

Erosion Control by Ground Modification

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Background

□ Hurricane Katrina

- Made landfall on August 29, 2005 as a category 3 hurricane
- Storm surge was estimated to be 12-14 feet
- In addition, it was also estimated that 14 inches of rainfall fell with 24 hours

□ Erosion Caused by Plunging Water

- Approximately 50 breaches in hurricane protection system
- 46 of these breaches were caused by overtopping water

□ Goals

- Develop and test methods of ground modification in order to reduce or prevent erosion from plunging water.



Outline

- Introduction
- Set Up and Test Equipment
- Summary of Reinforced Soils
- Results
- Conclusions
- Future Plans

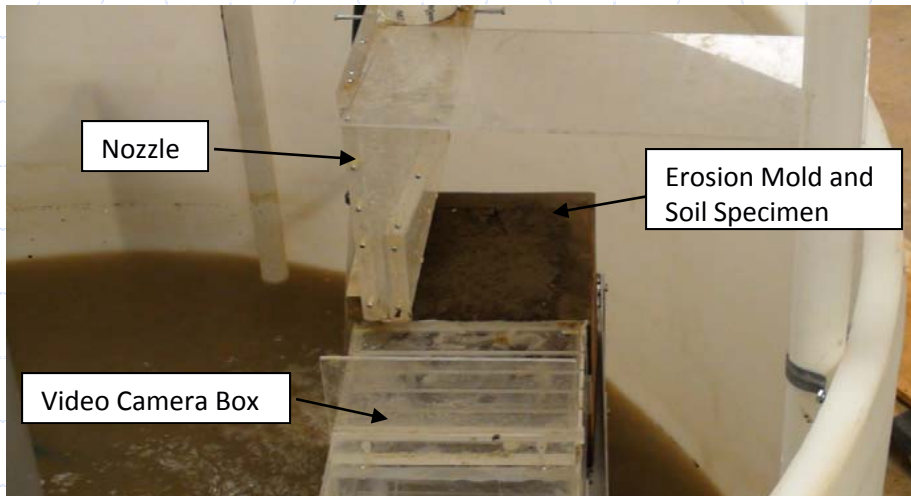
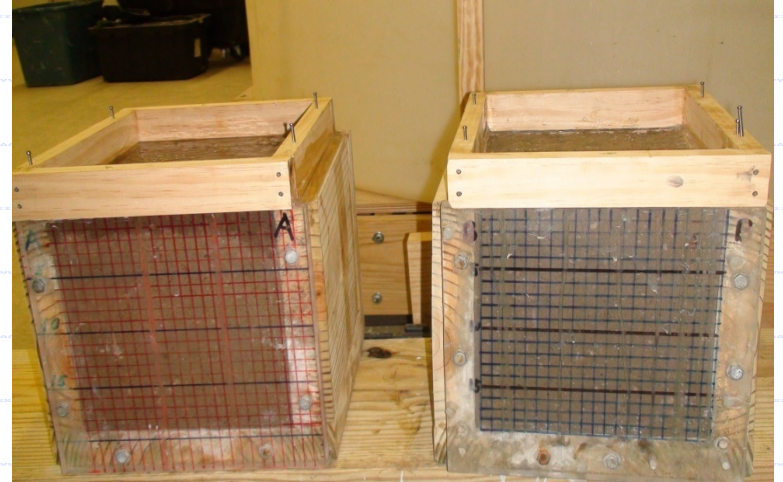


Sample Preparation





Erosion Testing





Summary of Tested Soils

□ F50S50

- DOC-83%
- Clay-15%
- Silt-35%
- Sand- 50%

□ F57S43

- DOC-88%
- Clay-18%
- Silt-40%
- Sand- 42%

□ F65S35

- DOC-91%
- Clay-20%
- Silt-45%
- Sand- 35%

□ F73S2

- DOC-97%
- Clay-23%
- Silt-50%
- Sand- 27%



Reinforced Soils

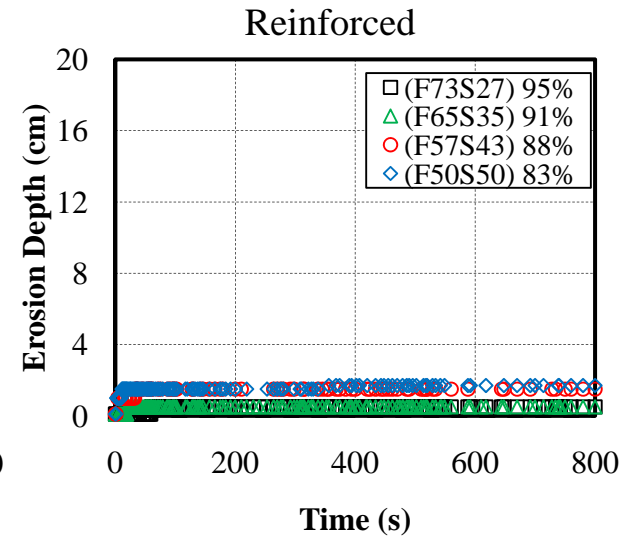
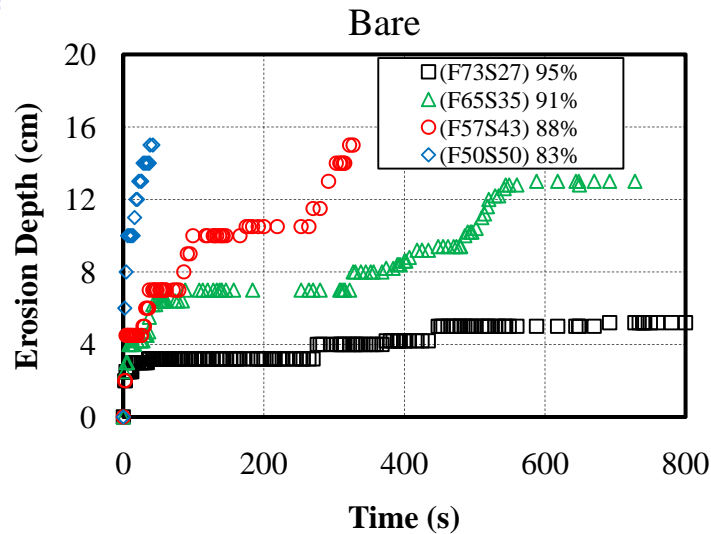
- Four typical samples (F50S50, DOC 83%; F57S43, DOC 88%; F65S35, DOC 91%; F73S27, DOC 95%) were selected for reinforced tests.

- **Soil cement:** Geotechnical solution
- **Vetiver:** Biological solution
- **POSS:** Chemical solution
- **Geotextile:** Material solution
- **Engineered floodwall** (Structural solution): Apart from the methods reinforcing soil, engineered floodwall that can reduce erosion force was introduced by Song et al. (2009).



Soil Cement

- 5% of cement powder was added, then compacted at maximum dry density and OWC.
- Samples were cured for two weeks and then submerged for two days before testing.
- Test results showed outstanding erosion resistance, and were eroded less than 2 cm.
- Samples showed no signs of swelling after two days of submersion; however, bare samples swelled (1-1.7 cm) due to dispersion.



Swelled



Non-swelled



Vetiver



www.vetiver.org



After

Before

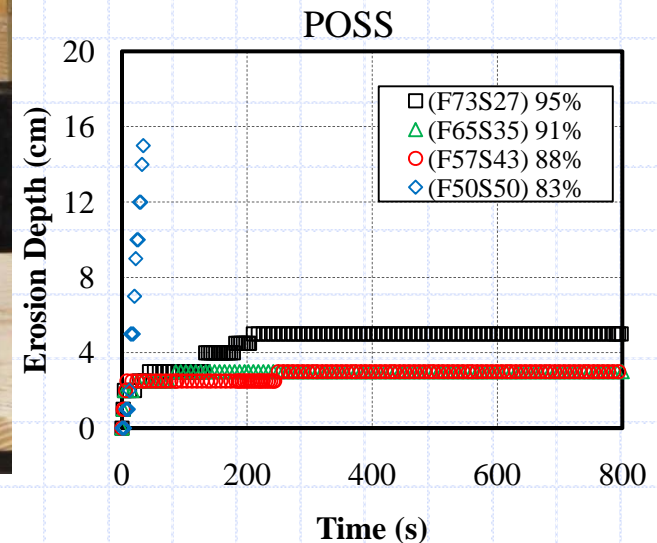
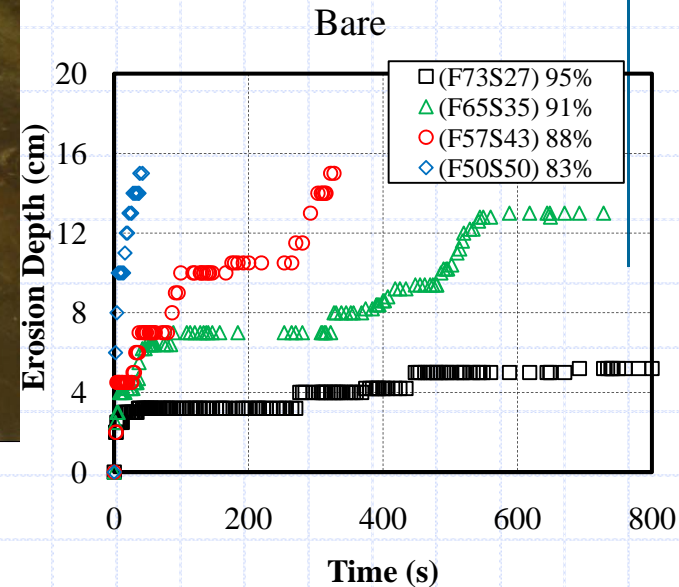


- ❑ Samples were prepared in two ways:
 - 4 inches of stems
 - Root System
- ❑ Plunging water was applied to the top of the vetiver.
- ❑ Due to the dense vegetation and root system, water was unable to penetrate any soil sample.



POSS (Polyhedral Oligometric Silsesquioxane)

- POSS is a hybrid composition of silica (SiO) and silicone (R_2SiO) and has material properties of an intermediate between polymers (organic) and ceramics (inorganic).
- 5% of POSS was added on the top of samples, cured for two weeks, submerged two days, and tested.
- Significant improvement for F57S43 (88%) and F65S35 (91%) but little improvement for F50S50 (83%) and F73S27 (95%).



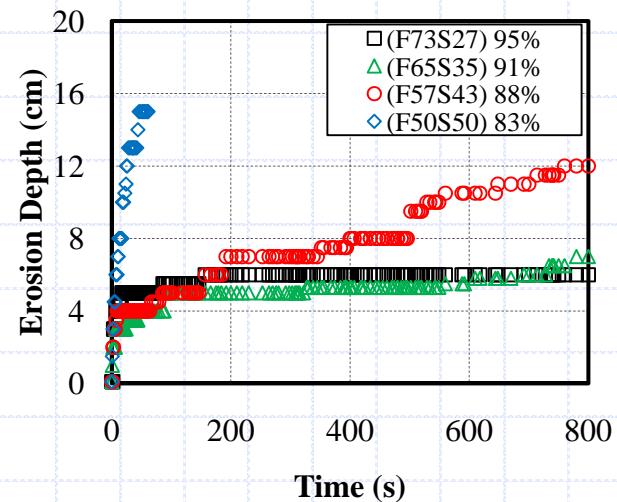
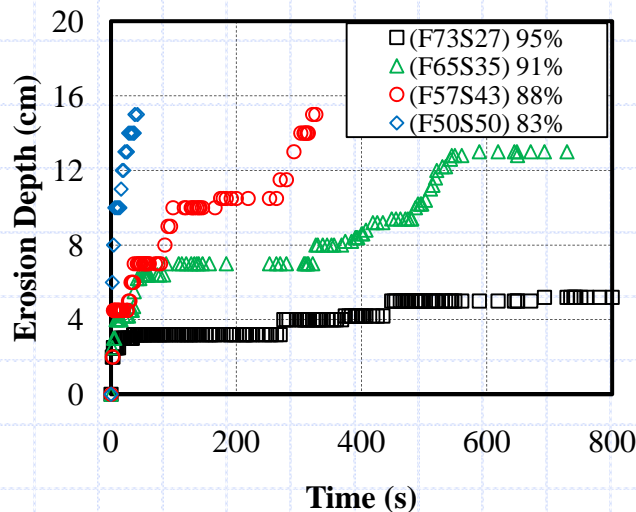


Geotextile (1)

Woven fiber



- Woven geotextile (HP300) were cut into small pieces (1-2 inches).
- 2 percent of geotextile was added to soil.
- F57S43 (DOC88%) and F65S35 (DOC91%) were improved, but the poorly compacted F50S50 (83%) and high clay contented F73S27 (95%) sample showed little improvement.
- This trend is similar to POSS treated samples

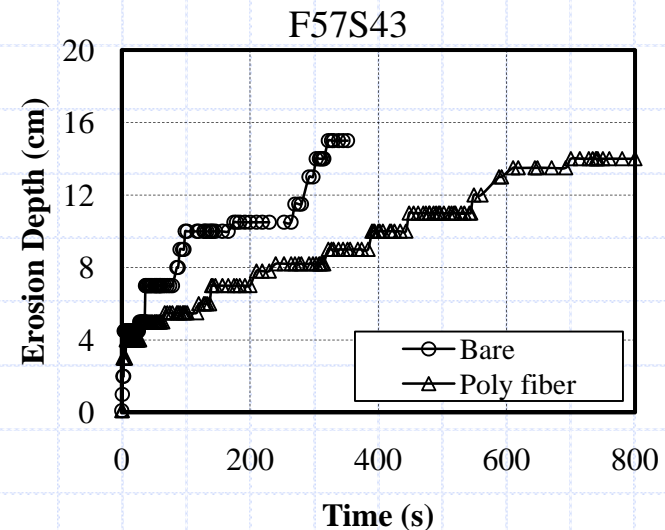
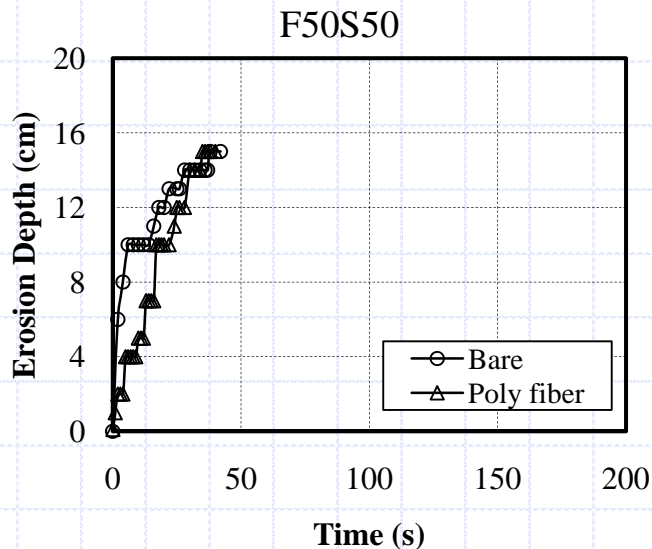




Geotextile (2)



- Two additional samples (F50S50, 83%; F57S43, 88%) were reinforced with polyester fibers (0.7 inch) by adding 0.5 % of polyester fibers.
- No improvement was observed for F50S50 (83%) while F57S43 (88%) showed some improvement but not as much as POSS, soil cement or vetiver.





Summary of Reinforcement

- **Soil cement** (Geotechnical solution)
The most recommendable reinforcement showing the highest erosion resistance. **Need forced mixing.**
- **Vetiver** (Biological solution)
Applicable to areas having good soils, abundant rainfall and mild weather condition. **Green.**
- **POSS** (Chemical solution)
Recommendable for soils having low clay percentage (less than 20%) and medium degree of compaction (88%-92%). **Surface Spraying.**
- **Geotextile** (Material solution)
Showed little improvement, not recommendable for soils subjected to plunging water. **Need forced mixing**



Summary of Reinforcement

- For both POSS and geotextile tests, F50S50 (83%) and F73S27 (95%) showed little improvement while F57S43 (88%) and F65S35 (91%) showed improvement.
- F50S50 (83%), is compacted to low to take advantage of reinforcement.
- Erosion behavior for F73S27 (95%), appears to be dominated by clay content and subsequent dispersion rather than reinforcement.



Conclusions

- Soil cement reinforced with 5% of cement powder showed the highest erosion resistance compared to other reinforced soils.
- POSS: applicable to soils having medium degree of compaction (88%-92%), and low clay content (less than 20%).
- Vetiver: applicable to areas of warm or humid, and abundant rainfall condition.



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Thank You

