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Waste Shear Strength Lower Limit and Parameter Distribution Recommendation

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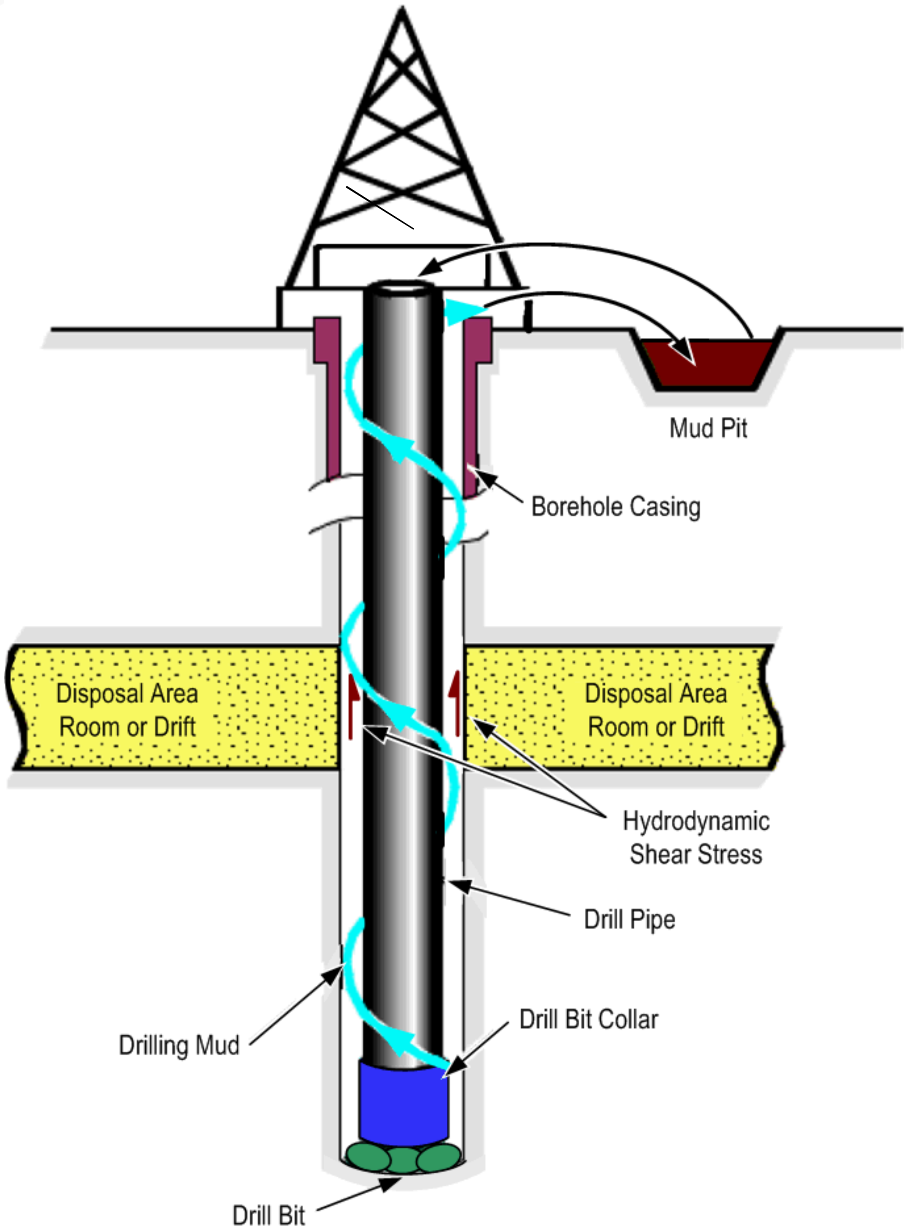
Outline

- Introduction and implementation history
- Implementation in Performance Assessment
- Summary and criticisms of methods used to obtain a new lower limit of TAUFAIL
- Vertical erosion flume
- Test matrix
- Results
- Recommendations for the lower limit and distribution

What is the Waste Shear Strength?



- The **cavings** component of a direct surface release is caused by hydrodynamic shearing action of the drilling fluid (mud) on the waste
- The borehole diameter is assumed to grow until the fluid's shear stress on the borehole wall is equal to the shear strength of the waste
- **Waste shear strength (TAUFAIL)** is the ability of the waste to resist erosion

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Implementation of TAUFAIL in PA

	CCA	PAVT – present
RANGE	0.05 to 10 Pa	0.05 to 77 Pa

CCA – Compliance Certification Application
PAVT – Performance Assessment Verification Test

- The lower value of 0.05 Pa is from Berglund (1996)
  - Value based on San Francisco Bay mud
- The upper value of 77 Pa is based on analysis (Wang and Larson, 1997) using the results of an Expert Panel Elicitation on WIPP waste particle size distributions (CTAC, 1997)
- Log-uniform distribution over the range [0.05, 77] Pa

Importance of Revising TAUFAIL

- **Provide a more accurate parameterization of the waste shear strength**
  - **Experimental results based on a realistic, accepted surrogate waste material**

- **1996 Conceptual Models Peer Review**

  "…in the absence of experimental data, the effective shear resistance to erosion of the repository waste is similar to ocean bay mud or montmorillonite clay. In the absence of accurate waste characterization or knowledge of the form this waste is in at the time of intrusion, this assumption appears appropriate because of the low shear strengths of these substances."

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Summary of Past Methods Used to Evaluate the Lower Limit of TAUFAIL

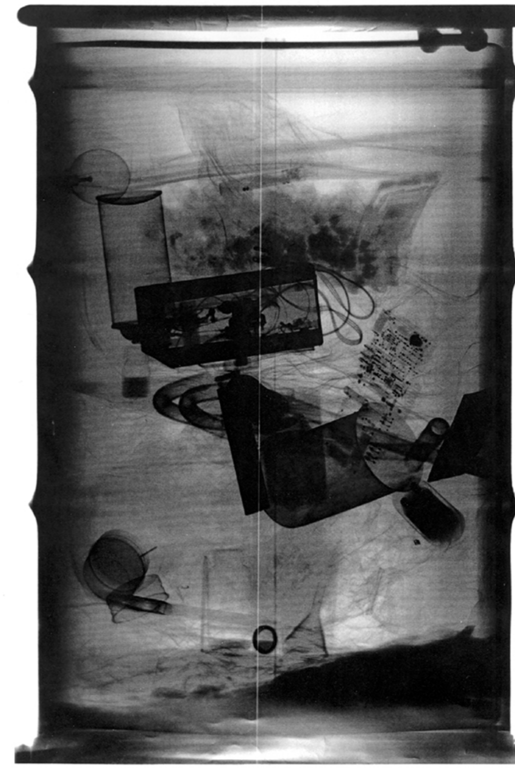
- Expert elicitation on particle size in Shields curve
- Extensive literature review
- Waste consolidation and compression numerical analysis
- Newer San Francisco Bay mud data
- Horizontal flume experiments on surrogate waste

WIPP Waste Materials

WIPP waste consists of:

- Metals (fittings, fasteners, mechanical parts, building waste, pipes, lab equipment, motors, etc.)
- Cellulosics, plastics, and rubbers (paper, wipes, cardboard, cloth, gloves, lab materials, PVC, polyethylene, etc.)
- Inert materials (glassware, ceramics, vitrified waste, etc.)
- Process sludges (concrete, etc.)

Waste Types Emplaced in WIPP



55-gallon drums – “Standard” waste container

Emplacement of Waste in WIPP

Past Tests Performed on Surrogate Waste Materials

- **Erosion tests were performed by Jepsen et al. (1998) using SEDflume**
- **Materials were the same as those developed for the Spallings model parameter experiments (Hansen et al. 1997, 2003)**
  - **50% degraded**
  - **100% degraded**

Percent degradation indicates the anticipated amount of iron corroded and the amount of cellulosics, plastics, and rubbers (CPR) that are degraded by weight.

Assumptions Made in Developing the Surrogate Waste

- Hansen et al. (1997) considered degradation of each waste constituent assuming:
  - ample brine availability
  - extensive corrosion
  - extensive microbial activity
  - absence of strengthening processes
    - cementation
    - mineral precipitation
    - salt encapsulation
    - corrosion products volumetric expansion
    - more durable packaging
- Material is far weaker than expected state of the waste after regulatory period

Appropriateness of the 50% Degraded Surrogate Waste Material 1

- Degraded waste derived by tracing the degradation processes and evolution of the underground
  - Beginning with known inventory of waste, products of reactions were used to assemble relevant surrogates
- Hansen et al. (2003) used the 50% degraded surrogate waste material to obtain the parameters for the spallings model
  - For the majority of performance assessment calculations, half or more of the initial iron and CPR inventory remains

Appropriateness of the 50% Degraded Surrogate Waste Material 2

- **Experimental testing emphasizes conservative saturated conditions**
  - **Strength of degraded waste increases as saturation decreases because of cementation between particles or lack of degradation**
  - **Brine saturation decreases as gas pressure in the repository increases**

Criticisms of the Suggested Parameter Value Change

- Effect of gravity on shear strength of the material
  - Gravity acts to hold the material on the sediment bed increasing the shear strength
    - A scoping analysis suggested that the effect is minimal
- Specimen preparation
  - Jepsen et al.'s specimens were compressed at 5 MPa for 15 hours; unloaded; packaged in plastic wrap, aluminum foil, and wax; shipped across country; cut in half; and machined to fit into UCSB sample holders.
    - Hansen et al. (2003) showed 5.0 MPa is conservative
    - Numerical analysis suggests expected minimum compaction pressure of 2.3 MPa
      - New gas generation rates not accounted for

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Parameter Value Change Criticisms (cont.)

- Surrogate material development
  - Hydrodynamic shear strength measurements are thought to be sensitive to as many as 60 parameters (Parchure, Sobecki, and Pratt, 2003)
  - Flume test results are sensitive to the characteristics of the test sample
    - Hansen et al.'s (1997) material represents exceptionally degraded state of the waste and excludes any strengthening or cementing effects
    - Material accepted as conservative surrogate for condition of waste after 10,000 yr regulatory period by Spallings model peer review panel and EPA

Flume Testing Objectives

- The hydrodynamic shear strength can only be obtained experimentally.
    - There is no known correlation between hydrodynamic and mechanical shear strengths
  - Experimentally obtain waste shear strength under a realistic orientation (vertical) and hydraulic conditions
    - Establish effect of gravity
  - Use of accepted surrogate degraded waste recipes
    - Hansen et al. (1997, 2003) material accepted by Spallings Peer Review Panel and EPA
  - Test surrogate samples using different compaction pressures and represented states of degradation
    - Establish effect of sample preparation

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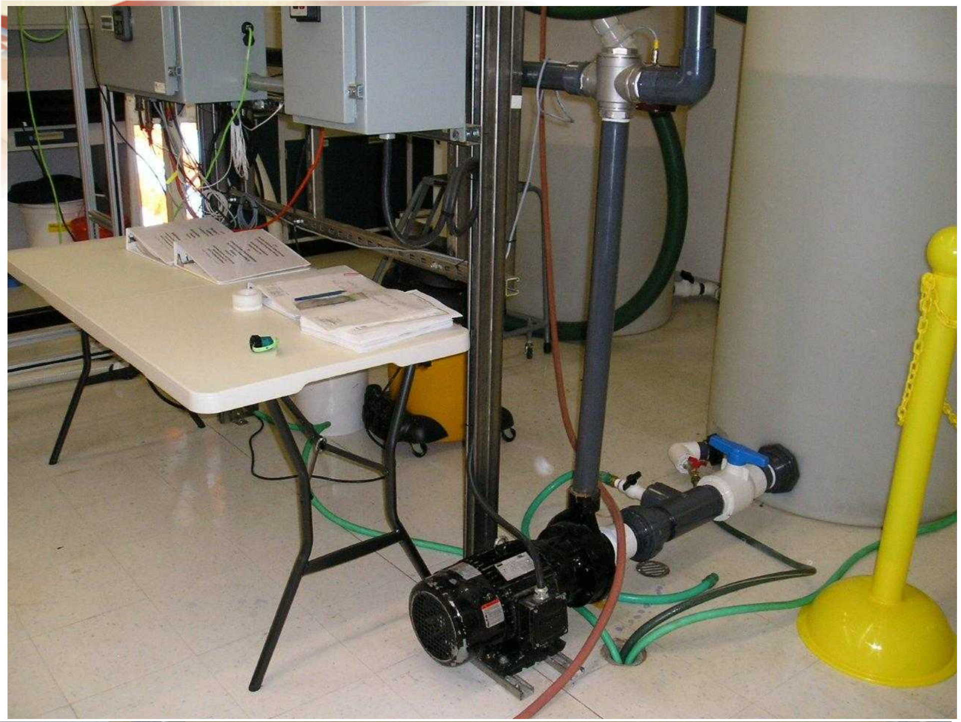
Horizontal and Vertical Erosion Flume

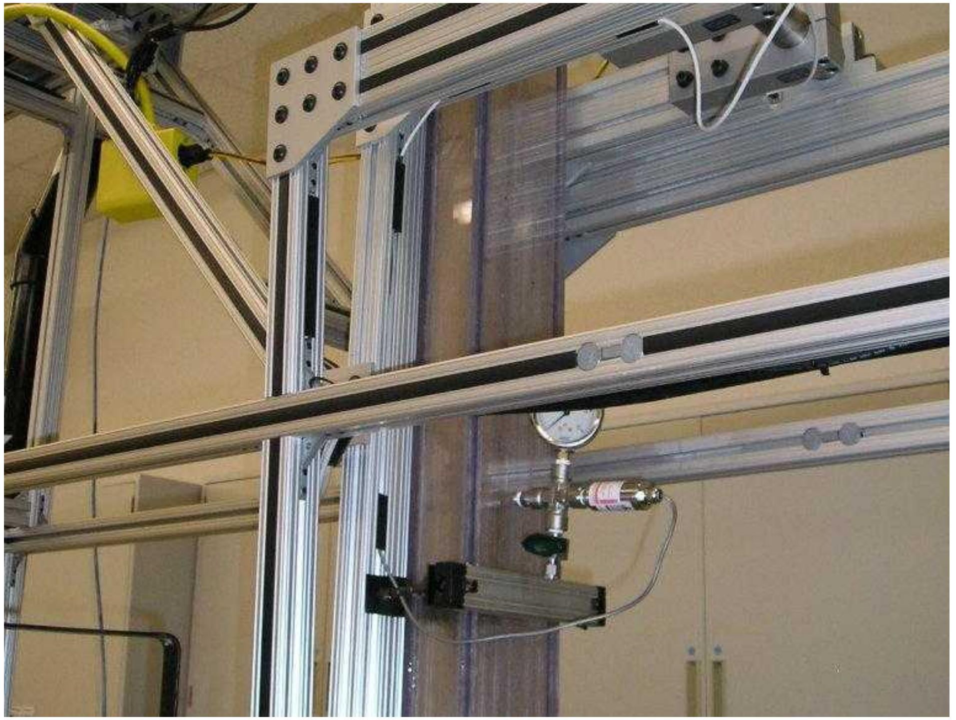
- Fluid pumped through an enclosed channel from bottom to top
  - Creates known shear stress across specimen's surface

τ range: 0.01 – 6 Pa

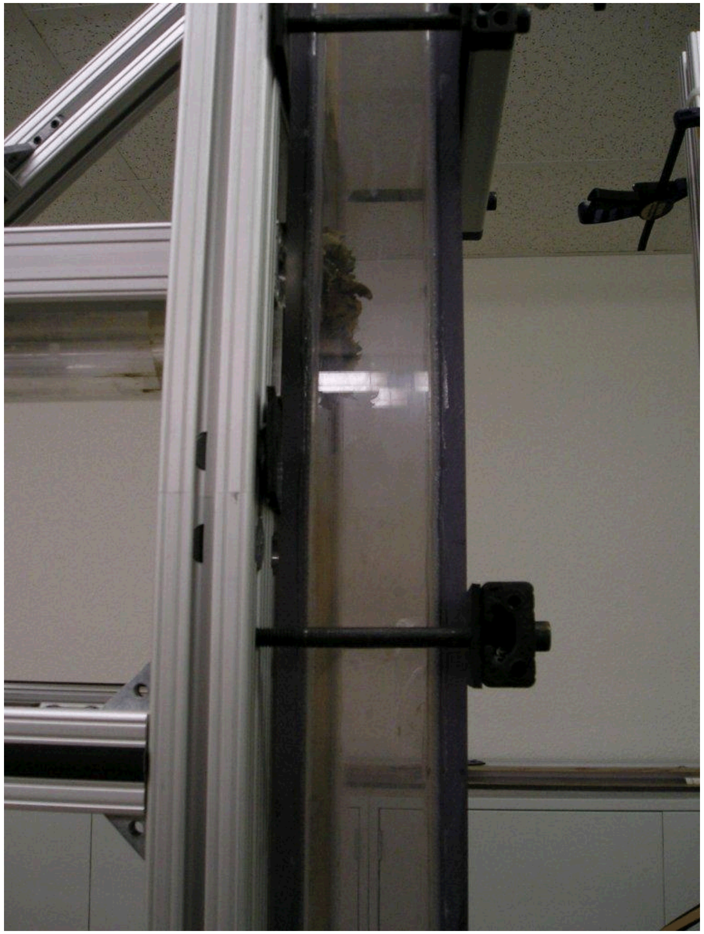
- Can create both laminar and turbulent flow
- Specimen is moved by piston into the erosion test section and kept flush with channel

Vertical Flume Pictures





Vertical Flume Pictures (cont.)



Test Matrix

Flume Orientation	% Degradation	Compaction Pressure (MPa)	
Vertical	50 75 100	5*	2.3**

* Duplicates Hansen et al. (1997, 2003) compaction pressure accepted for Spallings model

** Conservative minimum expected compaction pressure

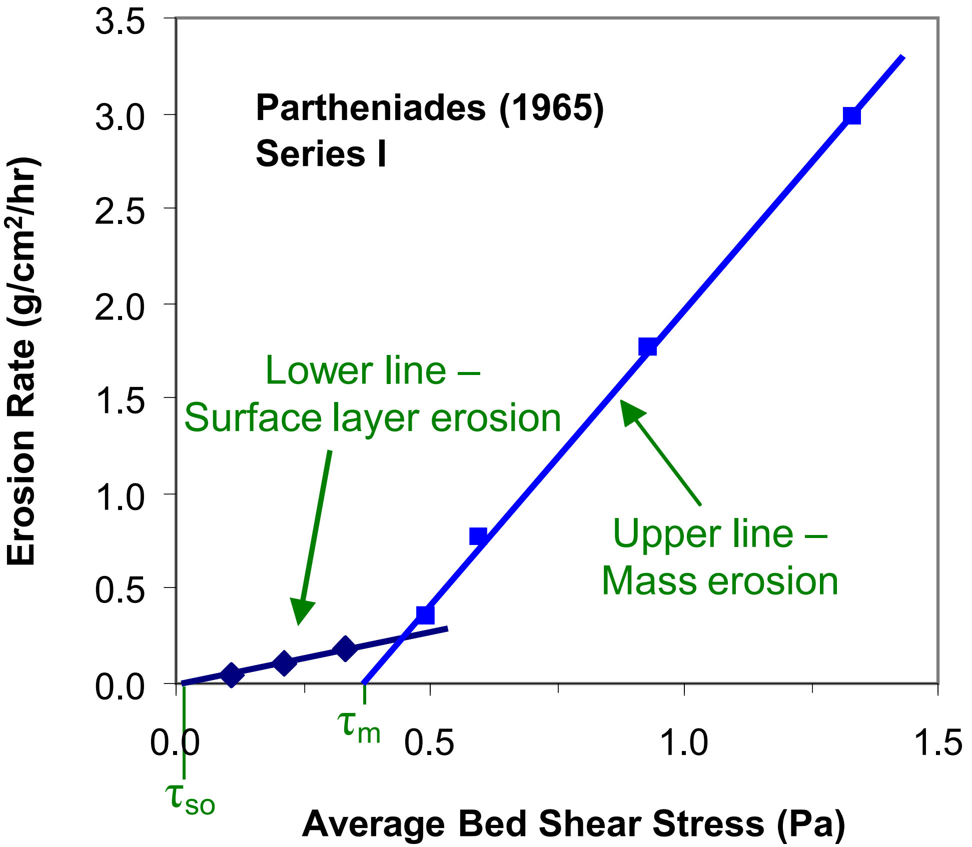
Test measurements and determinations:

- TAUFAIL and erosion rate under specified conditions
- Multiple tests (at least 5) to be performed at each condition
  - Assess precision, variability, and repeatability

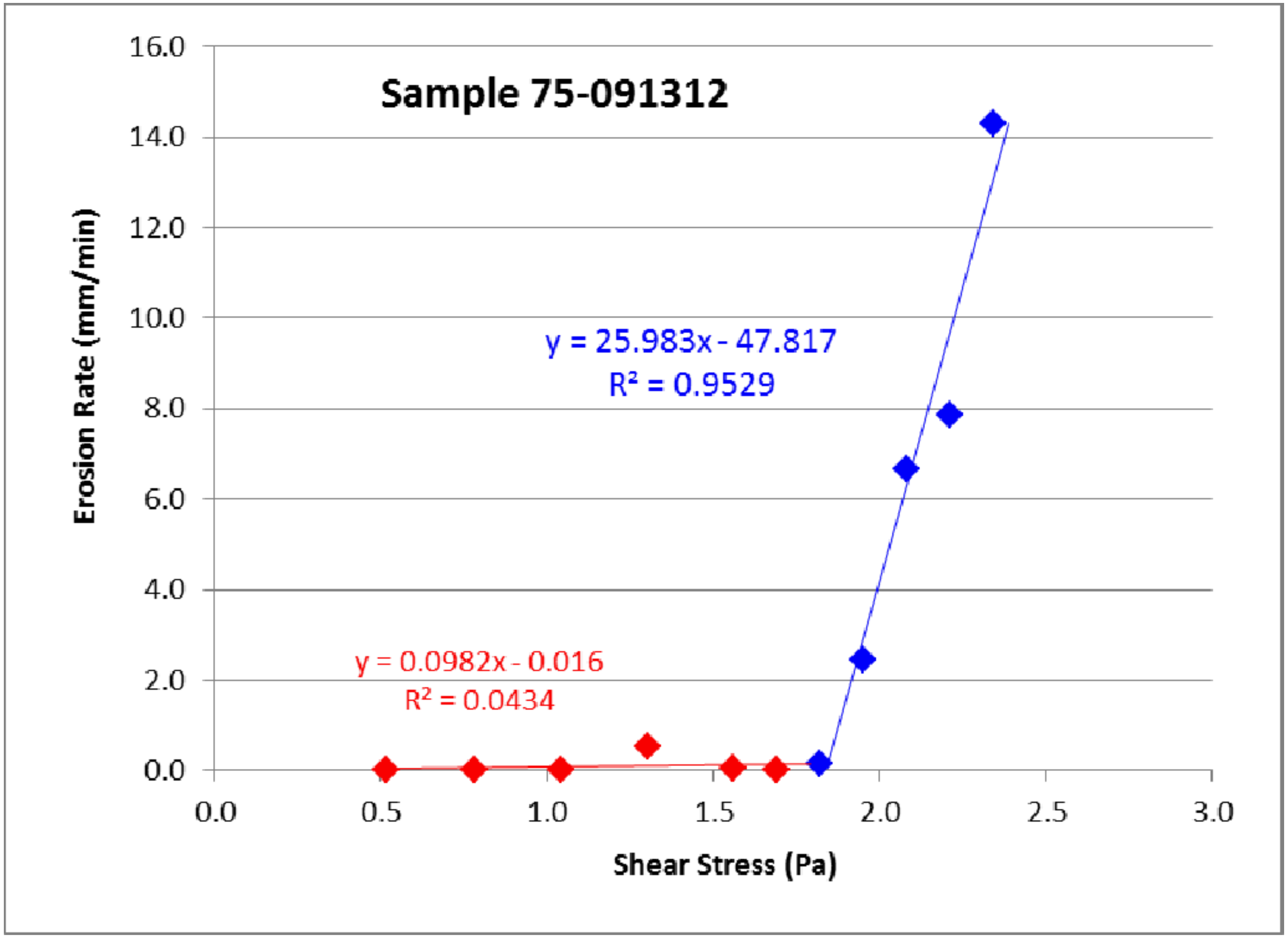
Interpretation of Results

UF Bilinear Method

- **Typical flume testing results yield bilinear results – one line for surface erosion and one for mass (or bed) erosion.**
- **The shear strength of the degraded waste is best represented by a value characteristic of the entire waste mass.**
- **The value of τ_m represents a conservative minimum shear strength of the mass.**



Example Result



τ_m = 1.84 Pa

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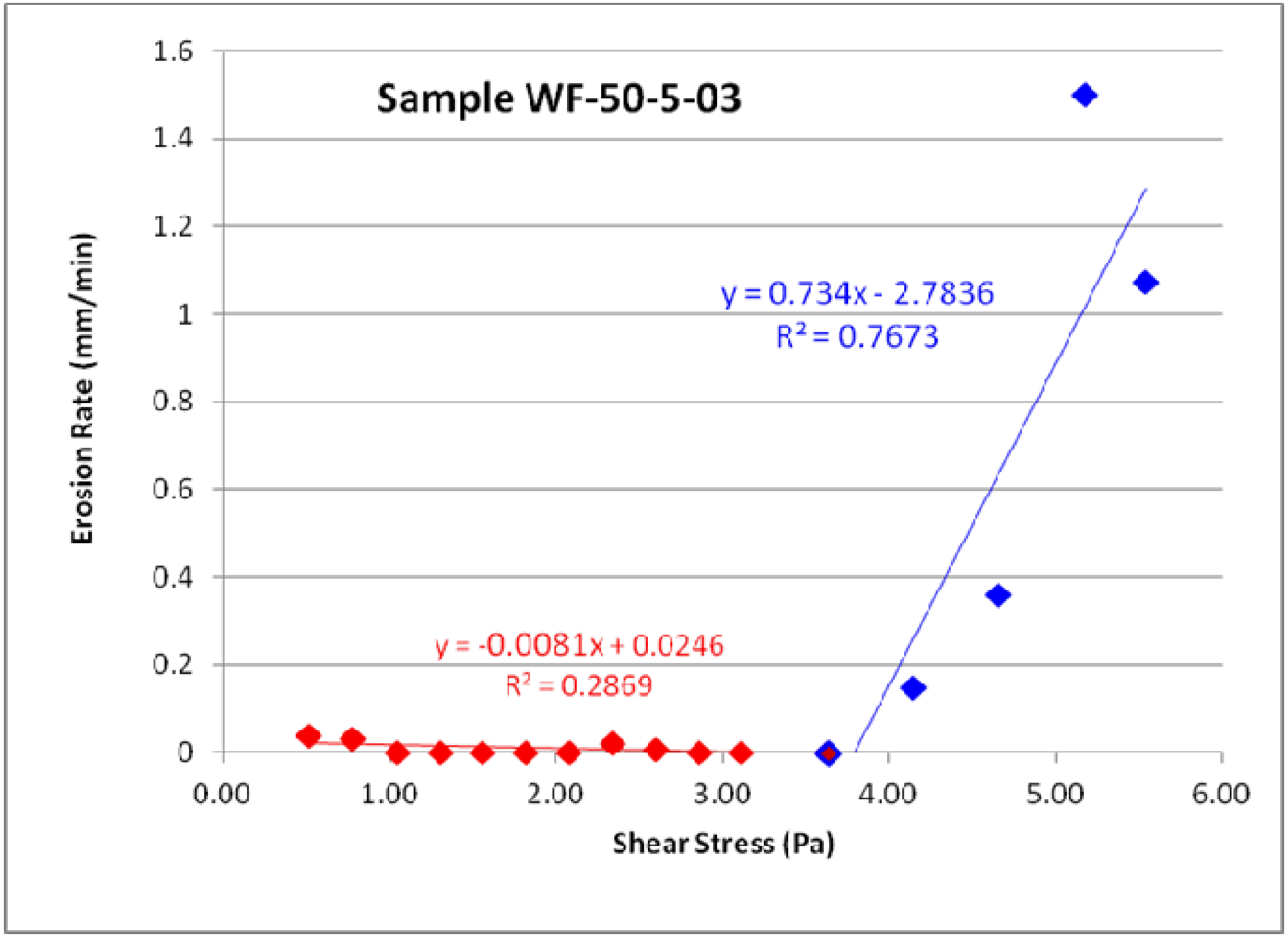
Another Example Result



$\tau_m = 3.79$ Pa

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Table of Results

Sample Type	Average Shear Strength [Pa]		
	UF Bilinear	UCSB Linear Interpolation	UCSB Power Law Fit
100% degraded waste, 2.3 MPa compaction pressure	----	----	----
100% degraded waste, 5.0 MPa compaction pressure	----	----	----
75% degraded waste, 2.3 MPa compaction pressure	1.53	1.38	1.49
75% degraded waste, 5.0 MPa compaction pressure	2.17	1.81	1.97
50% degraded waste, 2.3 MPa compaction pressure	2.22	2.58	2.85
50% degraded waste, 5.0 MPa compaction pressure	5.05	5.10	5.29

Summary

- The lower limit of TAUFAIL is very conservatively based on literature search considering surface layer of a mud
- TAUFAIL is best determined through direct measurement tests of anticipated surrogate waste materials
- Vertical Erosion Flume
  - Provides sample specific surrogate waste shear strength and erosion rate data
- Samples made from previously accepted 50% degraded surrogate material give a lower TAUFAIL limit of 5.05 Pa, making the TAUFAIL range 5.05 – 77 Pa and statistically requiring a uniform distribution

The End

Questions?