Structural, Material, and Geotechnical Solutions to Levee and Floodwall Construction and Retrofitting

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Title Page

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Project Description

- Forensic investigation of New Orleans levee failure found triggering mechanisms that caused structural underperformance, progressive and catastrophic failure of the flood protection system. The current research combines the structural, geotechnical, and material technologies to provide resilient solutions that can hold/stop the triggering mechanisms of the levee failure.

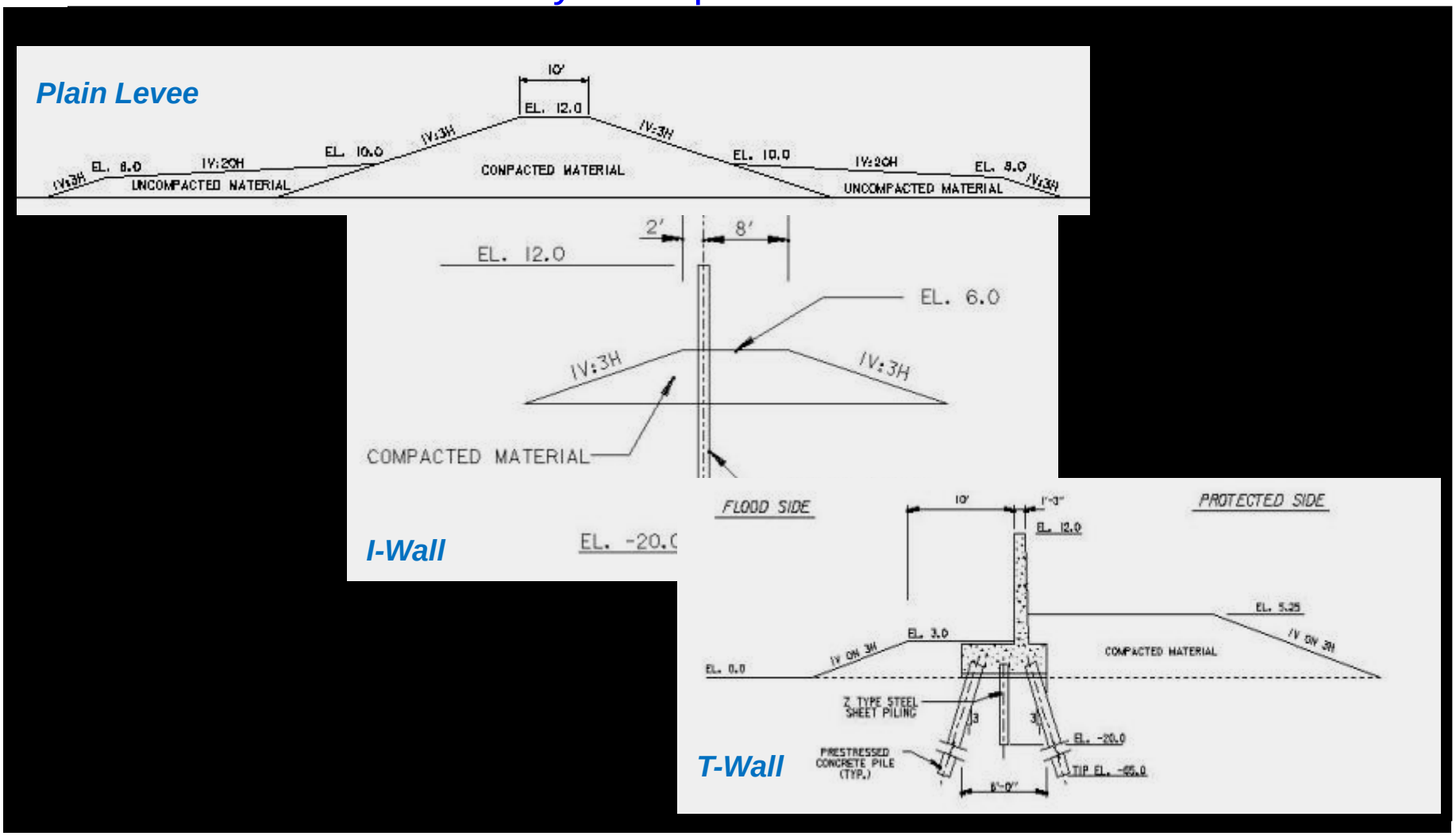
- The technologies developed in this study can be used for cost effective levee and floodwall retrofitting and new construction.

Capability Requirement Gap

- Nation's flood protection system should provide adequate protection from hostile weather conditions.
- Current practices of levee design, construction, and maintenance could not provide adequate protection as shown during Hurricane Katrina, 2005 and several other severe weather conditions. Unprecedented severe weather condition might be due to global warming, but we should prepare for worse conditions.
- Building even more massive flood protection systems will require substantial monetary burdens. This study develops a technique that is economic but provide multiple layers of protection to existing and new flood protection system.
- The product of this result will stop/hold triggering mechanisms of levee failure so the levees can survive severe weather conditions. The product of this research can be used for innovative and resilient but economic solutions for retrofitting existing levees and designing new walls.
- Direct cost/benefit is not computed this study.

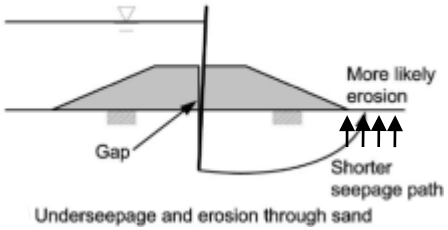
Overview

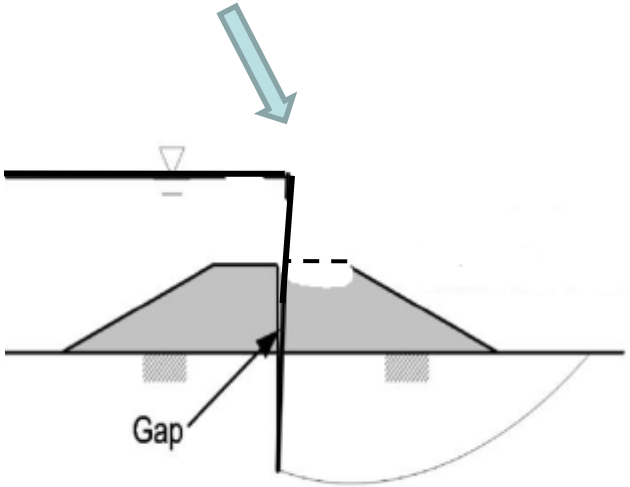
General schematics of major hurricane protection structures in New Orleans and many other places.

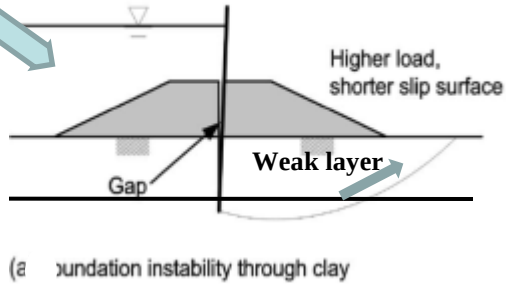


Overview
Failure Mechanisms during Katrina

- **IPET investigated 4 major failure mechanisms**
  - Gap Formation- almost all breaches
  - Piping failure- London Canal Ave. South
  - Shear failure of the weak soil- 17th St. Canal
  - Erosion- IHNC



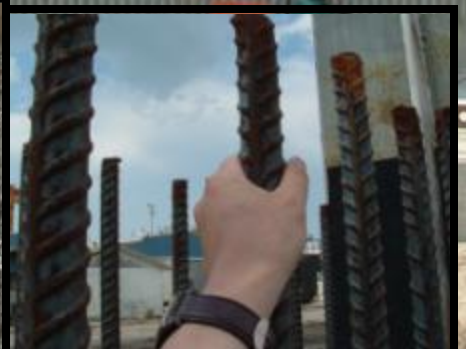




(Duncan Et al. 2008)

I-WALL

T-WALL



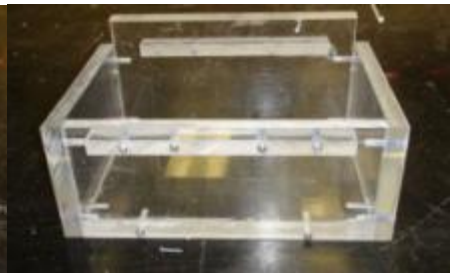
Soil Erosion

- Soil erosion test
- Soil erosion analysis
- Soil erosion countermeasures
  - Erosion energy dissipation structure
  - Developing erosion resistance soils

Soil Erosion

Tests using UM Erosion Test Bed

Adjustable Flow Rate:
2600, …460 k Gal/hr
Adjustable Nozzle Size/Type

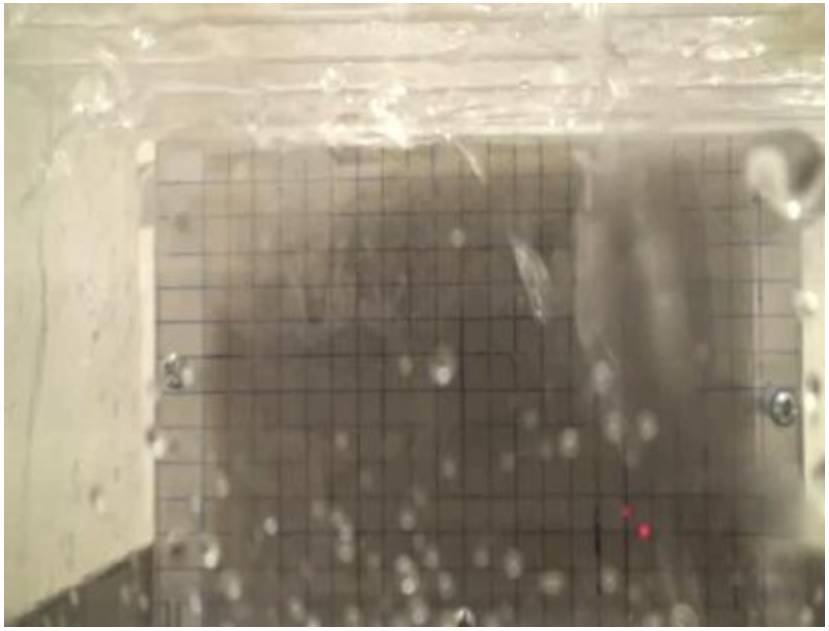


Use a digital video camera to record and analyze the erosion process.

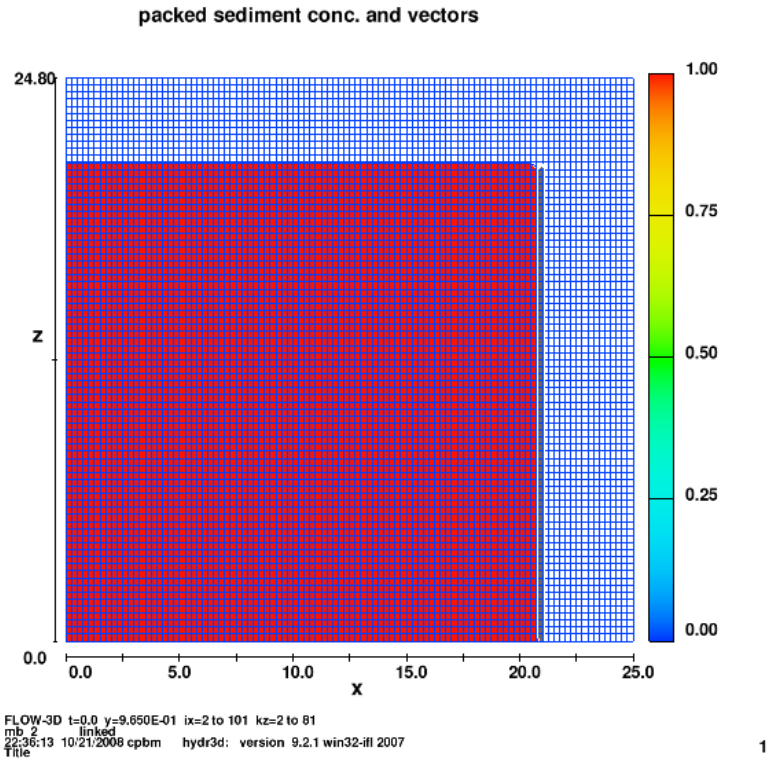
Soil Erosion

UMETB Test and Numerical Verification for ASTM C-190 Ottawa Sand

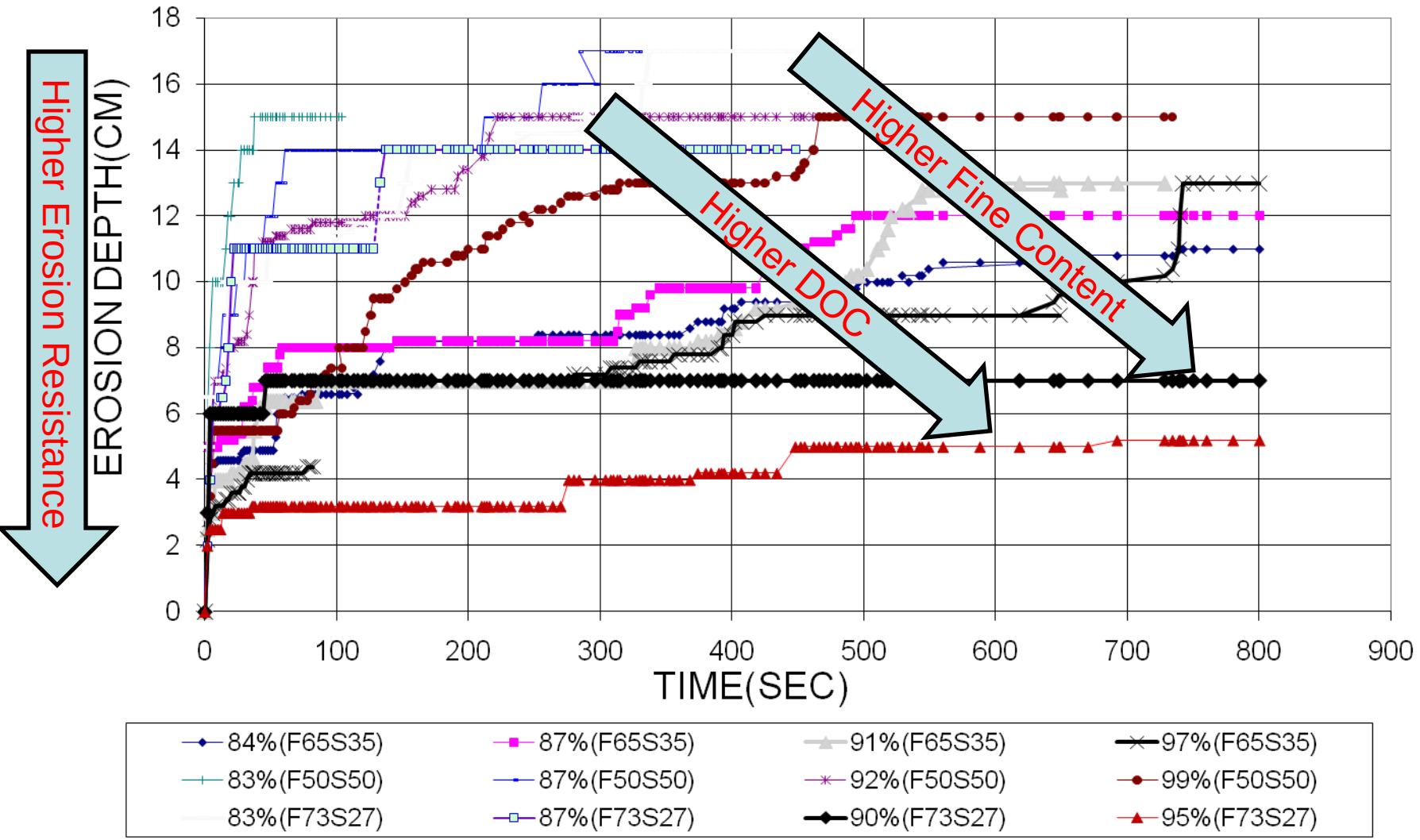
Experimental Result with 7600 gal/hr Flow Rate



Analytical Result with 7600 gal/hr Flow Rate

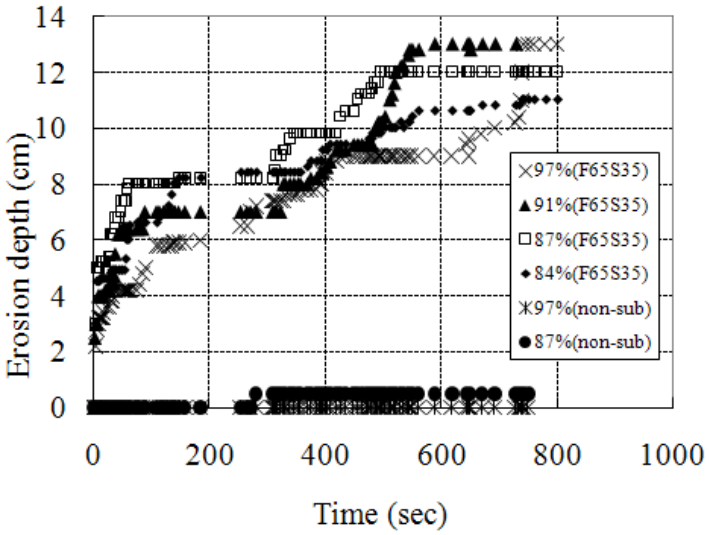


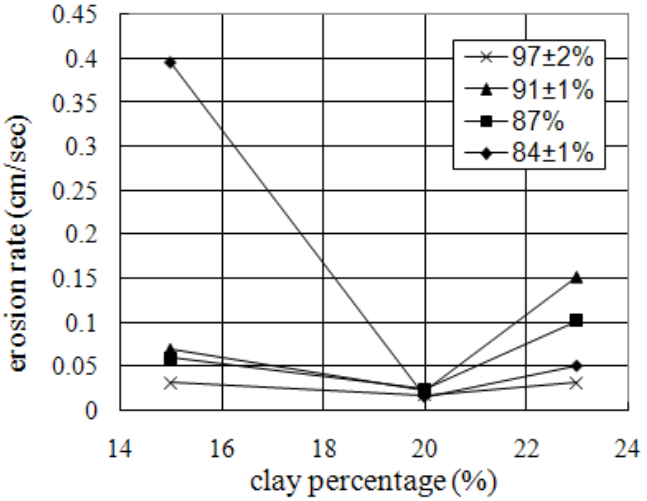
Soil Erosion
(Erosion Test)



Soil Erosion

Erosion resistance of Actual Levee Materials





Soaked soils showed much weaker erosion resistance.

Need to modify test procedure.

Expansive clay minerals should be avoided!

Higher clay contents do not always increase the erosion resistance.

Critical clay contents concept is needed in Levee material specification.

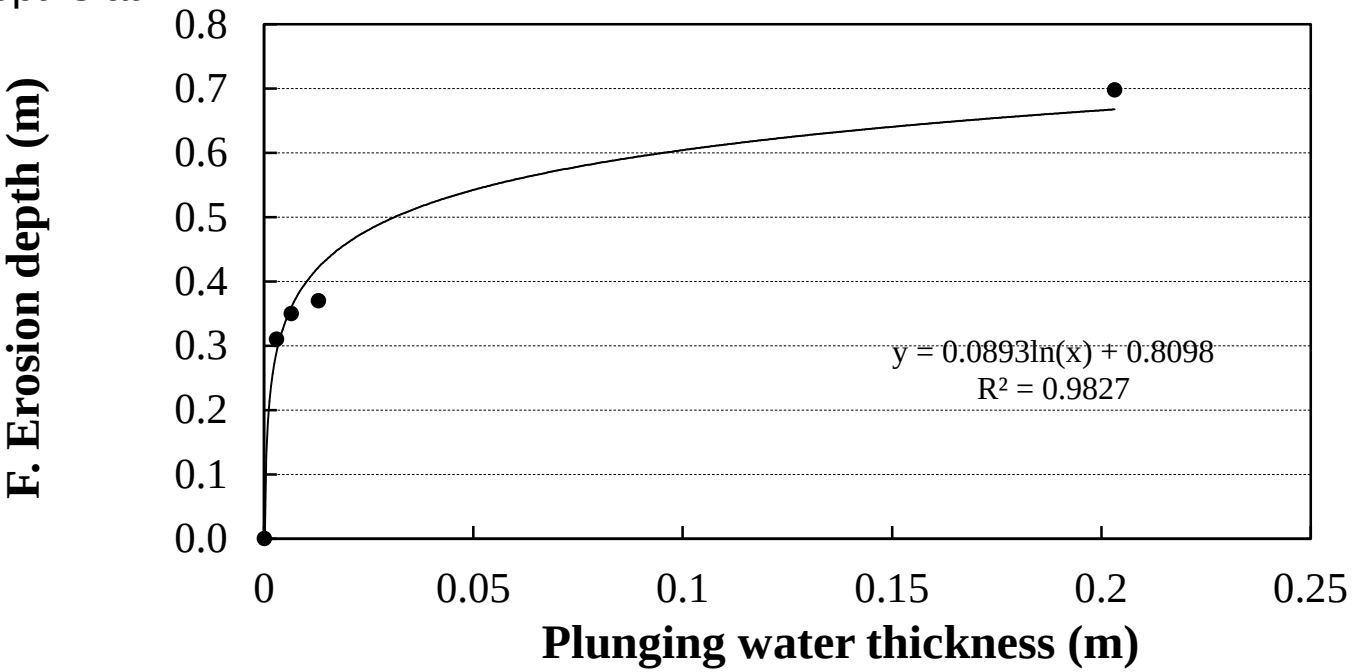
Soil Erosion

(Prediction of Erosion Depth)

Predicted Erosion Depths at IHNC: 1.3-3.42 m

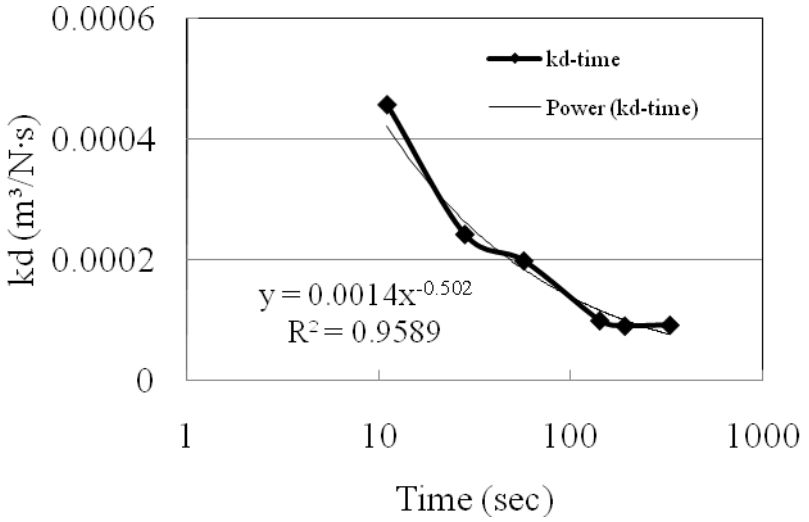
Observed Erosion Depths at IHNC: 1.98-4.57 m

Aeration! Eqn's are developed for air to air jet.



How can we fill the gap?

Erosion depth prediction



- Governing Equation

  Excess shear stress concept

$$\frac{dD}{dt} = k_d(\tau_0 \frac{D_p}{D} - \tau_c)$$

Field equation

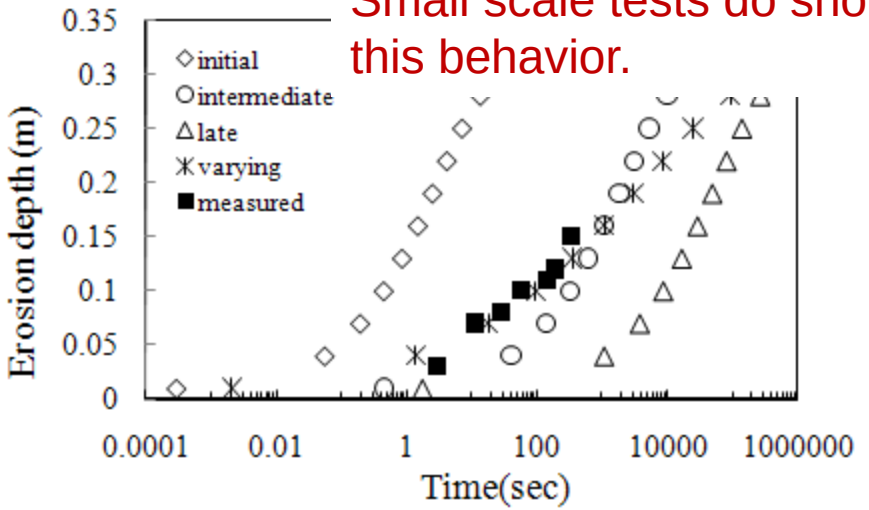
$$t = \left[51.46 \left\{ \frac{21D^2}{2.28 - 6.92D} - \frac{D - 0.0165}{0.33} + \ln\left(\frac{0.3135}{0.33 - D} \right) \right\} \right]^2$$

Erosion coefficient is not a constant!

Small scale tests do show this behavior.

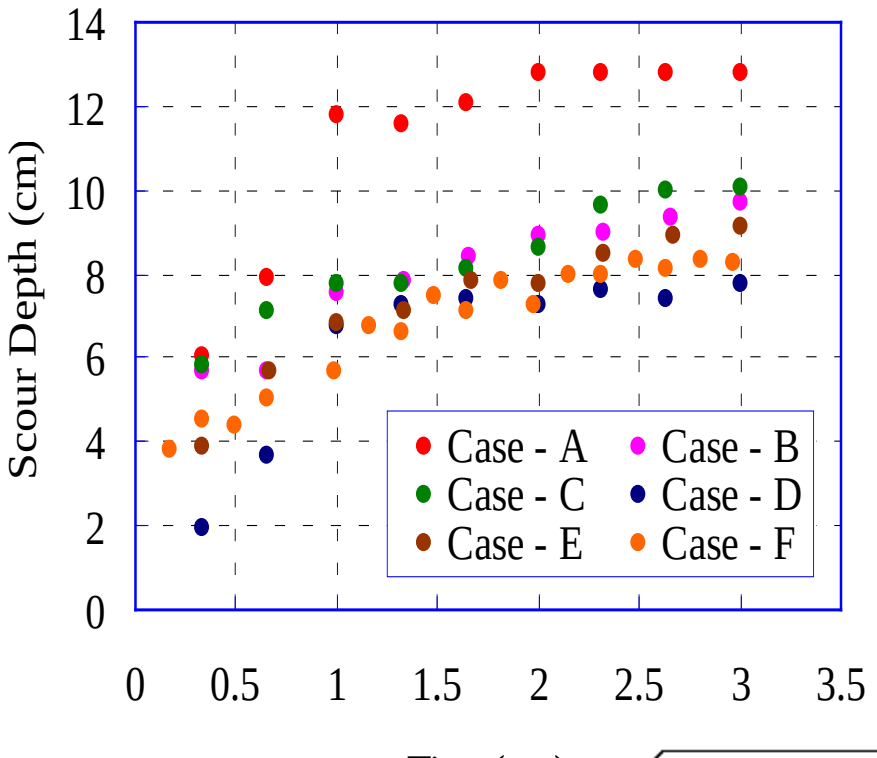
Predicted Erosion Depths at IHNC: 1.3-3.42 m

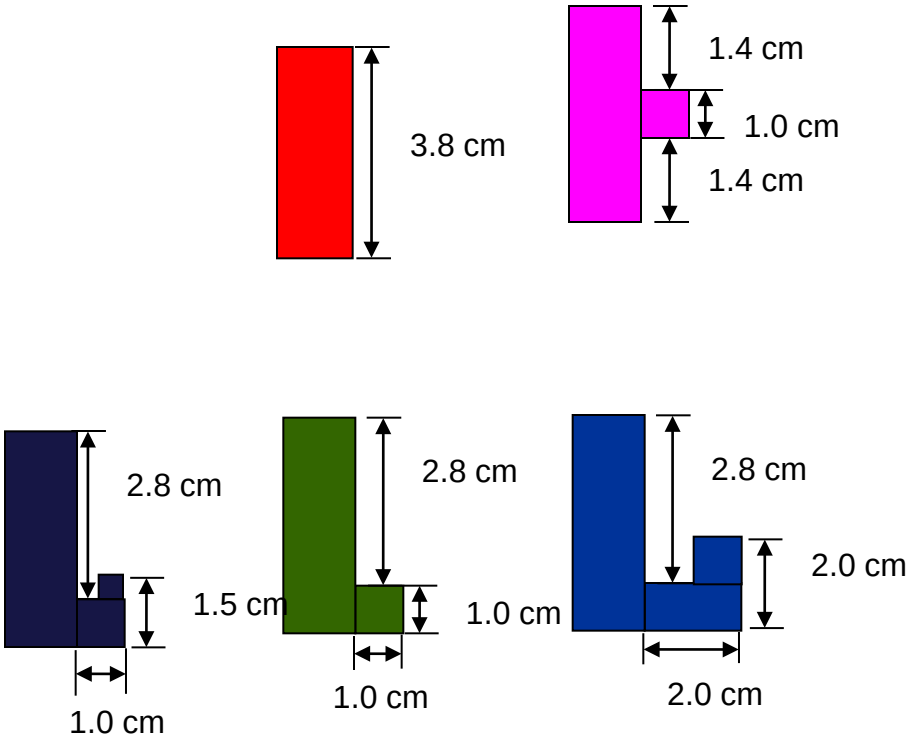
Observed Erosion Depths at IHNC: 1.98-4.57 m



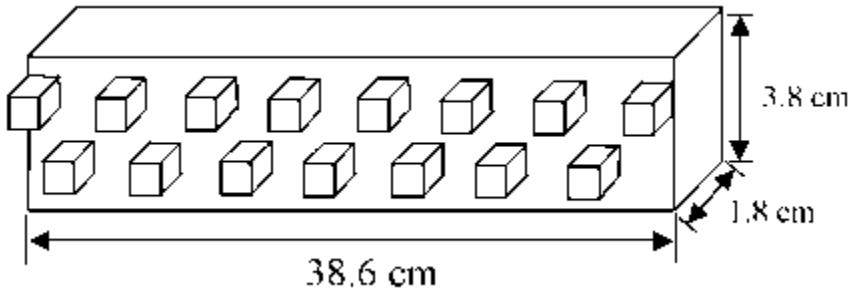
Soil Erosion

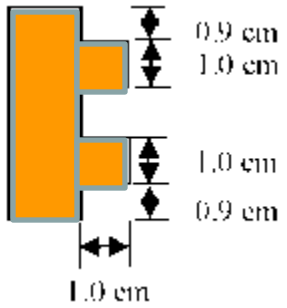
Evaluation of water breaking structure to reduce erosion for ASTM C-109 Ottawa Sand





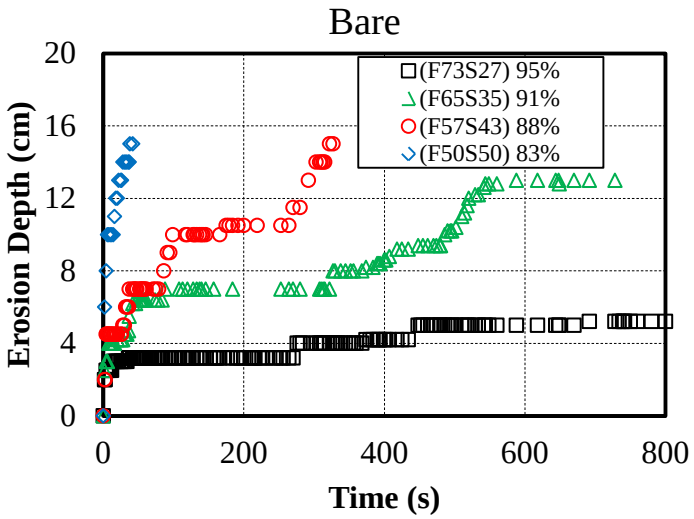
Water breaking structure could reduce the erosion depth as much as 40%, erosion time as much as 400%.

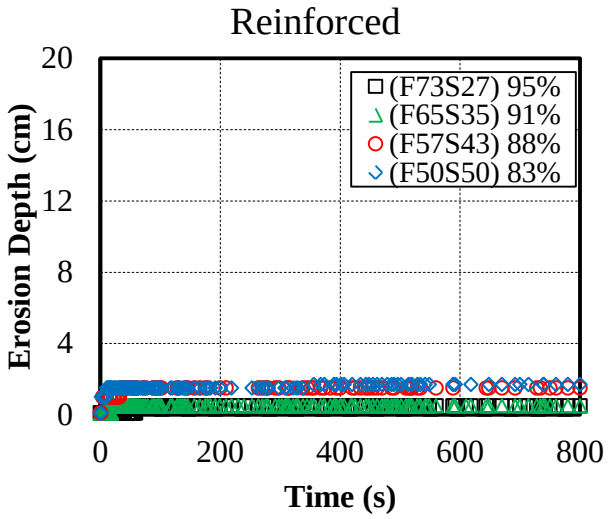




Soil Erosion

Erosion resistant solution: Soil Cement





Swelled

Not-swelled

Soil Erosion

Erosion resistant solution: Vetiver

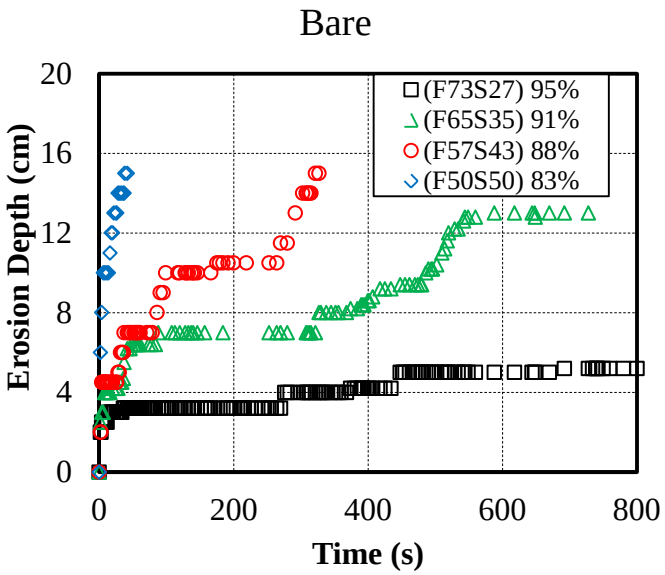
www.vetiver.org

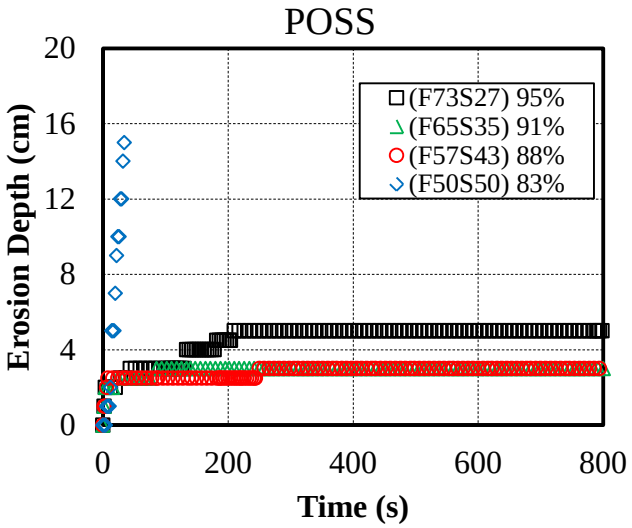
After Before

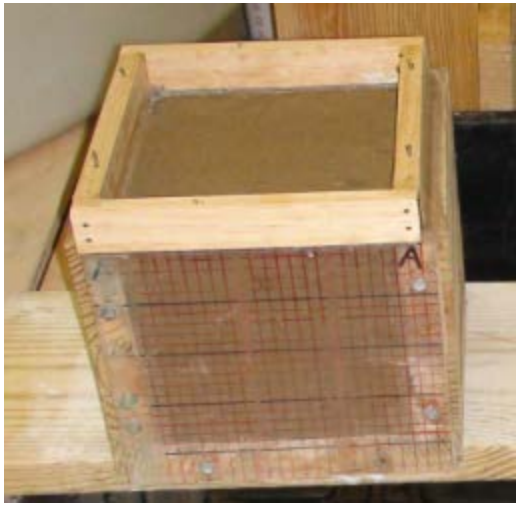
- No erosion at all!

Soil Erosion

Erosion resistant solution: POSS

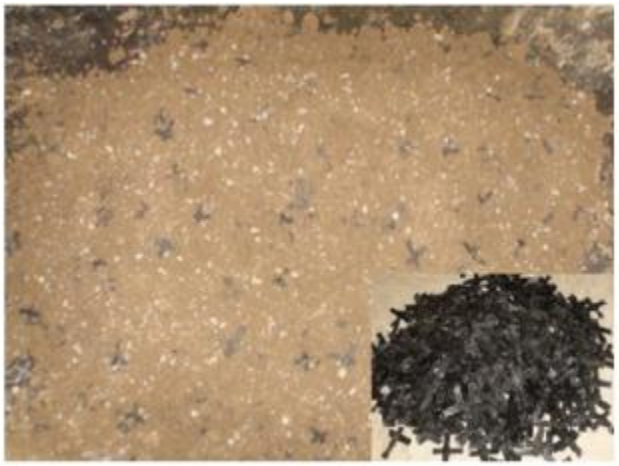




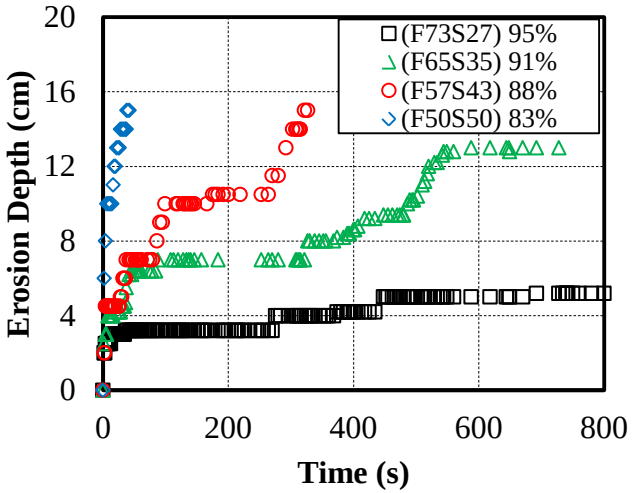


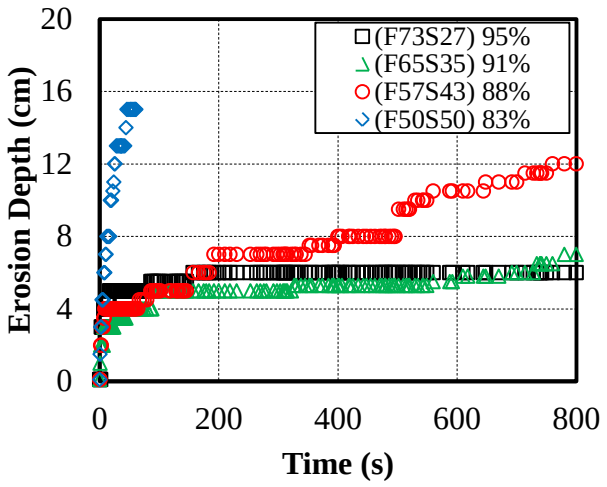
Soil Erosion

Erosion resistant solution: Geotextile



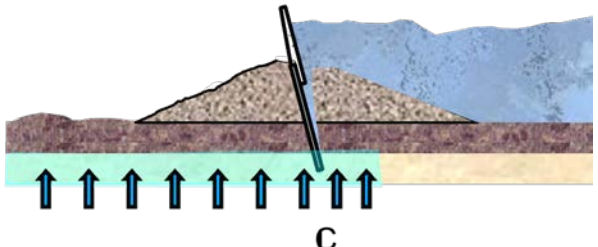
Soil Cement: Need field mixing
Vetiver: Need time to establish the grass
POSS: Need field spraying
Geotextile: Need field mixing



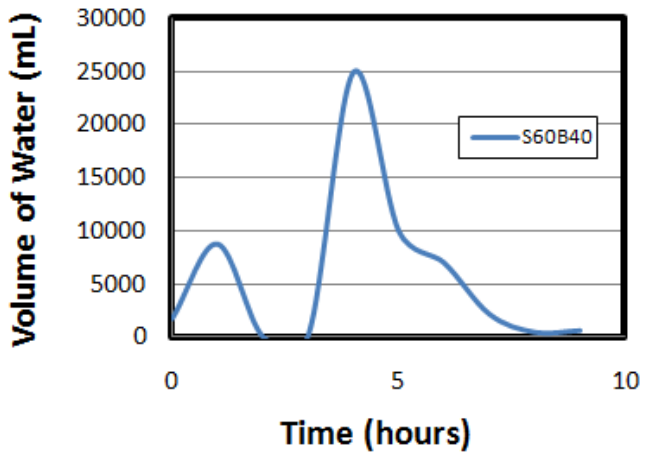


Gap Development/Sealing

Self Sealing Gap Solution



Sand:Bentonite = 60:40



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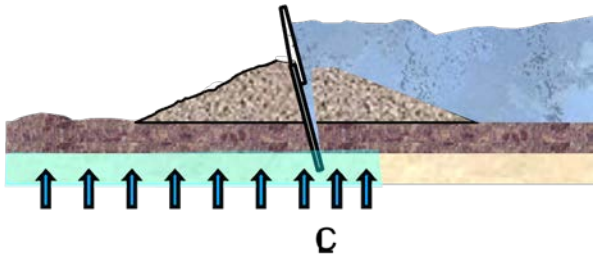
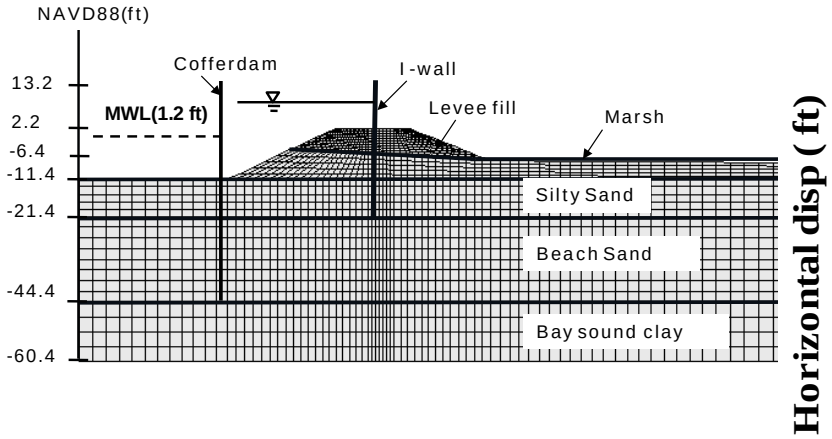
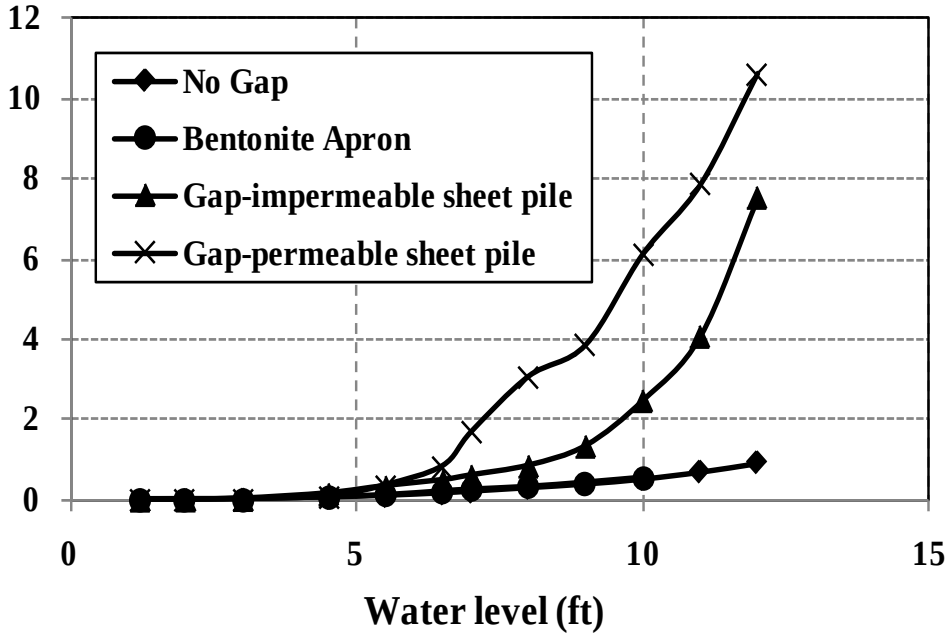


Sand:Bentonite = 60:40

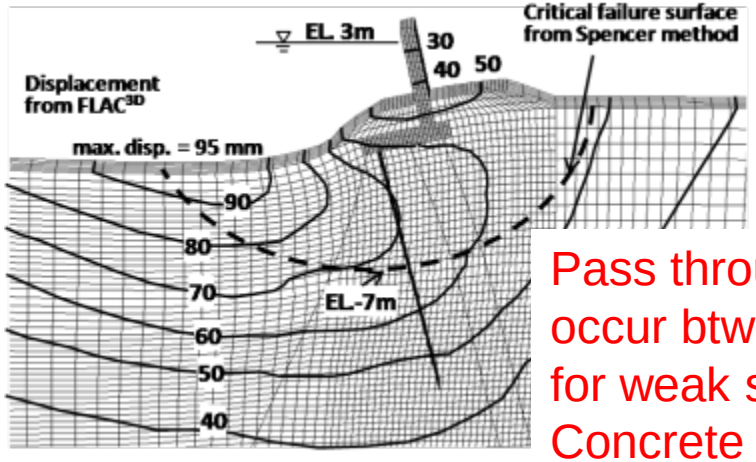




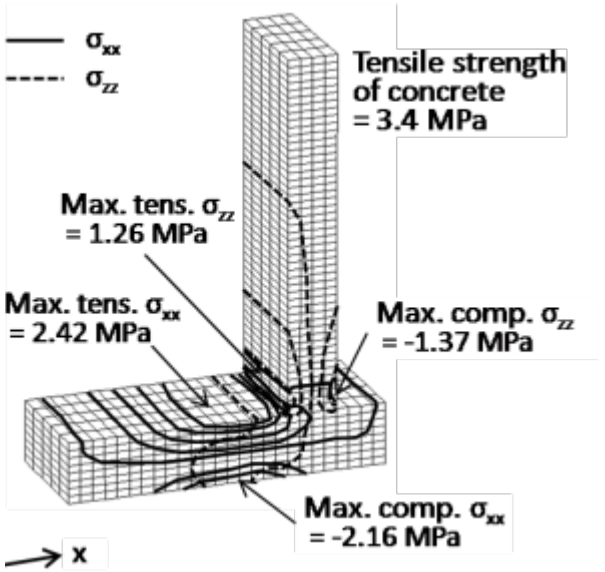
Self sealing the gap by bentonite substantially reduced the horizontal displacement of the flood wall.

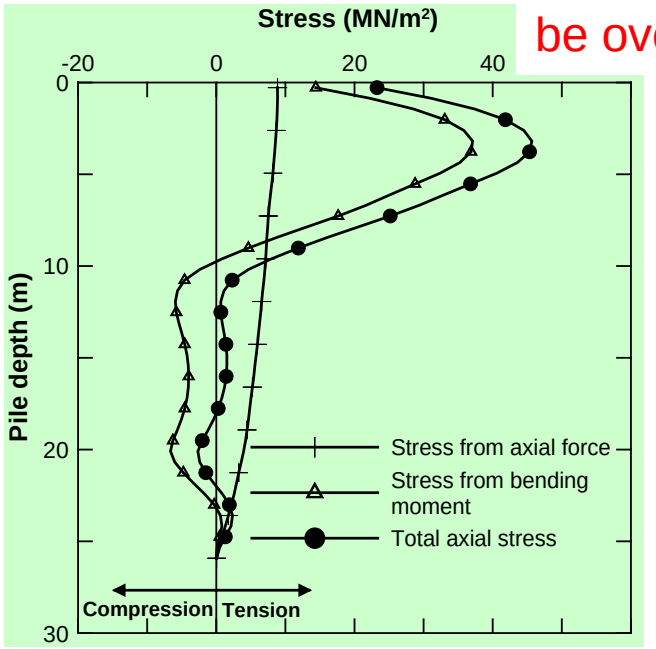
High End Numerical Simulation

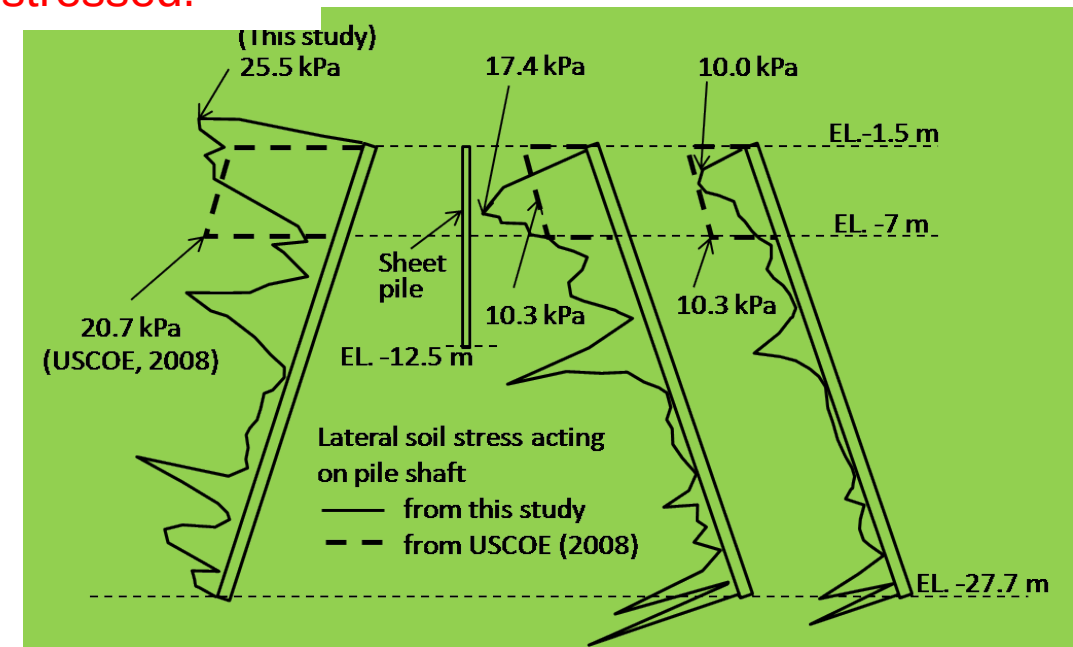
Time Saving 3-D Simulation of T-wall System



Pass through may occur btw pile groups for weak soil region. Concrete piles might be over stressed.

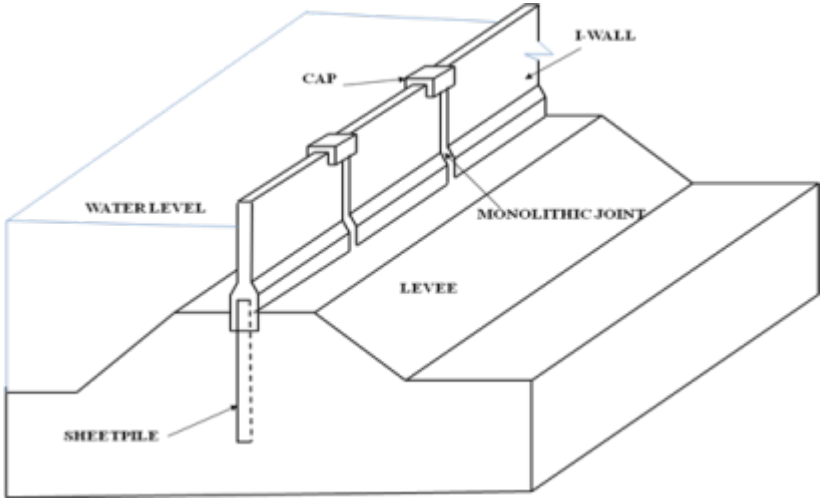






Structual/Material Solutions

Structural Cap



It may be helpful to have connections between walls to prevent such collapse and lateral movement.

So far we got promising results by numerical analysis. Results are under verification.

Picture Source: http://www.nytimes.com/2005/09/21/national/nationalspecial/21walls.html

Structural/Material Solutions

Structural Cap

Do these caps really work?

Play FinalMedia

Flood wall w/o cap, 64g
VTS_01_1-No Cap.VoB

Flood wall w cap, 64g
VTS_01_2-Cap.VOB

Structual/Material Solutions

Structural Cap

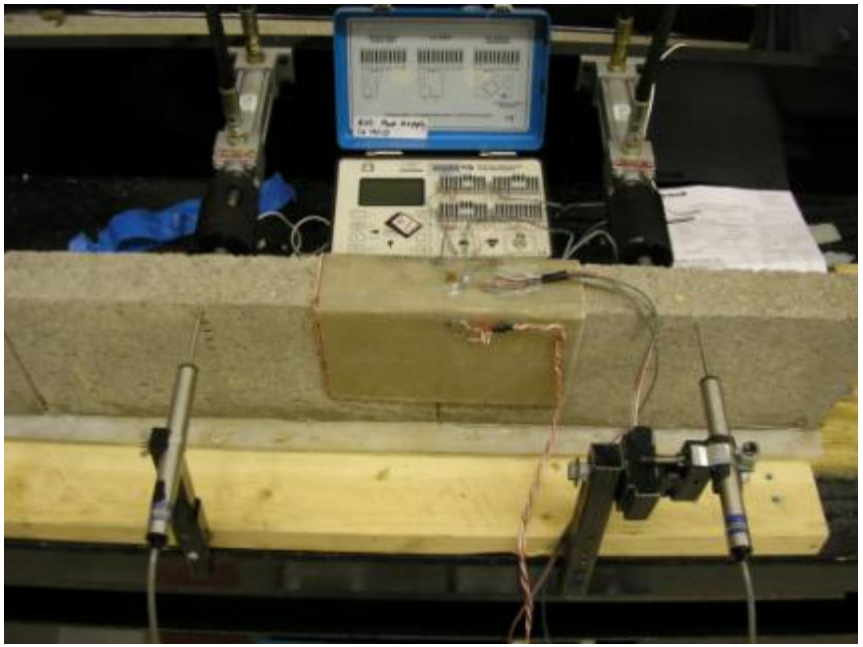
Not every cap works!

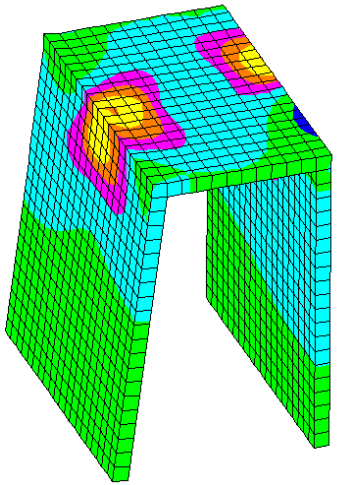
2nd-All cases.avi

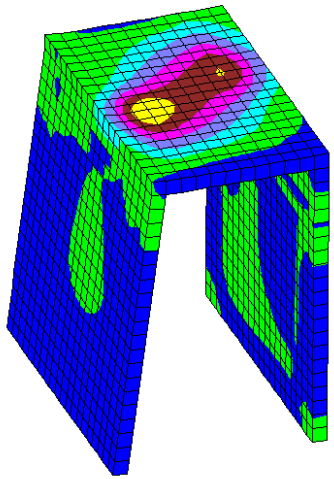
Structual/Material Solutions

Structural Cap

Max Bending: 40 ksf
Max Shear: 120 ksf



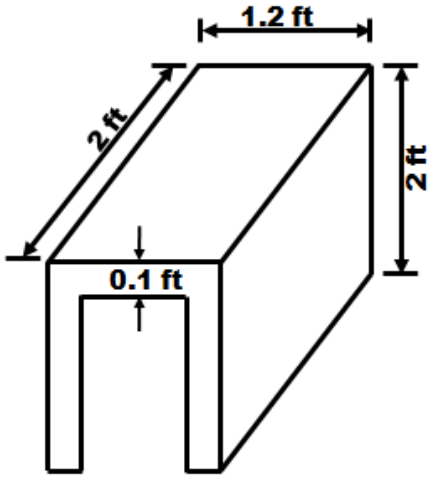




It may be helpful to have connections between walls to prevent such collapse and lateral movement.

So far we got promising results by numerical analysis. Results are under verification.

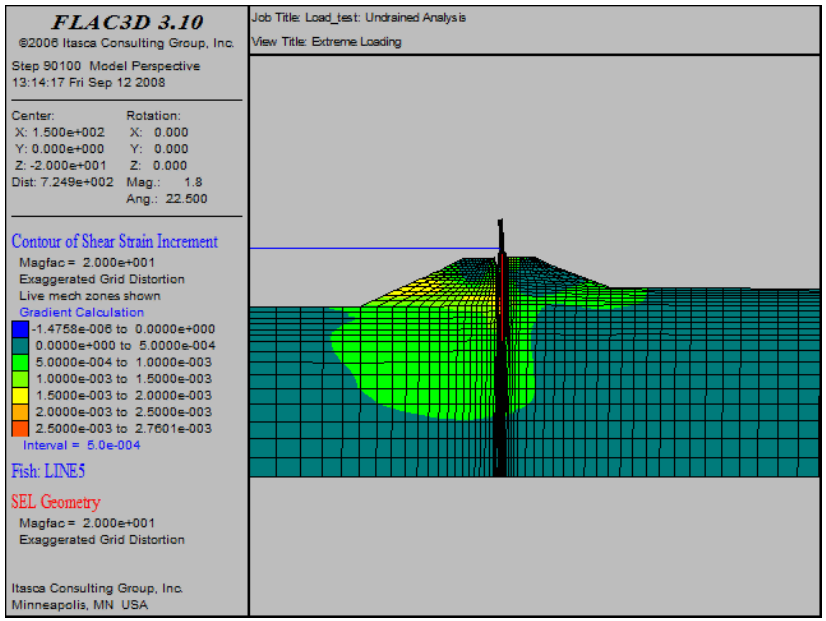
Tentatively the ideal cap should have following dimension and properties.



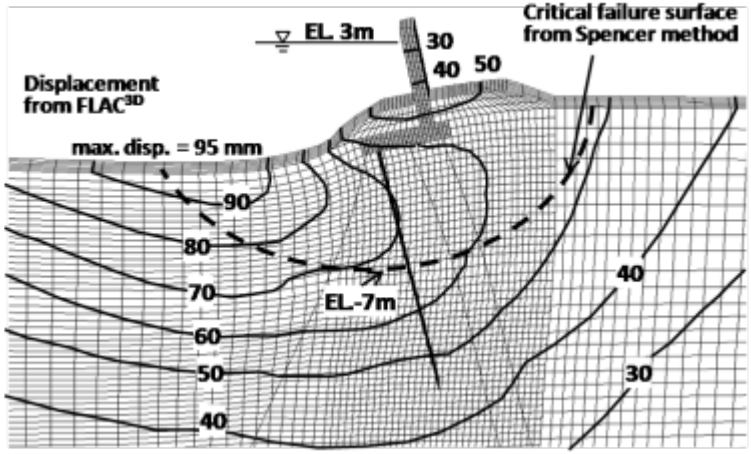
EI= 46.2 k-ft^2/ft

Possible extension of work scope

Weak Marsh Layer



I-wall



T-wall

Underlain weak layer is a main cause of many different problems!
Currently there is no systematic solution to treat this weak layer.
Need to explore effective soil modification techniques.

Possible extension of work scope

Full Scale Field Tests

- Techniques to retrofit the floodwalls and levees are developed. Erosion research results will particularly give strong impact to other researches.
- Techniques are analytically and experimentally verified (or under verification).
- To secure detailed data for field application, full scale field tests are needed, and they are proposed.
  - Overcome the scale effect
  - Provide data for equipment selection, cost estimation, and construction details for actual applications.

Schedule of Tasks (Shown from 2009)

Tasks	2009				2010				2011	
	1/4	2/4	3/4	4/4	1/4	2/4	3/4	4/4	1/4	2/4
1. Geotechnical Solutions										
1.1Database of bentonite expansion coefficient										
1.2 Design tool for bentonite curtain placement										
1.3 Database for soil erodibility index										
1.4 Correlation analysis with existing soil erodibility database										
1.5 Coupled analysis of soil-structure-fluid system										
1.6 Recommendation for retrofitting strategies										
2. Structural Solutions										
2.1 Analysis and design of stiff jointing										
2.2 Analysis and design of anchor station										
2.3 3D soil structure analysis										
3. Material Solutions										
3.1 Design of composite sheet pile										
3.2 Test results and design analysis										
3.3 Patented design										
3.4 Review report for nano matreials										
4. Testing and Validation										
4.1 Geotechnical – complete set of centrifuge test data and analysis										
4.2 Structural and Material– complete set of test data and anslysis										
Final Report										

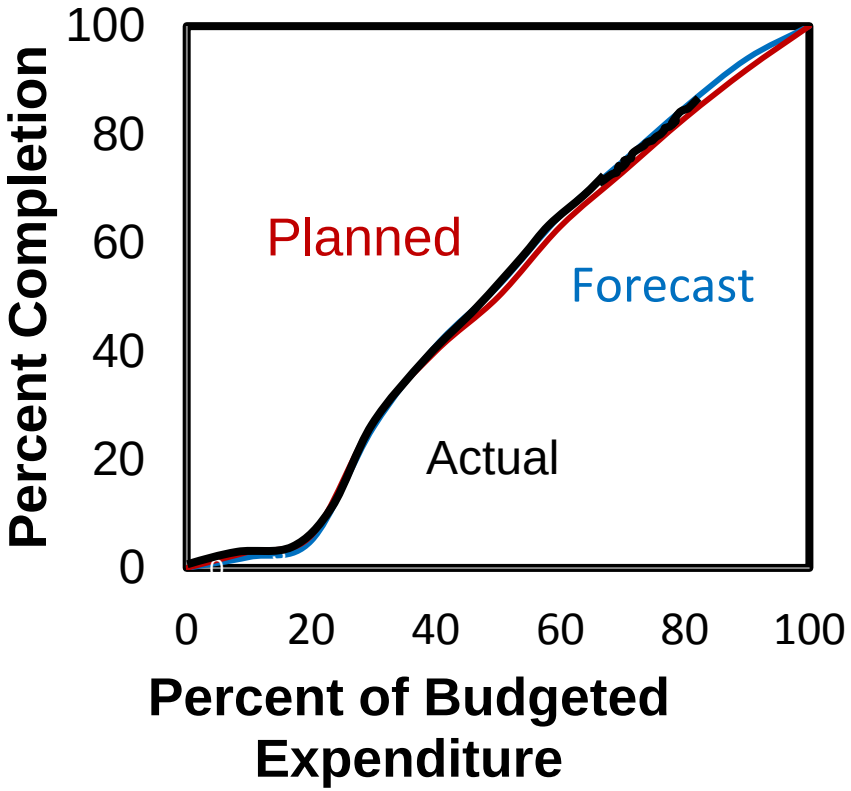
Completed

Near Completion

Delayed

Proportion of Project Completed vs. Expenditures (replacing budget plan)

- Progress Graph



- Comments

✓ Technical progress and budget expenditure is par with the schedule.

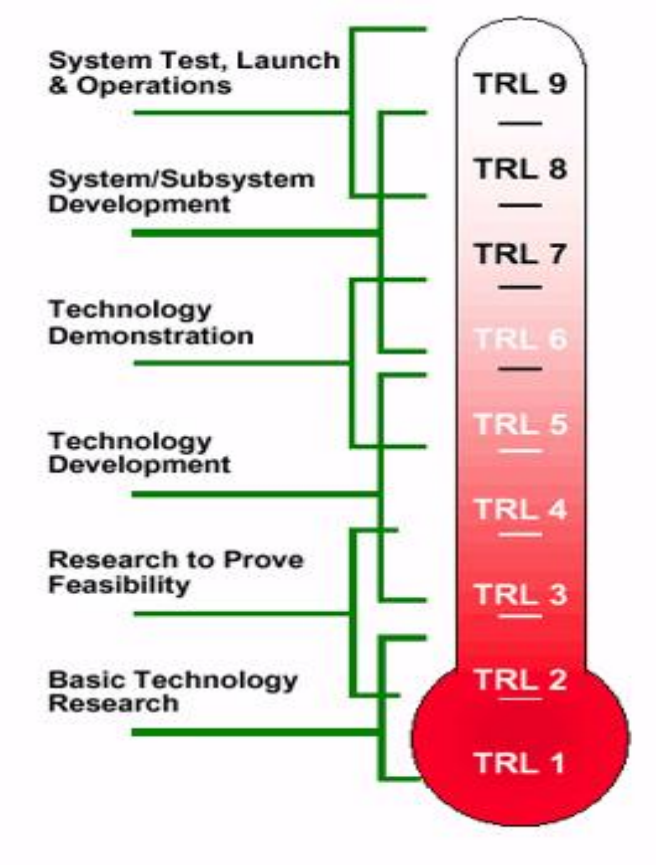
✓ There were no cost overruns

Collaborative Opportunities (revised)

- Corps of Engineers, New Orleans District.
- ERDC, Vicksburg
- USDA, Dam and Levee Erosion Lab.
- USDA National Sedimentation Lab
- NCCHE, University of Mississippi
- Mississippi State University
- Vetiver Network International
- FLOW Science

Technology Readiness Level (TRL) Assessment

(Replacing Commercialization Progress)



- Erosion prediction tech.: 9
- Erosion analysis tech.: 9
- I-wall analysis tech.: 9
- T-wall analysis tech: 9
- Self healing apron: 8 to 9
- Cap solution: 7 to 8
- Stiffer sheet pile: 7 to 8

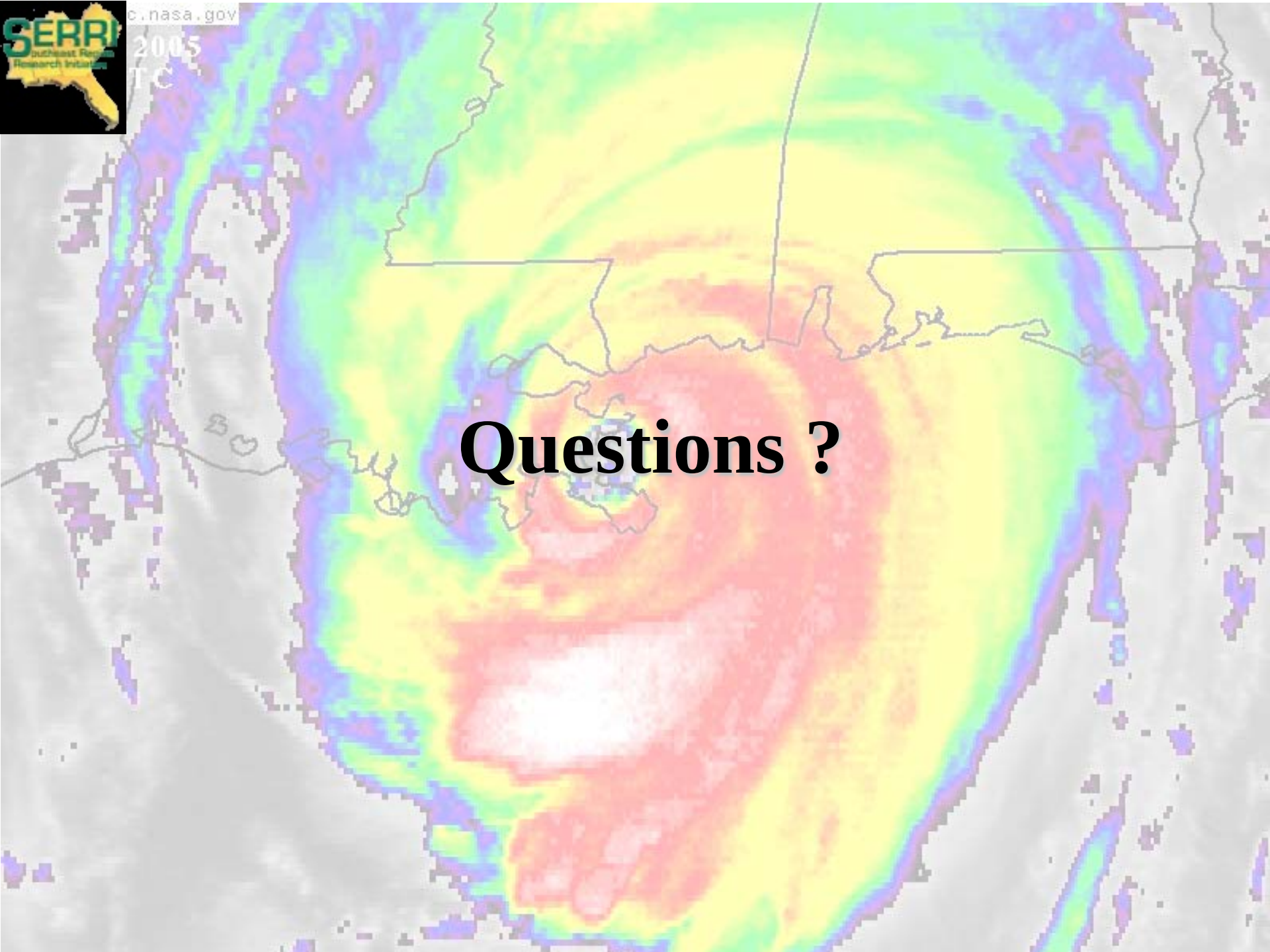
- At the end of the project, all test results will be level 7 to 9
- Product will be transferred to potential customers and/or end users through co-work during research (FLOW Science, ERDC, USACE, Hybrid Plastics, Vetiver International), conferences (ASCE, ASME…) and journal publications (ASCE, ASME, International Erosion Control Assoc….)

IP STATUS

- None so far.
- Collaboration with FLOW Science to disseminate results to erosion resistant design
- Disseminate results to ERDC, USACE and ASCE through meetings, conference presentations, and journal manuscripts.

Summary & Conclusions

- Research is well underway.
- The schedule for various tasks has been adjusted.
- The overall schedule is on time.
- In direct communication with Corps of Engineers, New Orleans District, one of the ultimate users of the project.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Questions ?