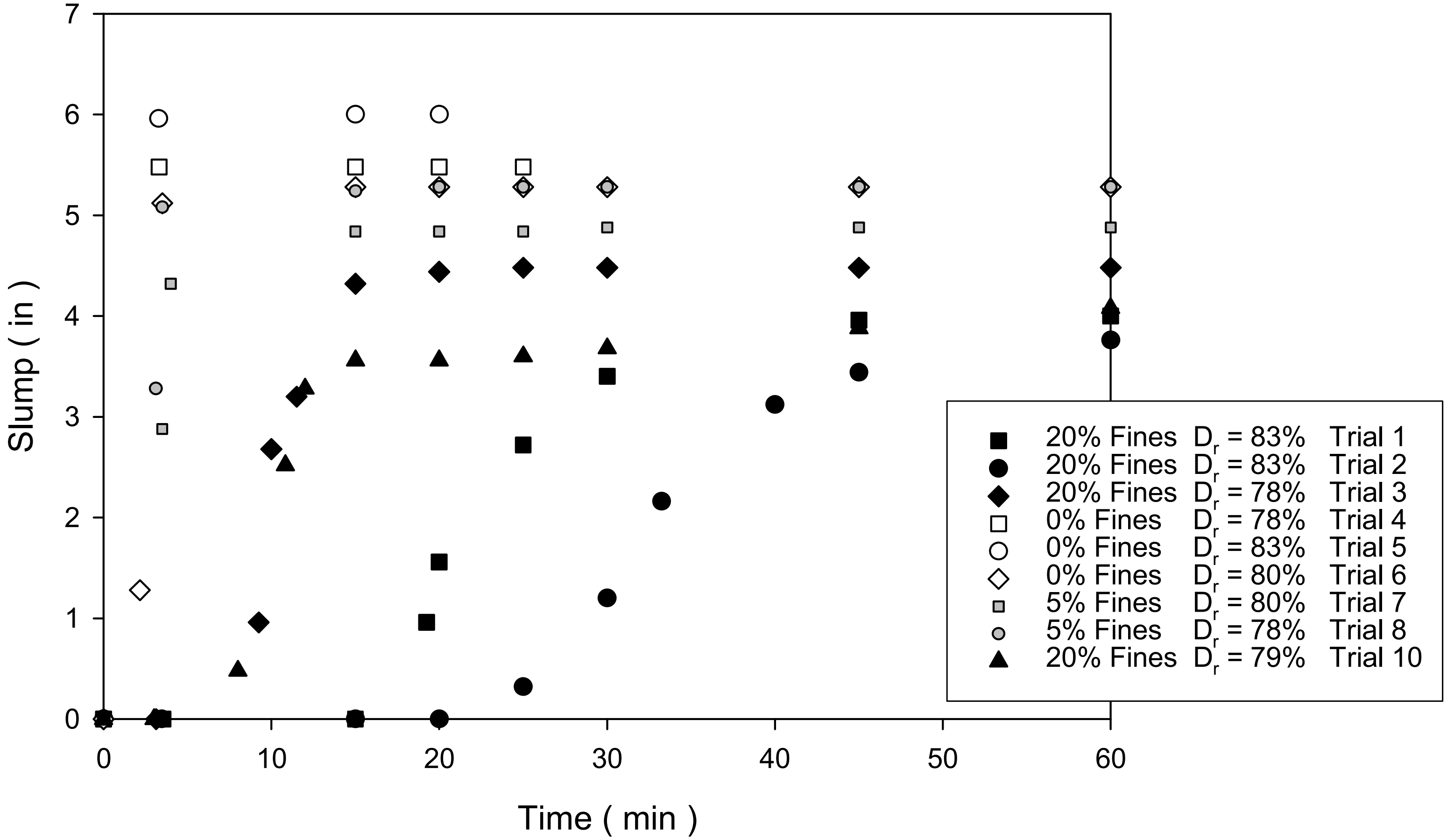
- Development of soil slump test (August 2006 to Present)

- Testing of filter materials with the soil slump test (January 2007 to present)

Soil Slump Test

Figure 1: Slump versus Time

21B Gravel, $w_c = 7\%$



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Research Approach (Future Activities)

- Experimental study on cracked filters using the 4" filter test device developed at Virginia Tech (Spring 2007)
- Experimental study on the self-healing ability of broadly graded filters using the 4" filter test device developed at Virginia Tech (Summer 2007)

Engineering Manual for Organic Soils and Peat

Start: April 2003 End: May 2007

Student: Heather Hickerson

- Supervisors: George Filz, C. J. Smith, Mike Duncan
- Sponsors: CGPR

<u>Objectives</u>

- Collect and compile data on classification and engineering properties of organic soils and peat
- Compile and discuss mitigation methods for organic soils and peat, based on case histories

Organic Soils and Peat

Weight loss upon heating from 105°C to 440°C

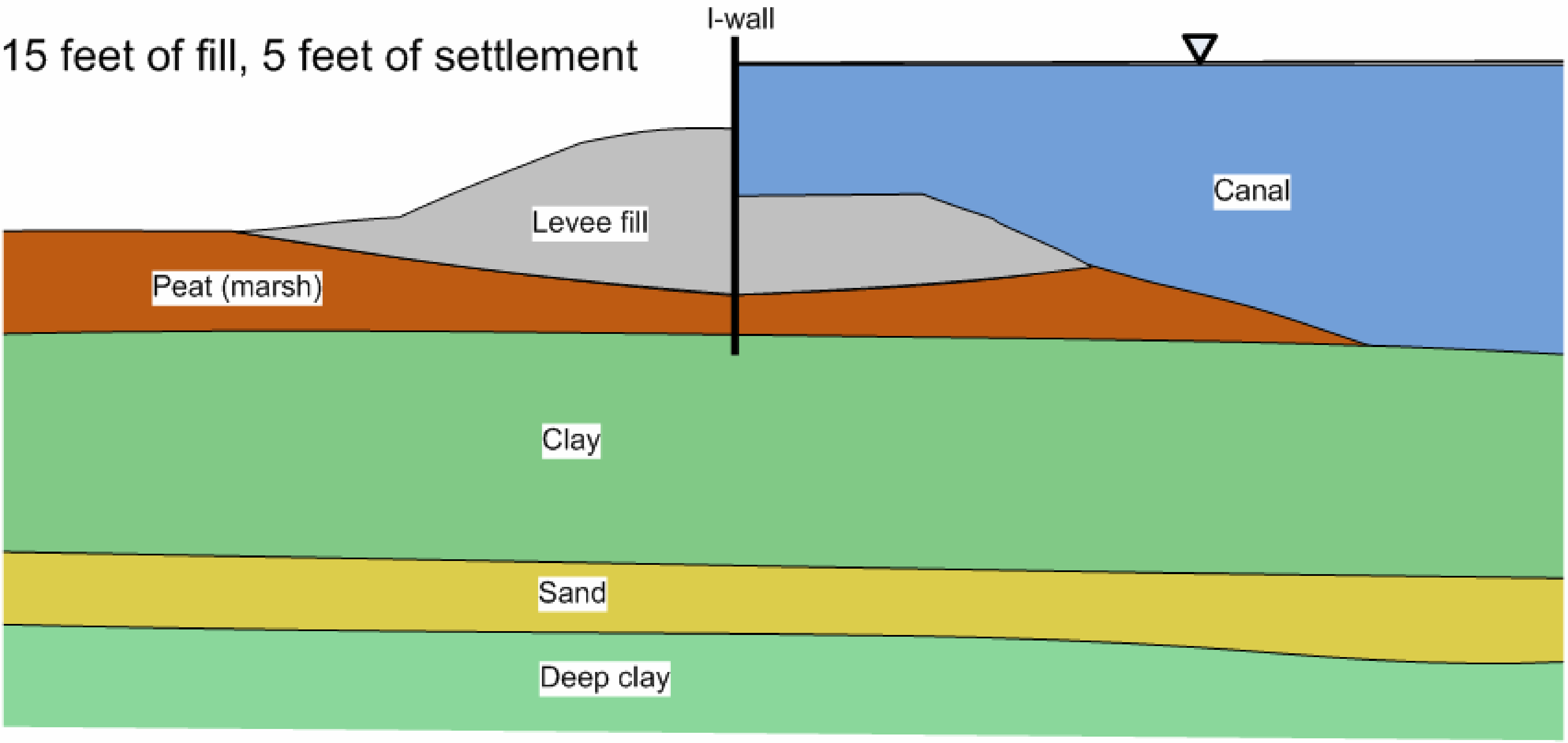
- 75% or more → Peat
- 30% to 75% → Peaty Organic Soil
- 5% to 30% → Organic Soil
- 1% to 5% → Soil with Organic Content
- Less than 1% → Inorganic

Organic Soils and Peat

Engineering Problems

- Large primary settlement
- Large secondary settlement
- Corrosivity
- Low strength

New Orleans – 17th Street Canal



15 feet of fill, 5 feet of settlement

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Organic Soils and Peat

Mitigation Techniques

- Excavate and replace
- Use deep foundations – piles, drilled shafts
- Preload foundation
- Apply admixtures (lime)

Fully-Coupled Staggered Solution of Fluid Flow Behavior in Porous Media Based on the Biot's Theory

Start: August 2004 End: August 2007

- Student: Imsoo Lee
- Supervisor: Dr. Marte Gutierrez
- Sponsors: American Chemical Society

<u>Objectives</u>

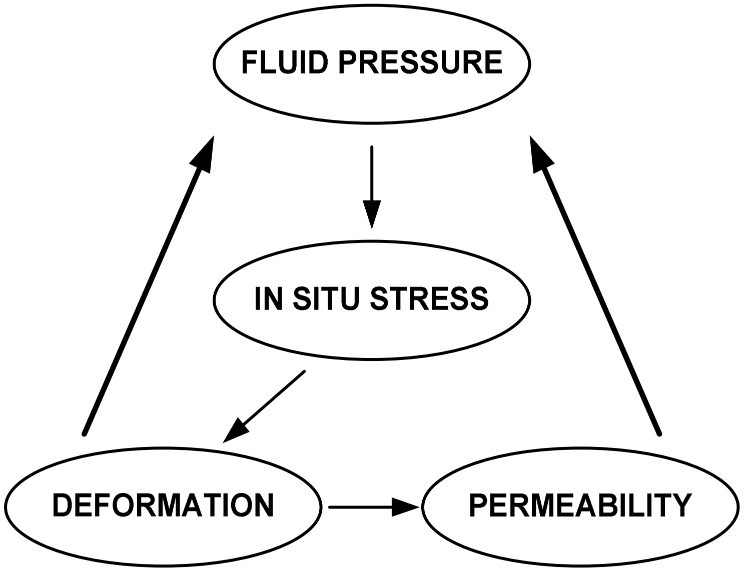
- Develop rigorous computational algorithm for coupled fluid flow and deformation processes in porous media.
- Apply the computational model to obtain better understanding of the behavior of fluid-saturated deformable porous media.

Geomechanics-Fluid Flow Coupling

- Interaction between fluid flow (pressure and flux) and the mechanical response (deformations and stresses) in fluid-saturated deformable porous media

- Neglect of Coupling Effect
  - Emphasis on the fluid flow problem
  - Oversimplification of the mechanical response through the use of "compressibility" term

- Categories of Coupling
  - One-way coupling
  - Partial coupling (stress-permeability)
  - Full coupling (deformation-flow)



The Finite Element Equation of Fully-coupled Biot's Theory

$$\begin{bmatrix}\mathbf{K_m} & \mathbf{L}\\ \mathbf{L}^{T} & \mathbf{S}-\Delta t\mathbf{K_c}\end{bmatrix}\begin{Bmatrix}\Delta\mathbf{u}\\ \Delta\mathbf{p}\end{Bmatrix}=\begin{Bmatrix}\Delta\mathbf{F_u}\\ \Delta\mathbf{F_p}\end{Bmatrix}$$

u = displacements vector
p = pore pressures vector
$\mathbf{K_m}$ = stiffness matrix
L = coupling matrix
$\mathbf{K_c}$ = conductivity matrix
S = compressibility matrix

- Fully-coupled fluid flow formulation

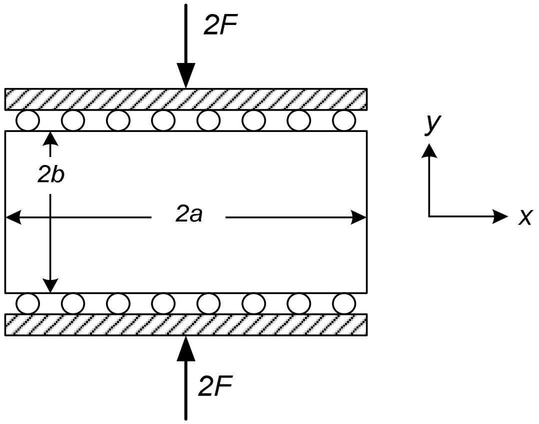
$$\left[\mathbf{L}^{\mathbf{T}}\mathbf{K_m}^{-1}\mathbf{L}-\Delta t\mathbf{K_c}\right]\mathbf{P}^{n+1}=\mathbf{L}^{\mathbf{T}}\mathbf{K_m}^{-1}\mathbf{L}\mathbf{P}^{n}+\mathbf{L}^{\mathbf{T}}\mathbf{K_m}\mathbf{F_u}$$

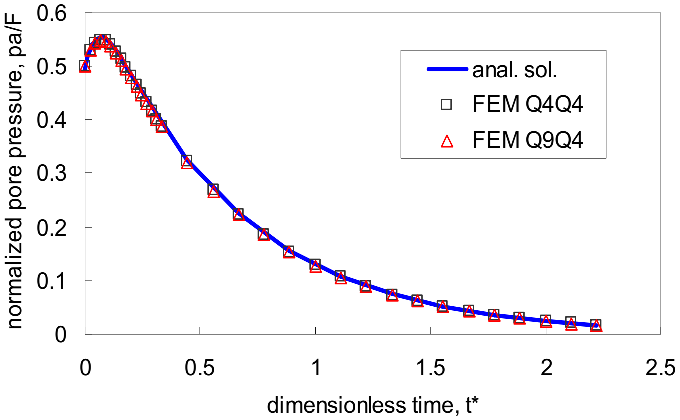
- Conventional fluid flow formulation

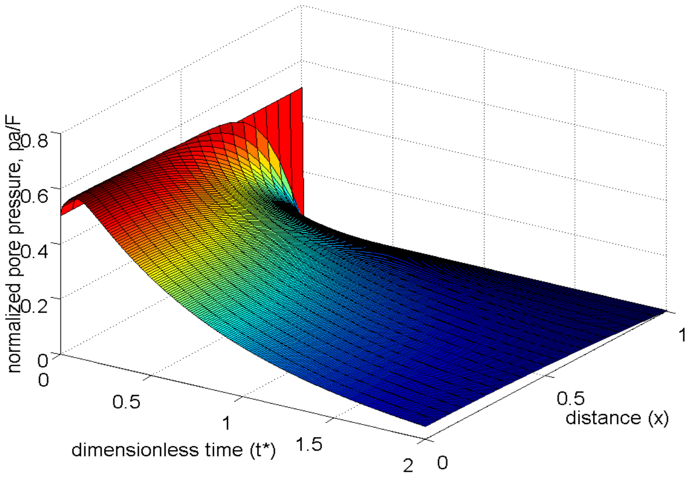
$$\left[c\mathbf{M}_{m}-\Delta t\mathbf{K_c}\right]\mathbf{P}^{n+1}=c\mathbf{M}_{m}\mathbf{P}^{n}$$

- Diagonalization of full compressibility matrix
  - Row sum method
  - Diagonal scaling method
  - using Eigenvalue & Eigenvector

Mandel’s Problem







Future Work

- Develop efficient algorithm for the matrix diagonalization
- Apply the developed coupling algorithm using an existing conventional reservoir simulator (e.g. BOAST)
- Implement other types of constitutive models (e.g. elasto-plastic, chalk) in the geomechanical code
- Analyze a case history (e.g. Ekofisk)

Long-Term Performance of Dam Seepage Barriers

Start: August 2004 End: August 2007

- Student: John D. Rice
- Supervisor: Mike Duncan
- Sponsors: U.S. Bureau of Reclamation, CGPR

Objectives

- Identify distress mechanisms that are unique to dams with seepage barriers.
- Enhance understanding of these mechanisms.
- Develop tools for assessing risk.

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Wolf Creek Dam

Losses due to pool lowering: $53 million per year

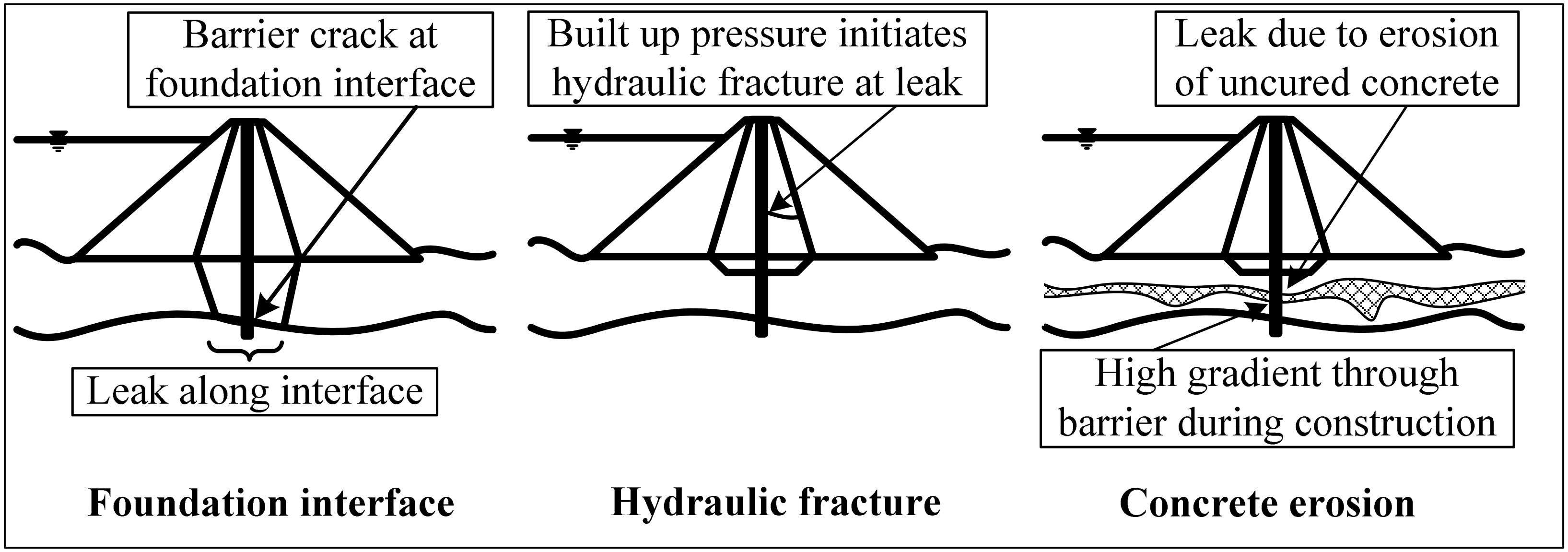
– Hydropower production	$34.2 million per year
– Recreation	$18.8 million per year

Source: USACE

Identification of Distress Mechanisms

Four types of distress mechanisms have been identified :

1. Leaks through the barriers,
2. Erosion along or through bedrock joints,
3. Erosion of solution void infill,
4. Erosion of internally unstable foundation soils.



Barrier crack at foundation interface

Leak along interface

Built up pressure initiates hydraulic fracture at leak

Leak due to erosion of uncured concrete

High gradient through barrier during construction

Foundation interface

Hydraulic fracture

Concrete erosion

Analyses

Purposes of analyses:

1. Enhance our understanding of behavior and distress mechanisms,
2. Develop tools to allow better assessment of the severity of distress mechanisms.

Types of analyses:

1. Steady seepage,
2. Soil-structure interaction.

Applicability to Risk Assessment

1. Guidance for identifying potential failure mechanisms based on case histories and distress mechanism scenarios:
2. Guidance for assessment of risk based on potential for:
   - Initiation of internal erosion
   - Continuation
   - Progression
   - Breach

DEM Simulation of the February 17, 2006, Leyte, Philippines, Rockslide

Start: August 2006 End: May 2007

- Student: Naya Asprouda
- Supervisor: Dr. Marte S. Gutierrez
- Sponsor: National Science Foundation

Objective:

To investigate the underlying mechanism(s) of the February 17, 2006 Leyte, Philippines, Rockslide by performing Distinct Element simulations.

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Background

February 17, 2006

- Overhanging rock detached from Mt. Cabac
- Guinsaugon village covered by as much as 30m thick soft and unstable debris, making rescue operations very difficult.
- 1,300 people reported missing

Photo from USDOD

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Precursor Events

- Excessive <u>Rainfall</u> – five times the average amount of rain during rainy seasons in the area
  - La Niña
  - Inversion Zone in Southern Leyte
- Four minor <u>earthquakes</u> occurred the morning of the slide.
  - Two were of magnitude Mb≈4.5
  - Along the Philippine Fault Zone (PFZ)

Did these events influence the triggering and behavior of the slide?

Photo by M. Gutierrez

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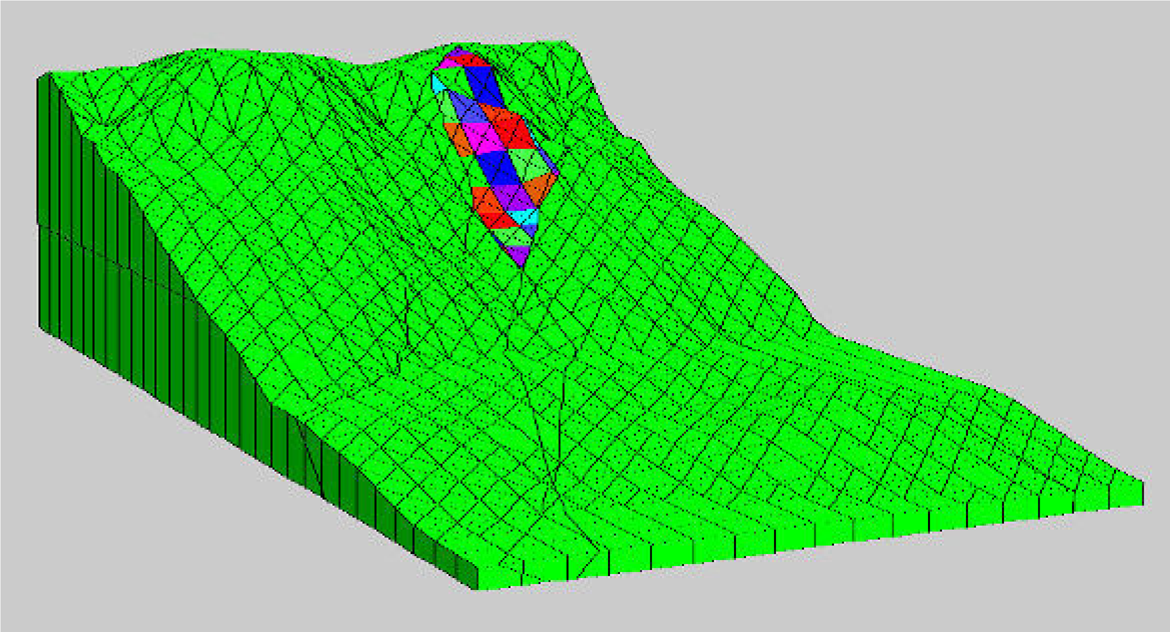
3DEC Analysis

- Digital elevation model of the area prior to the slide
- Major failure surfaces, identified during a site survey, added to the model
- Resulting "wedge" assumed rigid to limit computation time



Research Plan

- Study the effects of ground acceleration and hydraulic pressurization of the fault
- Refine model, geometry and material properties to better analyze the debris flow
- Compare results to witness accounts and actual debris behavior during and immediately after the slide.

A Guide to Settlement of Valley Fills

Start: March 2006 End: August 2006

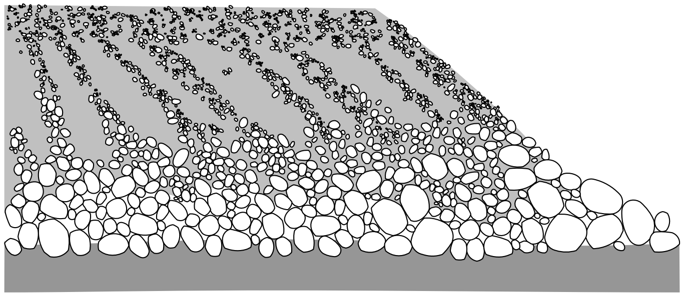
- Student: Andrew Bursey
- Supervisor: Mike Duncan
- Sponsor: CGPR

Objectives

- Review case histories of valley fill settlement
- Identify principal causes of valley fill settlements
- Evaluate factors that control settlement magnitude
- Summarize methods for coping with settlement

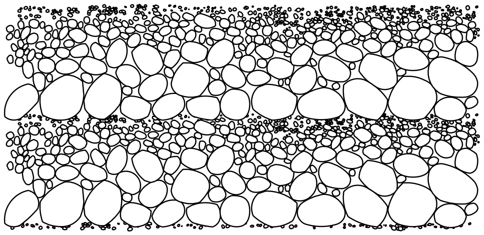
Dumping or spreading causes segregation

- Makes exploration difficult, makes fills hard to characterize
- Leads to differential settlements in end-dumped fills



<u>End-dumped fills:</u>

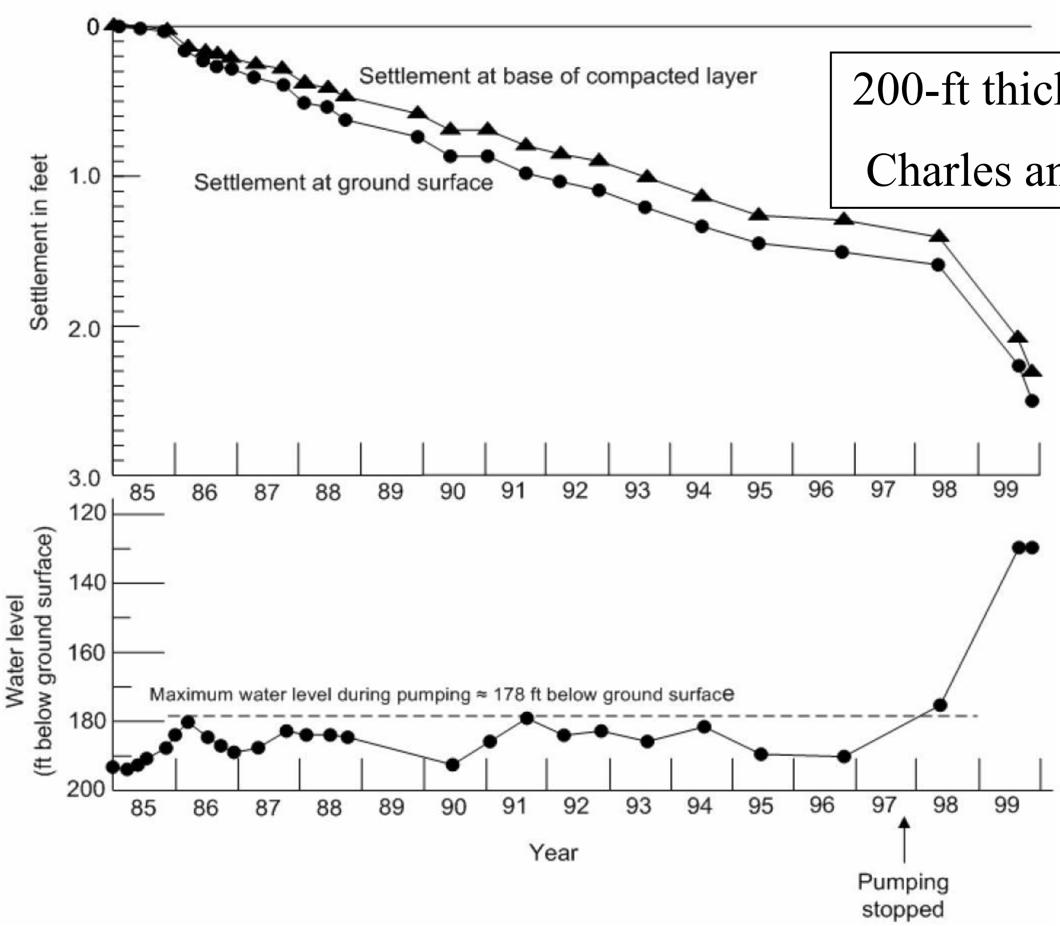
- Inclined stratification
- Coarser material at depth



<u>Roller-compacted fills:</u>

Coarser material at base of lift

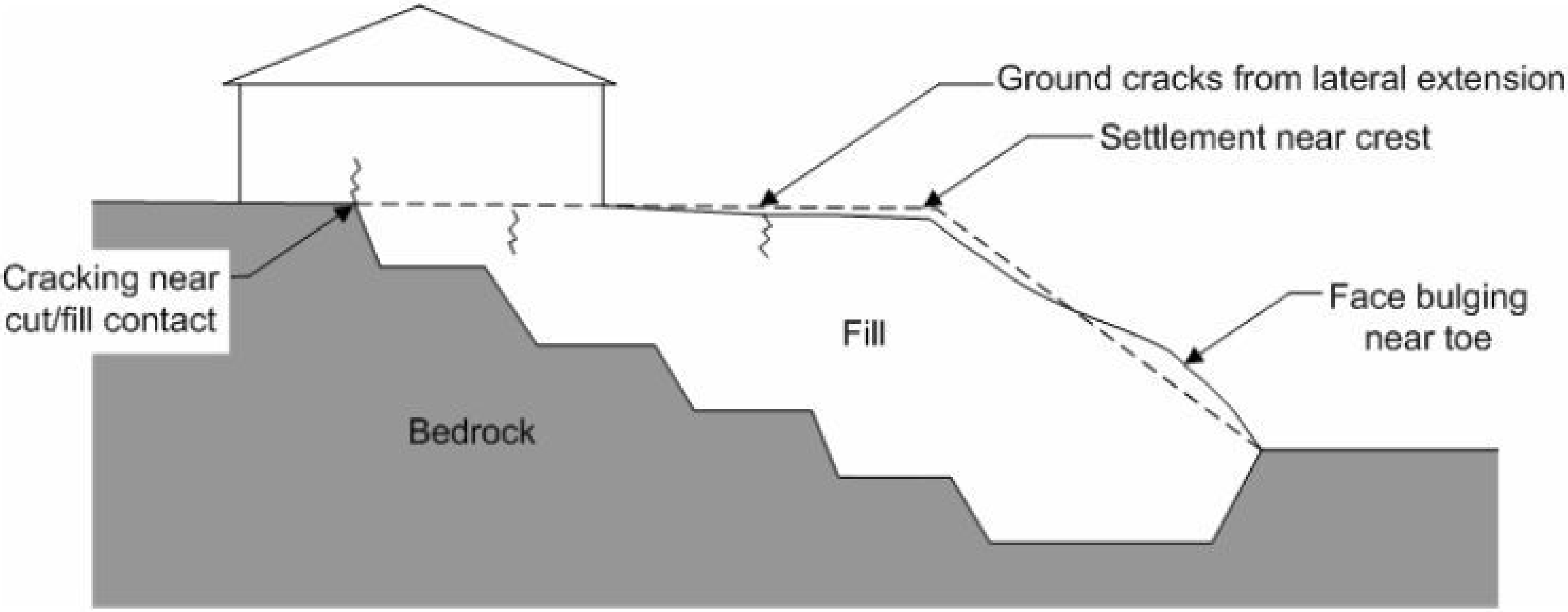
- Wetting can cause large, unexpected settlements long after fill placement completed
- A broad spectrum of fill types is susceptible



200-ft thick fill - data from Charles and Watts. (2001)

EQ shaking can induce differential settlement

- Liquefaction is not required for damaging settlements
- Variations in fill thickness and distance to free face are important factors
- Damage is usually concentrated at cut/fill transitions and near the crests of slopes



20-ft to 100-ft thick compacted fills, data from Stewart et al. (2001)

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Dealing with valley fills

Full-scale field tests and experience show:

- Dumped rock and mixed fills are especially problematic
- Locations of structures on fills is an important factor in damage due to settlement
- Accurate topography before filling is useful for evaluating fill thickness variations, but is often unavailable
- Densification reduces settlement, but densification to adequate depth is frequently not possible
- Wetting due to irrigation or subsurface flow poses large risk well into service life of most fills

Technology Demonstration of Rapid Stabilization of Soft Clay Soils

Start: March 2003 End: May 2009

- Student: Liselle Vega-Cortés
- Supervisor: Thomas L. Brandon
  George M. Filz
  James K. Mitchell
- Sponsors: Air Force Research Laboratory

<u>Objectives</u>

- Stabilization of very soft materials for airfields
- Technology demonstration using lime and cement admixtures

Previous Research

- Investigated and tested mechanical, chemical, and conventional admixtures
- Determined soil properties needed for airfield design
- Developed recommendations for treatment type
  - ✓ Lime and cement admixtures

Craney Island

- 2,500 acre dredge material disposal site
- Owned by US Army Corps of Engineers
- Site soils are very soft
- Receive double of design capacity

Craney Island (Photo from http://www.nao.usace.army.mil/projects/craney/facility%20 management/AerialPhoto.html)

Craney Island

- Sampling
- Field Testing
- Laboratory Testing
- Technology Demonstration
- Monitoring

J.H. Becker Equipment (Photos provided by J.H. Becker Construction Co.)

Fracture Modeling for Hard Rock Tunneling

Start: August 2003 End: May 2007

- Student: Jeramy Decker
- Supervisors: Matthew Mauldon
- Sponsors: National Science Foundation

Objectives

- Develop tools to assess fracture data and use the data to develop fracture models and rock mass parameters

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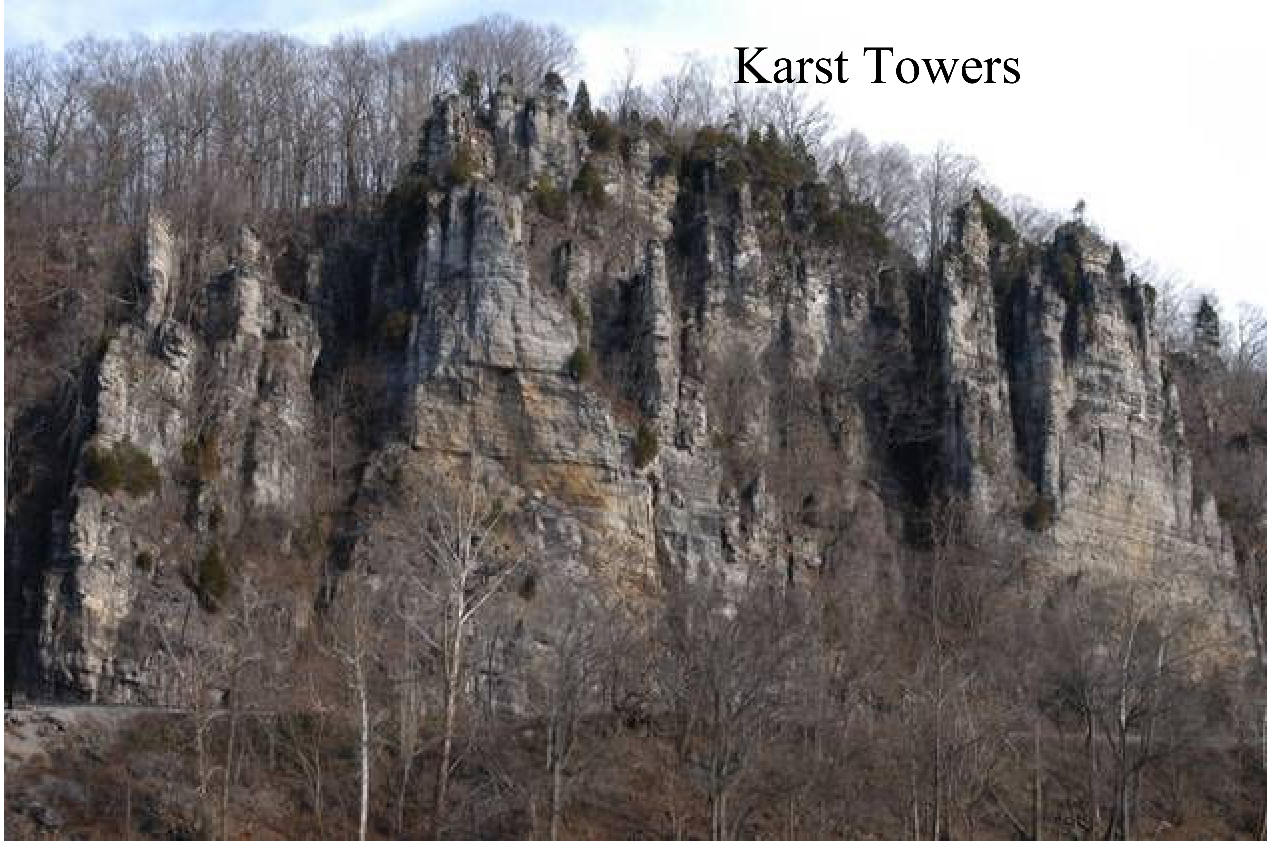
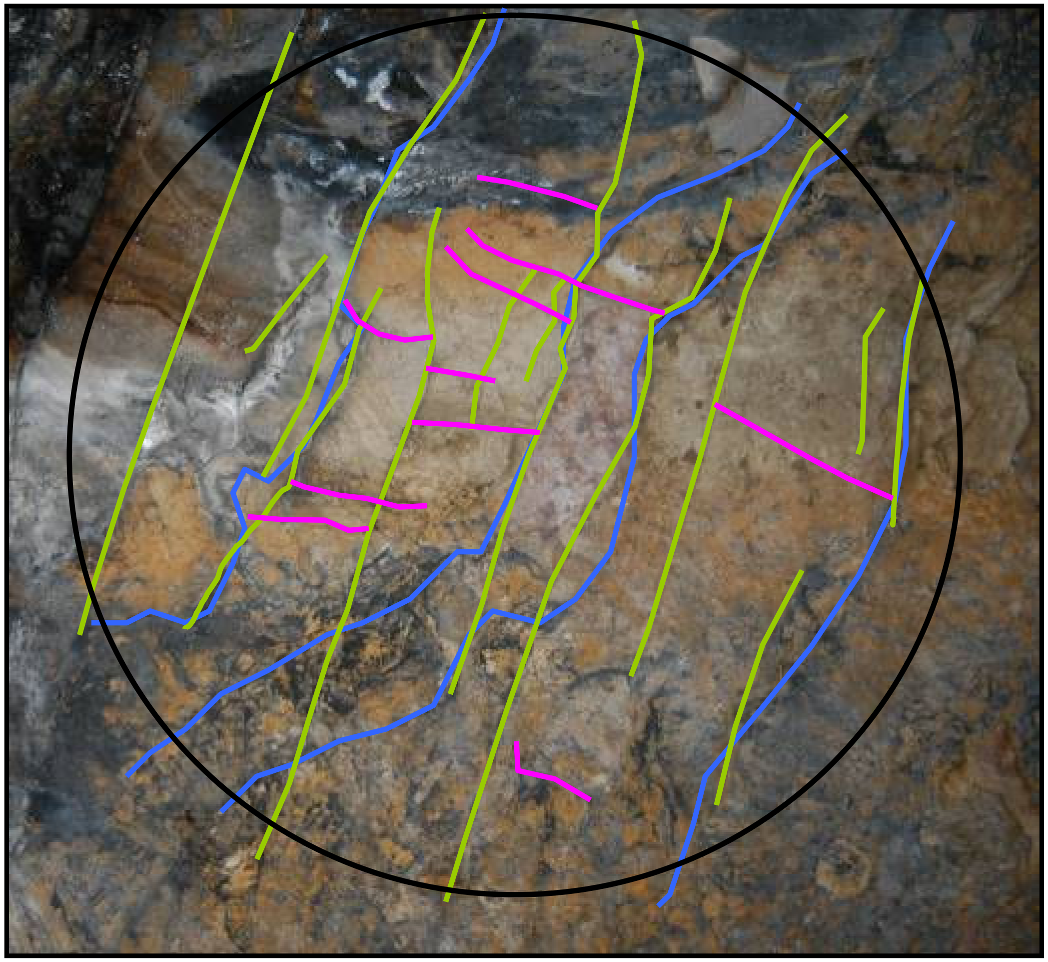
Characterization of fractures within tunnel.

Outline:

- Field observations
- Trace maps
- Statistical tools
- Fracture models

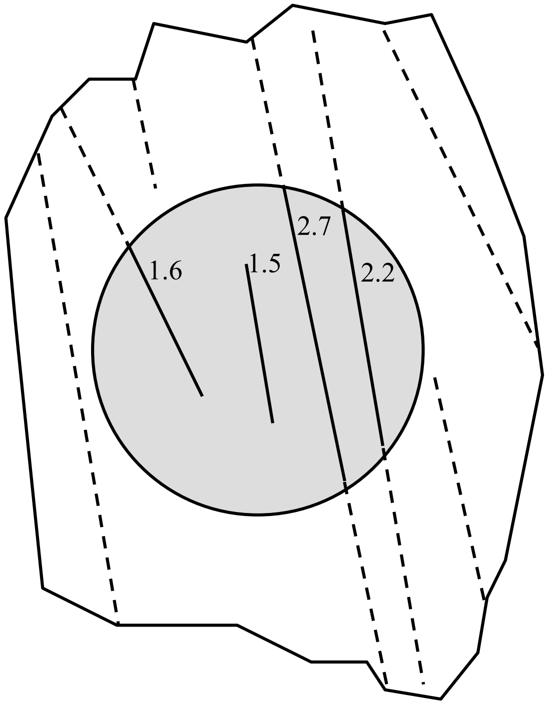

Karst Towers

Tracing fracture trace maps in lab.



Using statistical tools to evaluate trace maps.

Stereological Estimators



Derived stereological estimators

- trace density
- mean trace length

Differential Evolution

Differential Evolution algorithm utilized to infer fracture shape and size from trace data.

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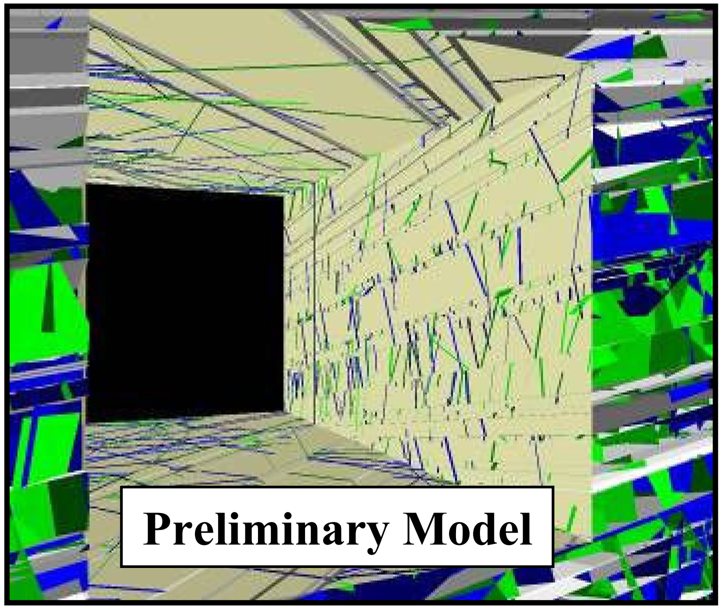
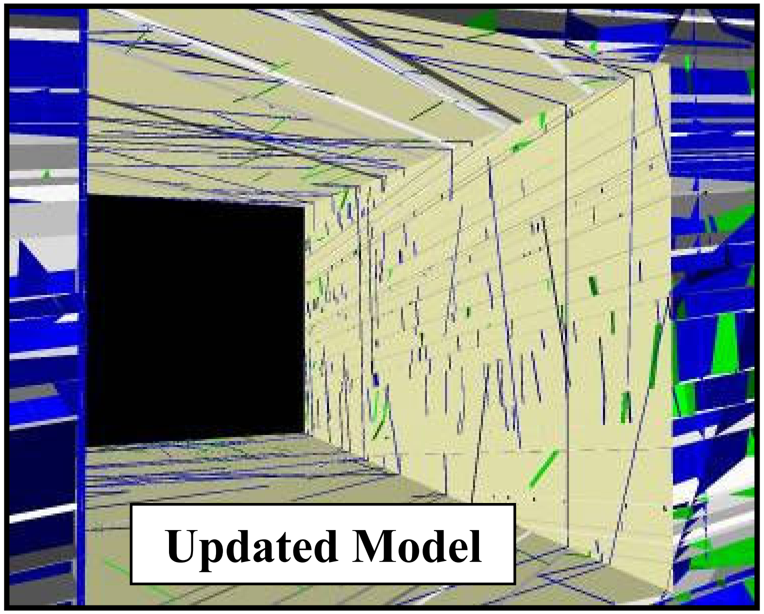
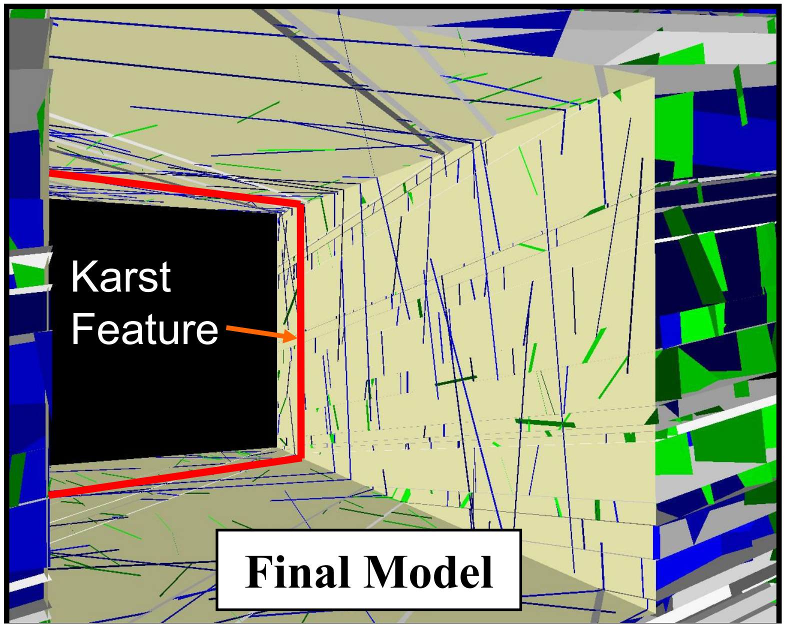
Verify and update fracture models based on data obtained in tunnel



Preliminary Model



Updated Model



Final Model

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Revised Reliability Manual

Start: August 2006 End: May 2007

- Students: Alfredo Arenas and Esther Ryan
- Post – Doctoral staff: Michael P. Navin
- Supervisor: Dr. J. Michael Duncan
- Sponsor: CGPR

Objectives

- To update and revise the current reliability manual to include new reliability methods and more examples

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Reasons for revision of the manual

- The current manual was written 8 years ago
- CGPR members found the manual difficult to use
- New information and methods have been developed
- Many engineers have difficulty estimating coefficients of variation

Revised and Reorganized Content

- Explain the basic concepts – “The language of statistics and probability”
- Add new reliability method - “Hasofer Lind”
- Provide step by step procedure on how to use the “Taylor Series Method” and the “Hasofer Lind Method”
- Use only normal distribution – Exclude the lognormal distribution
- Provide guidance on choosing the coefficients of variation

New Chapter:
“The Language of Statistics and Probability”

Chapter Headings

– Standard Deviation

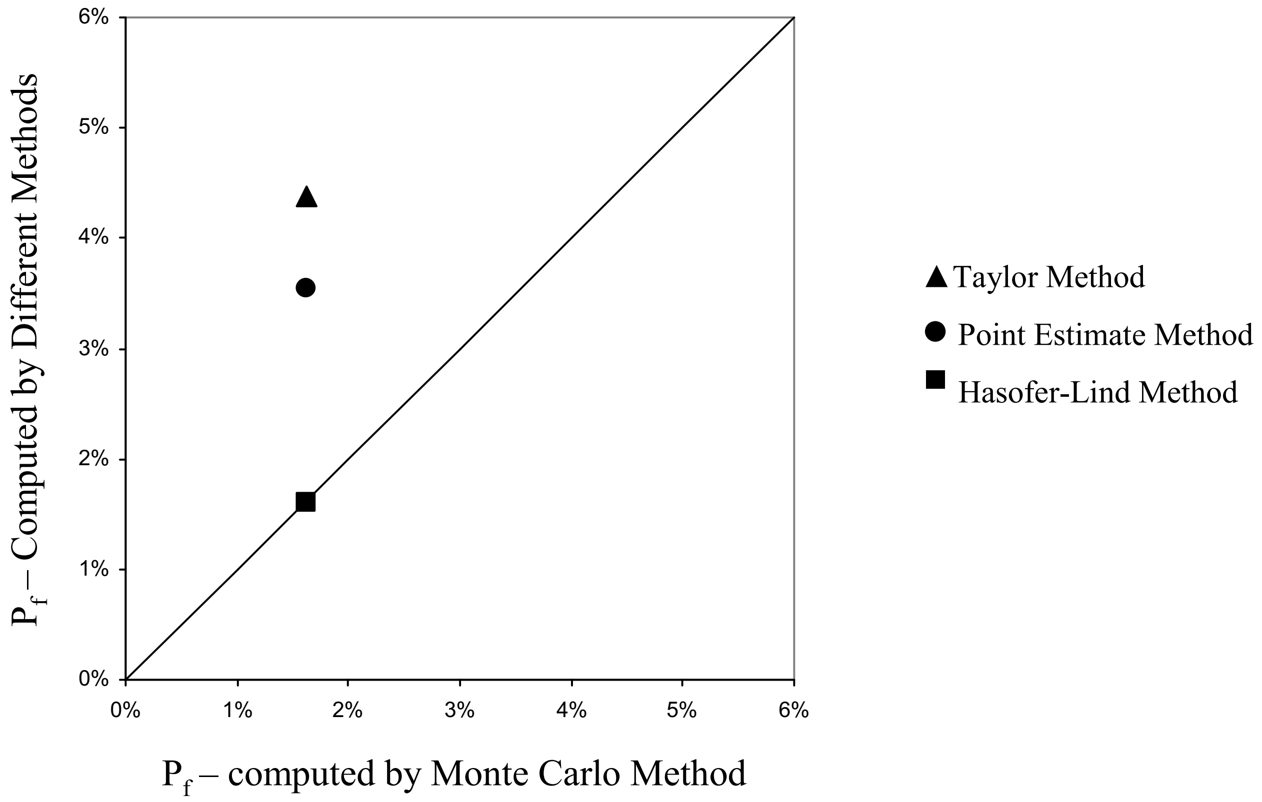
– Coefficient of Variation

– Histograms and Relative Frequency Diagrams

– Probability Density Function

– Normal and Lognormal Distribution, etc.

Hasofer Lind Method



Comparison of values of P_f for sliding mode of a retaining wall

Downdrag and Dragloads on Piles Subject to Negative Skin Friction

Start: August 2006 Projected End: May 2007

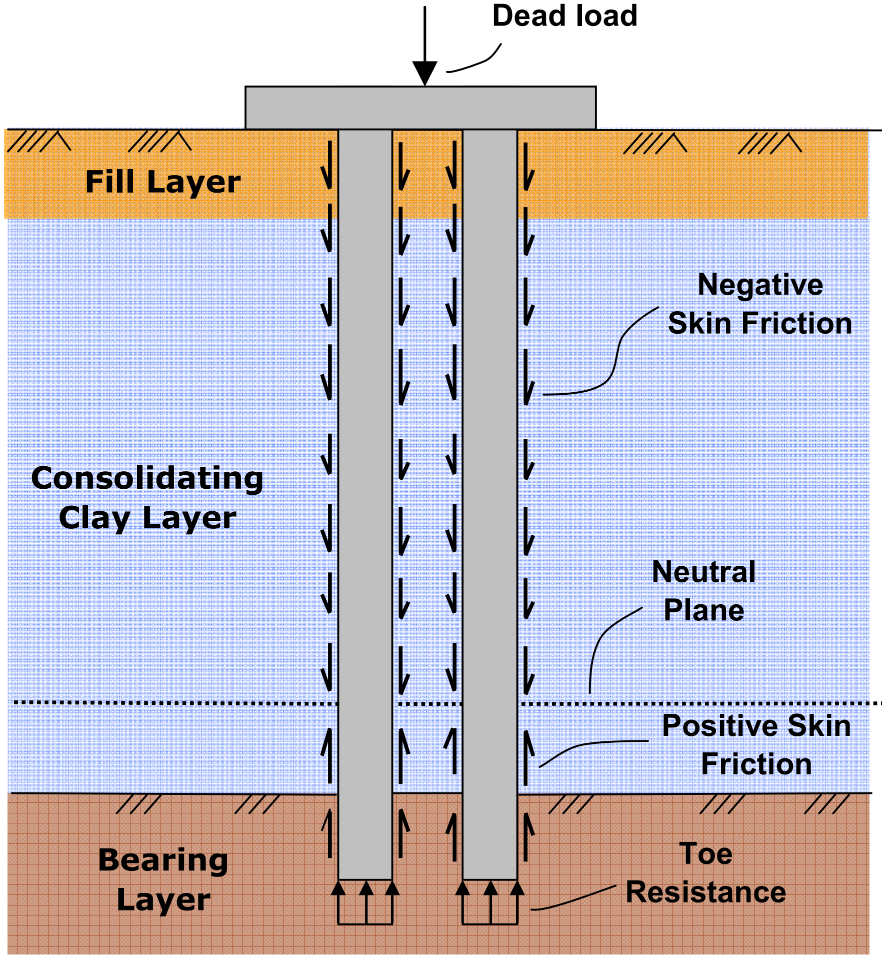
- Student: Mike Greenfield
- Supervisor: Dr. George Filz
- Sponsors: CGPR

<u>Objectives</u>

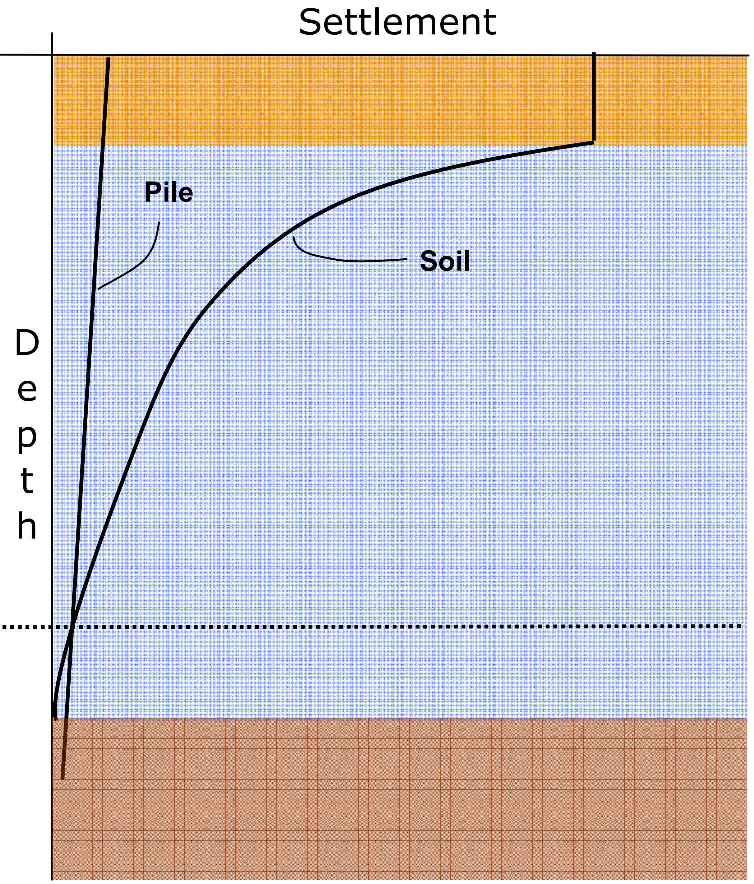
- Evaluate methods of analysis for use in practice
- Provide design recommendations

Review of Downdrag

Pile Group Diagram



Settlement Profile



After NHI Design and Construction of Driven Pile Foundations Workshop Manual, 1996

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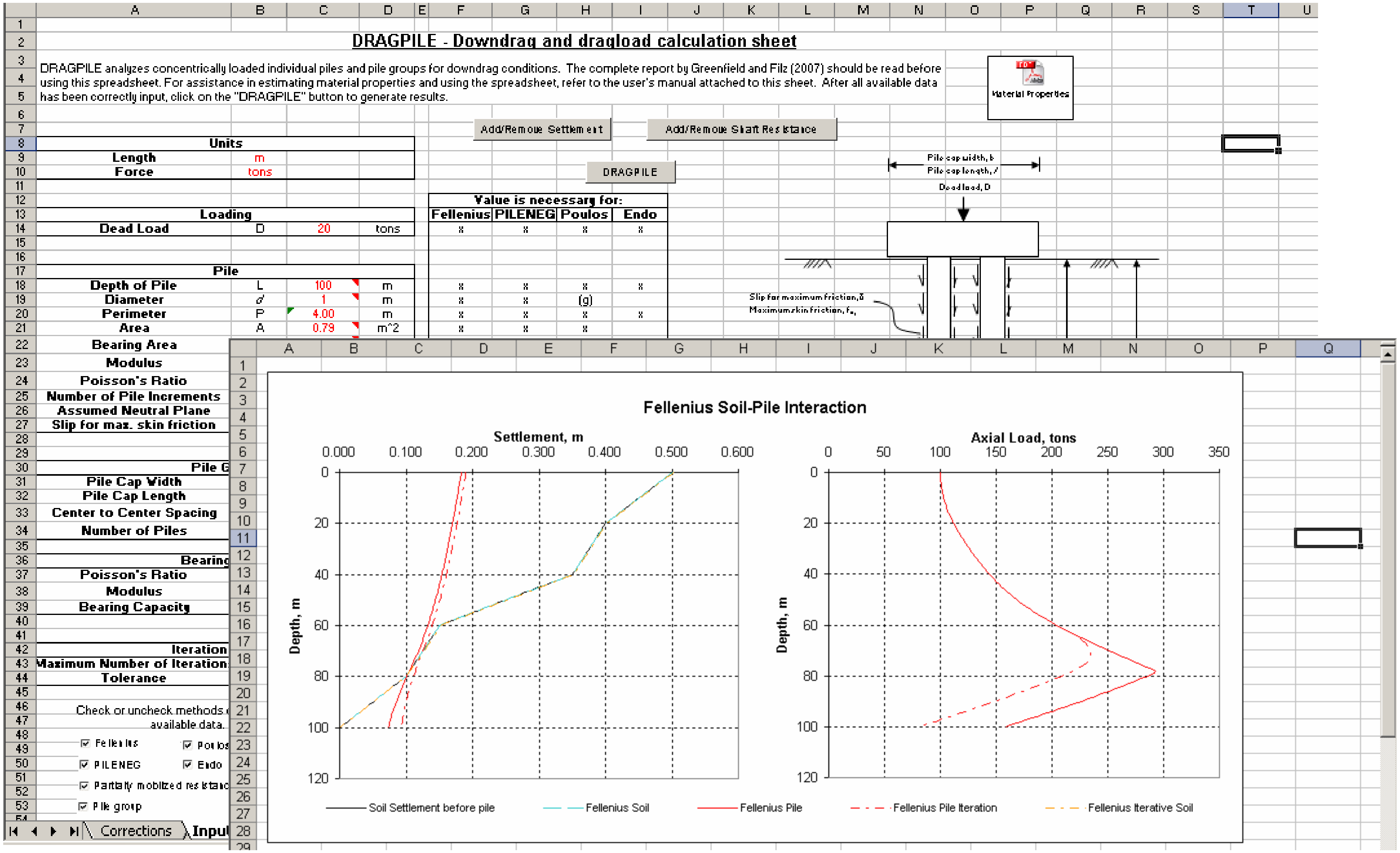
Scope of Project

- Methods of analyzing downdrag on single piles
  - 4 practical methods
  - 2 adaptations of practical methods
  - Microsoft Excel® Worksheet - DRAGPILE
- Pile group effects
- Material property guidance
- Design criteria

DRAGPILE – screen shots



DRAGPILE - Downdrag and dragload calculation sheet

DRAGPILE analyzes concentrically loaded individual piles and pile groups for downdrag conditions. The complete report by Greenfield and Filz (2007) should be read before using this spreadsheet. For assistance in estimating material properties and using the spreadsheet, refer to the user's manual attached to this sheet. After all available data has been correctly input, click on the "DRAGPILE" button to generate results.

Units			
Length	m		
Force	tons		

Loading				Fellenius	PILENEG	Poulos	Endo
Dead Load	D	20	tons	x	x	x	x

Pile				Fellenius	PILENEG	Poulos	Endo
Depth of Pile	L	100	m	x	x	x	x
Diameter	d	1	m	x	x	(g)	
Perimeter	P	4.00	m	x	x	x	x
Area	A	0.79	m^2	x	x	x	
Bearing Area							
Modulus							
Poisson's Ratio							
Number of Pile Increments							
Assumed Neutral Plane							
Slip for max. skin friction							

Value is necessary for:

Pile G	
Pile Cap Width	
Pile Cap Length	
Center to Center Spacing	
Number of Piles	

Bearing	
Poisson's Ratio	
Modulus	
Bearing Capacity	

Iteration	
Maximum Number of Iterations	
Tolerance	

Check or uncheck methods available data.

☑ Fellenius ☑ Poulos
☑ PILENEG ☑ Endo
☑ Partially mobilized resistance
☑ Pile group

Remaining Research

- Compare methods with case histories
  - –Which methods to use in which situations?
- Develop guidance for estimating material property values
- Recommend appropriate design criteria

Soil and Rock Modulus Correlations for Geotechnical Engineering

Start: September 2006 End: February 2007

- Student: Andrew Bursey
- Supervisor: Mike Duncan
- Sponsor: CGPR

Objectives

- Define stress-strain parameters and interrelationships
- Evaluate factors that control soil stiffness
- Provide useful correlations between soil and rock mass modulus and in situ and laboratory test results, and guidance for their use

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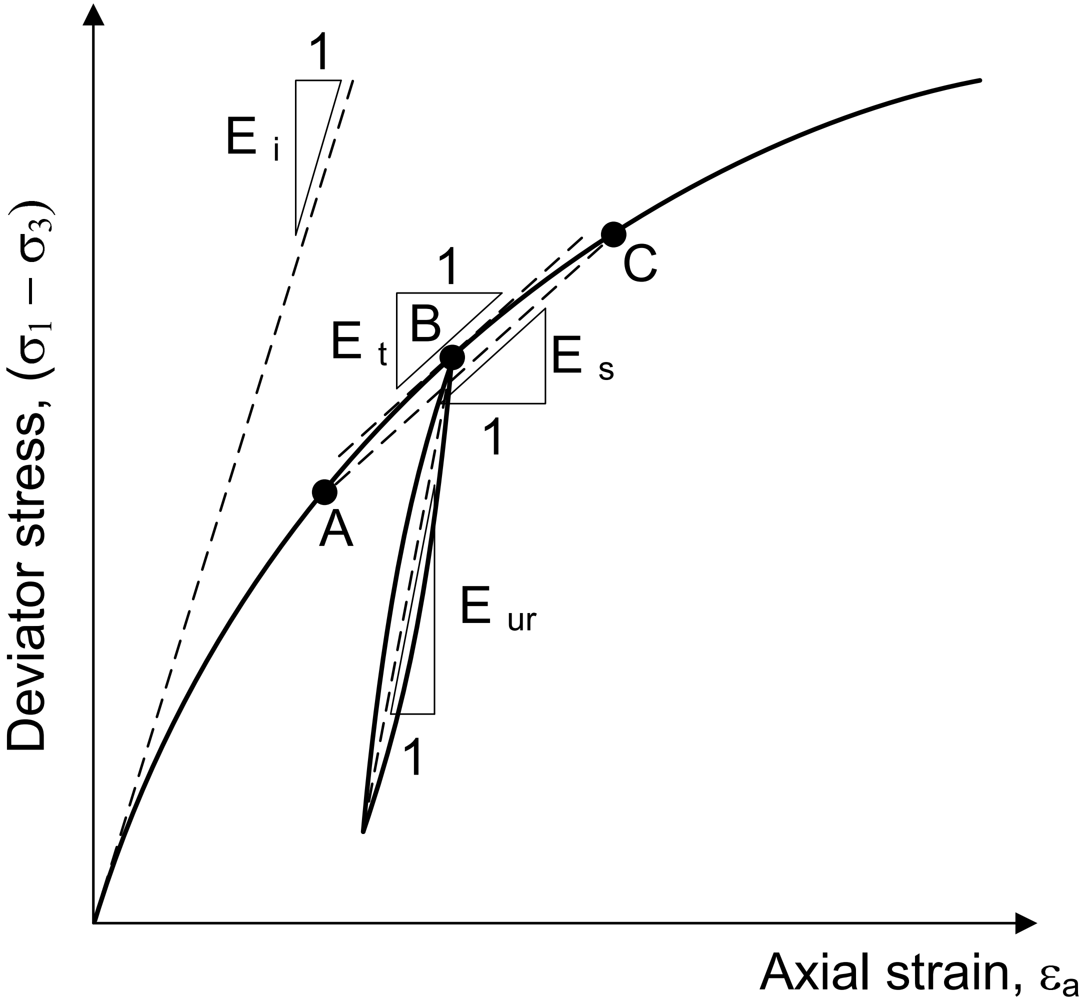
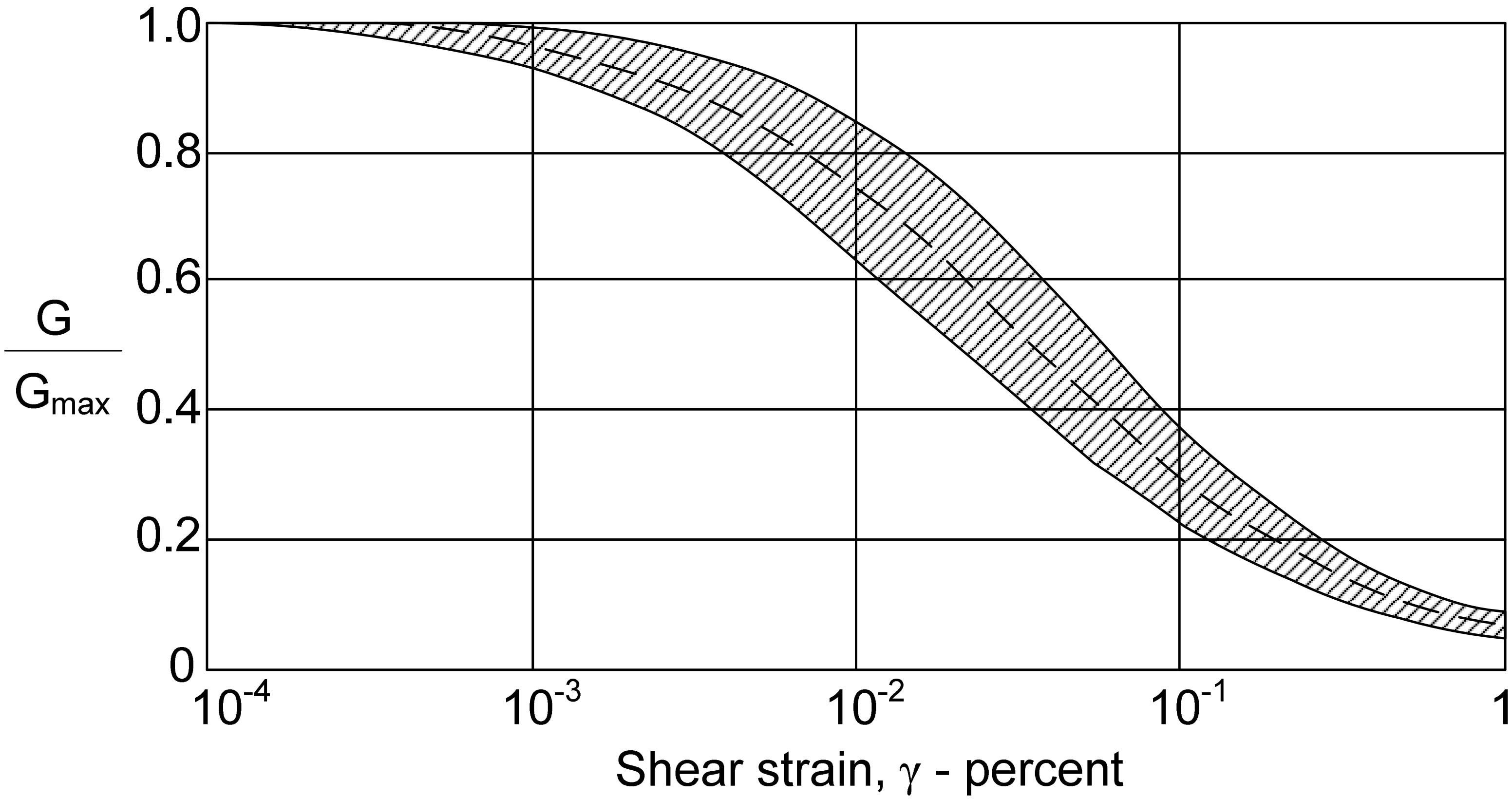
There are many ways to characterize soil stiffness



Soil stiffness decreases with increasing strain the effect is called “modulus degradation”



(Seed and Idriss, 1970)

Problems with modulus correlations

- Many correlations between modulus values and in situ or lab test results are available
- BUT, variations among them are large because of differences in
  - type of modulus (E, G, M),
  - stress state (E_i, E_t, E_s), and
  - strain magnitude (10^{-4} percent to 1 percent)

Guide to modulus correlations

Type of modulus and type of soil	**Basis for estimating modulus value**		
	SPT data	CPT data	---- Etc.
E_i for compacted (CL) clays			
M'_s for sand	**Figure 11**		
---- Etc.			

Leaching of Lime-Treated Soil

Start: May 2006 End: February 2007

- Students: Jaime Colby and Jessa Corton
- Supervisors: Dr. George Filz and Dr. Thomas Brandon
- Sponsors: J.H. Becker Company, Inc.

Primary Objective

– to determine the effects of leaching on the engineering properties of lime-treated soil.

Motivation:

- Extensive and increasing use of lime for subgrade stabilization and borrow stabilization.
- Concern about long-term strength of stabilized ground due to leaching

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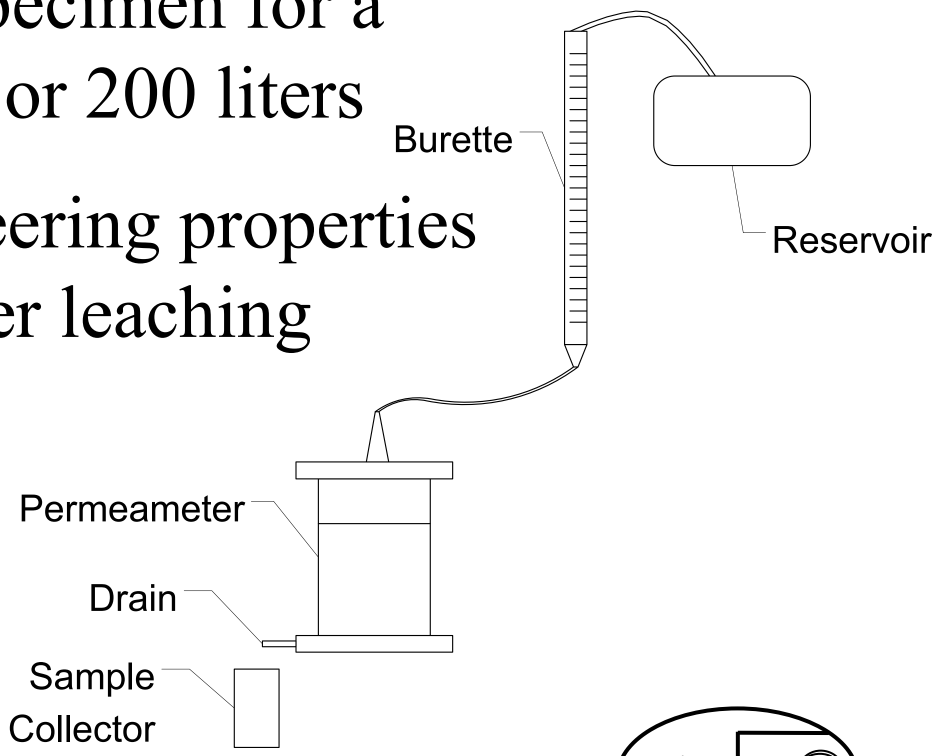
Procedure:

- Determine the engineering properties of the treated soil before leaching
- Leach lime-treated specimen for a minimum of 45 days or 200 liters
- Determine the engineering properties of the treated soil after leaching

JC1

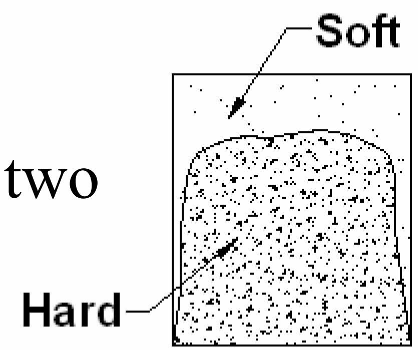


Slide 99

JC1 which includes the untreated and 0.5%, 2%, 4%, and 6% lime-treated soil.

Jessa Corton, 2/6/2007

Results:



- Post-leached specimens were found to have two different zones: hard and soft
- Plasticity index

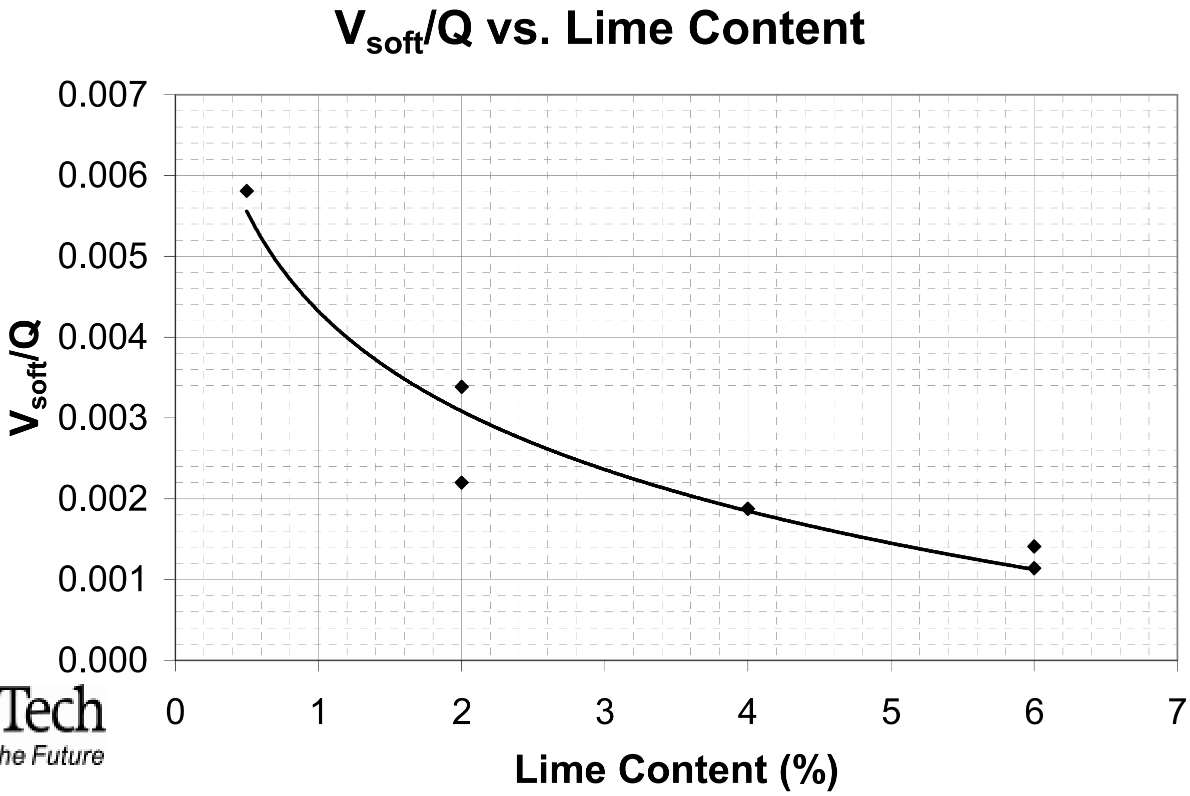
Lime Content (%)	Plasticity Index		
	Pre-leaching	Post-leaching Hard	Post-leaching Soft
0	28	---	---
0.5	18	20	20
2	11	28	40
4	NP	18	37
6	NP	ND	34

- Grain-size

Soil	Percent Passing No. 200
Untreated	90.9
Pre-leaching	66.9
Post-leaching Hard	76.3
Post-leaching Soft	91.9

Conclusions:

- Leaching has adverse effects on lime-treated soils
  - – Increases plasticity
  - – Reduces average grain-size
- Correlation between softened volume, V_{soft} , normalized by quantity of water, Q, versus lime content JC2



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JC2 This research provides information about the effects of leaching on one particular lime-treated soil. It is not intended to replace laboratory testing for site specific projects utilizing lime treatment.

Jessa Corton, 2/6/2007

Geotechnical Specifications of Little League Ballfields

Start: November 2006 End: December 2007

- Student: Tim Moore
- Supervisor: Dr. Thomas L. Brandon, Dr. Naraine Persaud, Dr. Mike Goatley
- Sponsors: USDA-Agricultural Research Service (ARS)

Objectives

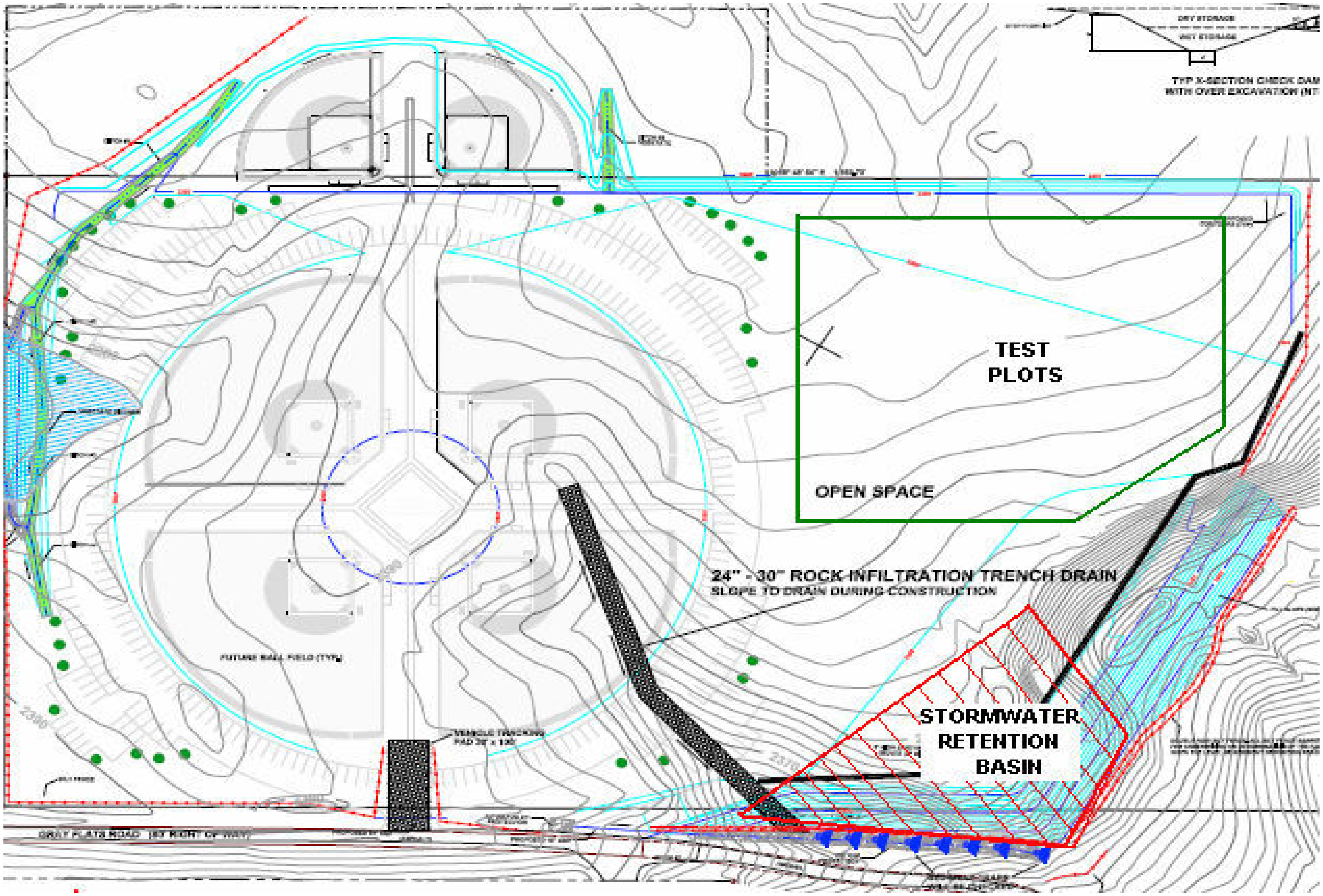
- To examine the application of current geotechnical specifications for little league ballfields
- To provide geotechnical quality control assistance during the construction of the ballfields

Little League Ballfields – Beckley, WV

Project Aspects:

- Construction of Ballfields
  - Recommend geotechnical specifications
  - Provide light quality control measures for compaction
- Research Plots
  - 3 test plots – differing compaction and soil treatments
  - Irrigated by on-site stormwater-retention basin
  - Long-term research to relate relative compaction, playability, and turf growth

Site Plan & Details



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Current ASTM Specifications

- ASTM Section 15.07 – Sports Equipment and Facilities:

  - Specifications and test methods for shock-absorbing and impact-attenuation of sports field playing surfaces

- ASTM Sections 4.08 & 4.09 – Soil and Rock:

  - Specifications and test methods for relative compaction, and impact values of soils

Research Test Plot Details

- 3-plots, each with a different level of compaction (80%, 85%, & 90% of standard Proctor)
- Each plot will have different soil/turf treatments (VT CSES Dept)
- Plots will be tested using current ASTM specifications to examine their applications (compaction, shock attenuation)
- Plots will be monitored long-term for differential settlement, and turf growth
- The on-site storm water retention pond will be used to irrigate the test plots, along with the ballfields
- Graded mine spoils will be used for the subgrade of the plots to present a suitable turf growth material

Central and Eastern United States Seismic Implications

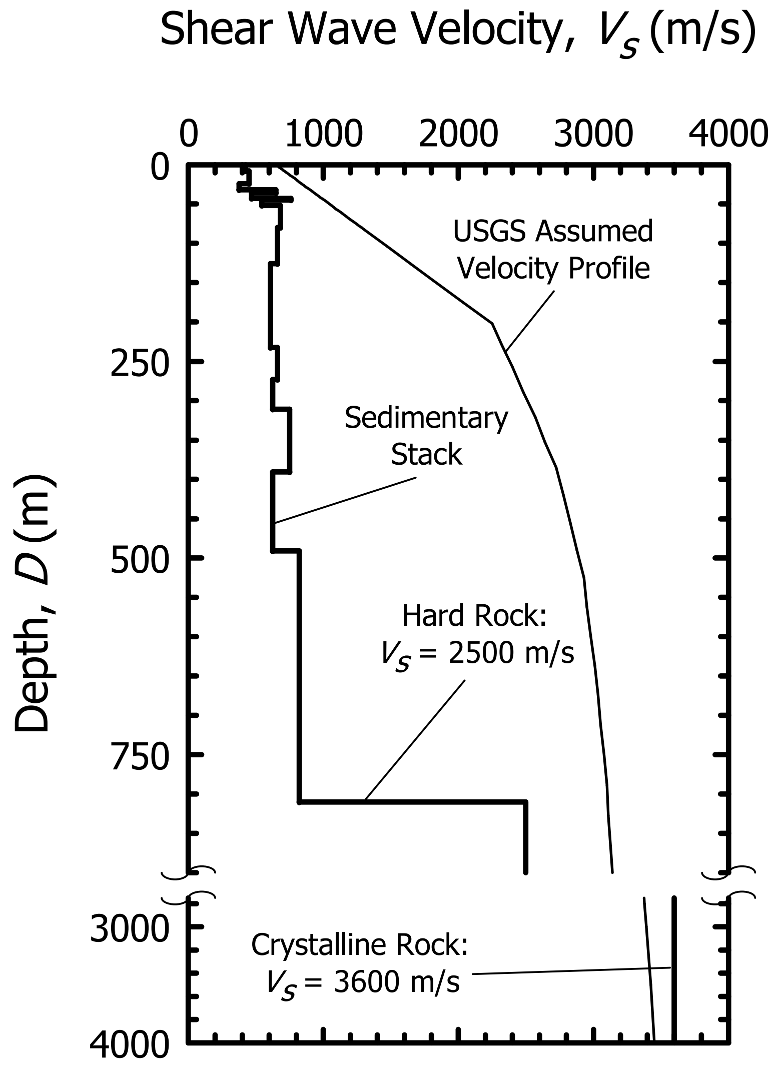
Start: Summer 2006 End: Summer 2007

- Student: Morgan Eddy
- Supervisor: Dr. James Martin
- Sponsors: ECSUS

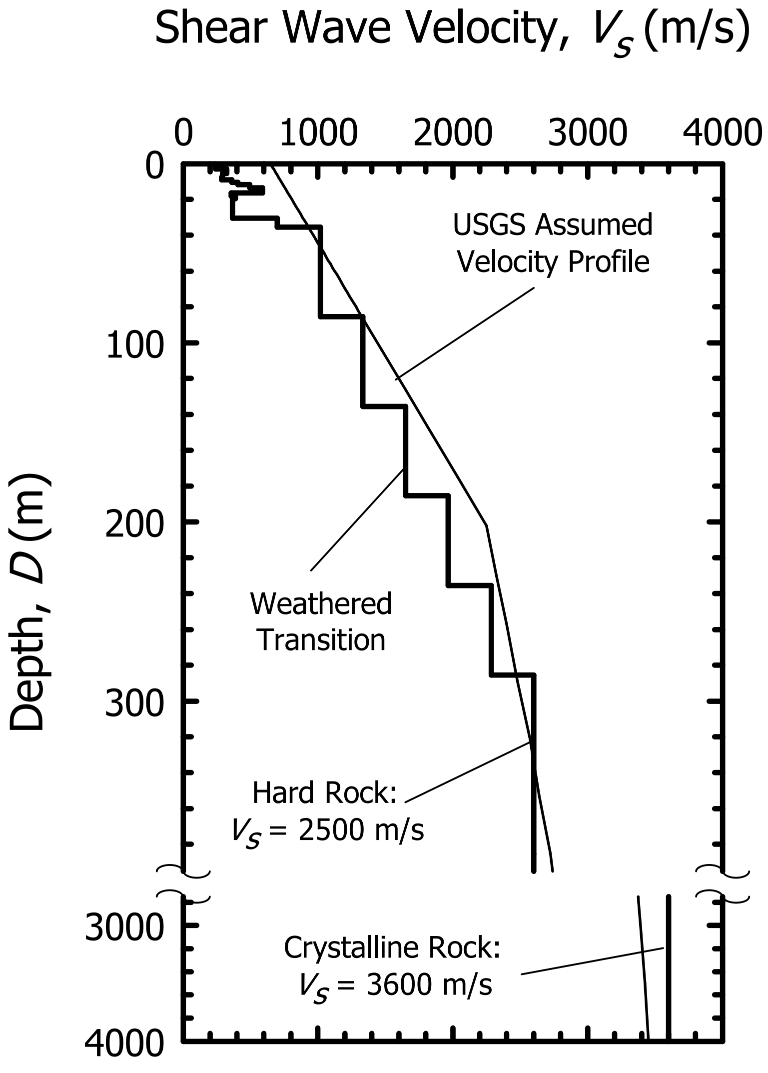
Objectives

- Investigate impact of CEUS geologic conditions on the International Building Code Seismic provisions
- Perform site response analyses of CEUS sites to assess implications of the IBC
- Provide recommendations for performing site response analyses of sites in the CEUS

Geologic Conditions



Charleston, S.C.

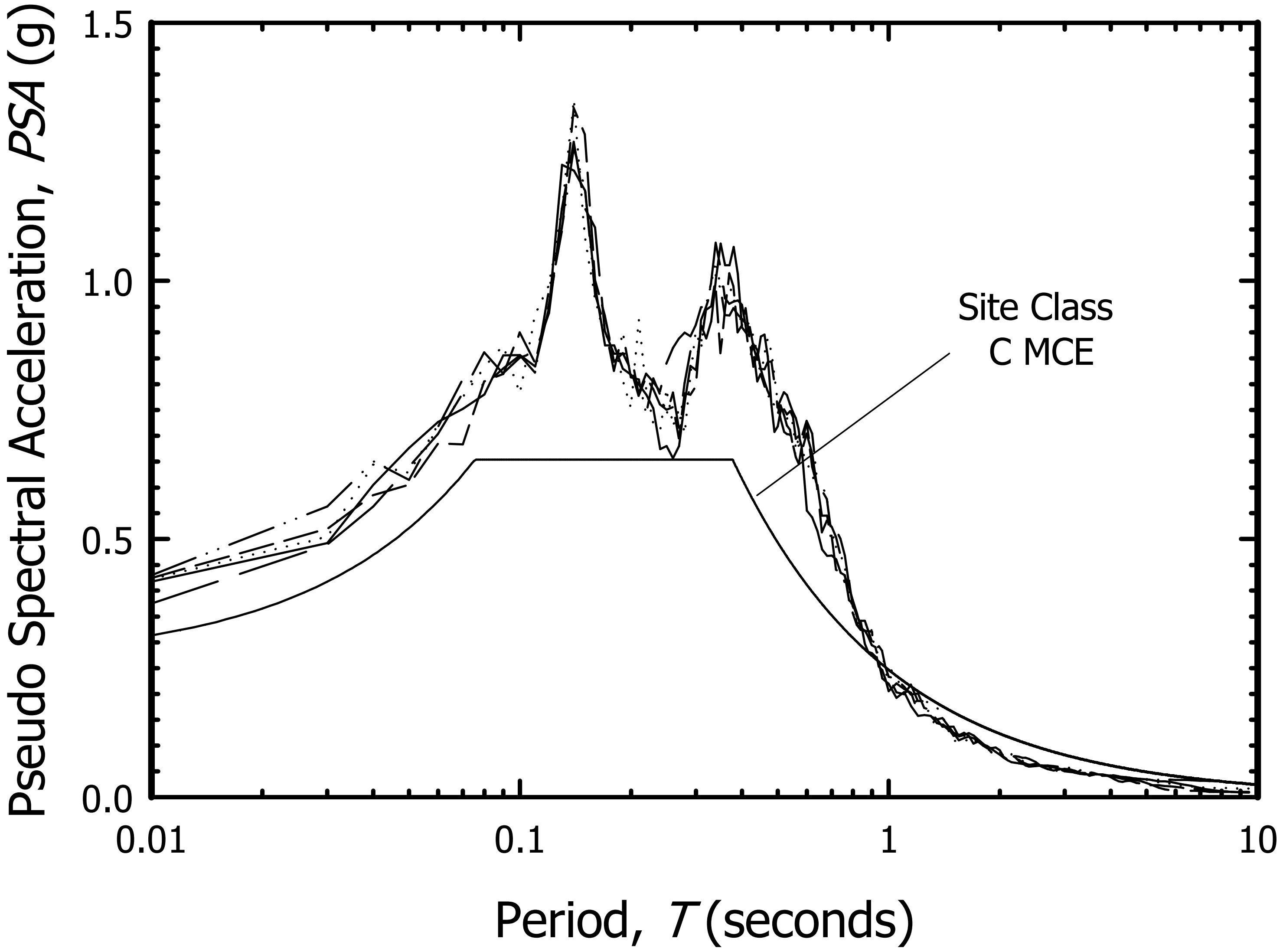


Columbia, S.C.

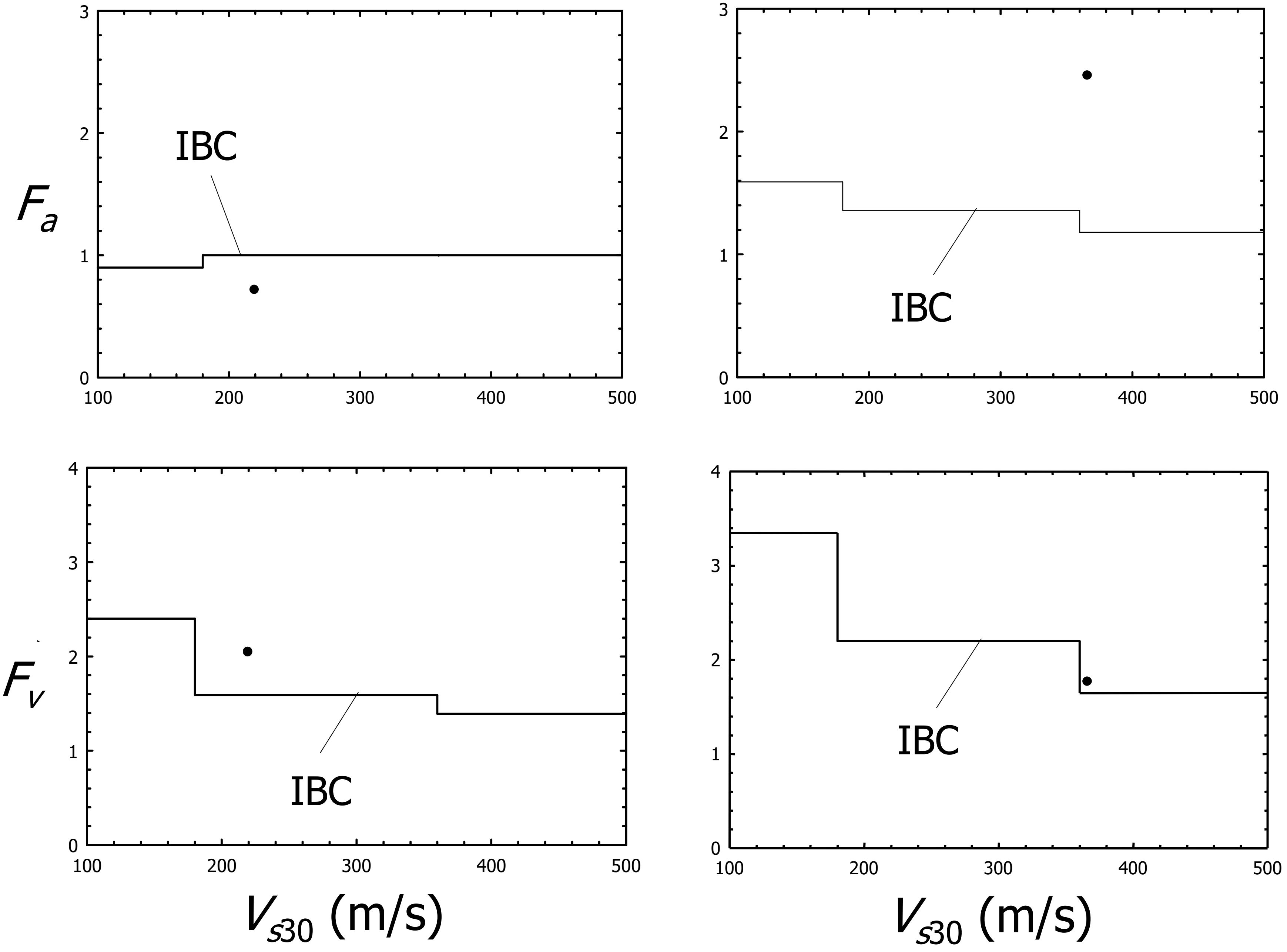
VirginiaTech
Invent the Future

CGPR

Response Spectra



Amplification Factors



Conclusions

- Geologic conditions found in the CEUS are not represented in the recent building codes
- Deep soil sites, such as in Charleston, can amplify long period motions above code values
- Sites where the hard rock is relatively close to the ground surface can amplify a broad range of motions above the code values
- Site amplification factors need to be adjusted to account for the conditions found in the CEUS