

Geotechnical Properties of Tidal Flat Muds: Responses to Tangential and Normal Stresses

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Grant Number: N00014-02-1-0663

LONG-TERM GOALS

The long-term goal is a quantitative and mechanistic understanding of the response of mud flat sediments to tangential and normal stresses and how these relate to the erosion rates of sediments.

OBJECTIVES

The rate of muddy sediment erosion is very difficult to predict, yet it is crucial to know in predicting the evolution of mud flats as a result of natural or anthropogenic perturbations. Our objective is to determine if fracture strength alone or in combination with other geotechnical properties of muddy sediments is a predictor of erodibility.

APPROACH

Our approach for the DRI includes a combination of work both lab testing and experiments at Dalhousie University, Nova Scotia, Canada and fieldwork in Willapa Bay, Washington State, USA study site. Listed below are the main approaches:

- (1) Measurement of geotechnical parameters (fracture toughness, Young's modulus, and shear strength) as functions of sediment depth, grain size, porosity, organic matter content, and temperature. (B. Johnson, M. Barry)
- (2) Measure the erodibility of the near-surface sediments using a rotary flume from the Bedford Institute of Oceanography. (P. Hill, in collaboration with Tim Milligan and others)
- (3) Measure the erodibility of sediments as a function of depth using a portable flume. (B. Johnson)

Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE 2011		2. REPORT TYPE N/A		3. DATES COVERED -	
4. TITLE AND SUBTITLE Geotechnical Properties of Tidal Flat Muds: Responses to Tangential and Normal Stresses				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Department of Oceanography Dalhousie University Halifax, NS B3H 4J1, Canada				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited					
13. SUPPLEMENTARY NOTES FY10 Annual Reports of S & T efforts sponsored by the Ocean Battlespace Sensing S & T Department of the Office of Naval Research., The original document contains color images.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT SAR	18. NUMBER OF PAGES 5	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

(4) Establish any correlations between the measured geotechnical parameters and between geotechnical and physical properties. (B. Boudreau, B. Johnson, M. Barry)

(5) Explore relationships among the measured parameters and sediment erodibility. (all group members)

WORK COMPLETED

In 2010 we participated in the DRI field experiment (February/March) at Willapa Bay, Washington. Stress-strain (Young's modulus) profiles were made at most of cored sites using the elasticity probe developed and tested at Dalhousie University. The elasticity probe (figure 1) was completely rebuilt to improve reliability, resolution, and noise level over the previous design used in the 2008 DRI field experiments. Fracture toughness was measured with depth on the same cored sites, as well as grain size and x-rays collected on cores that geotechnical measurements were made in.

The portable straight flume was tested at Dalhousie University to determine the effect of surface flaws on the erodibility of sediments. Both size and geometry of the flaw were varied to explore their effect on the shearing forces required to erode the sediment.



Figure 1. Elasticity probe used to measure the stress-strain response of sediments. A secondary attachment allows for the probe to be secured atop of sediment core liner.

RESULTS

Stress-strain: Measurement of the stress-strain behaviour of sediments with depth across the transect revealed major differences between the tidal flats and channel sediments. Tidal flat sediments tended to behave elastically (figure 2a), more so with increasing depth, while channel sediments had a behavior similar to lab experiments using molasses (figure 2b). Plasticity was noticeable in many stress-strain measurements but became less pronounced as depth increased.

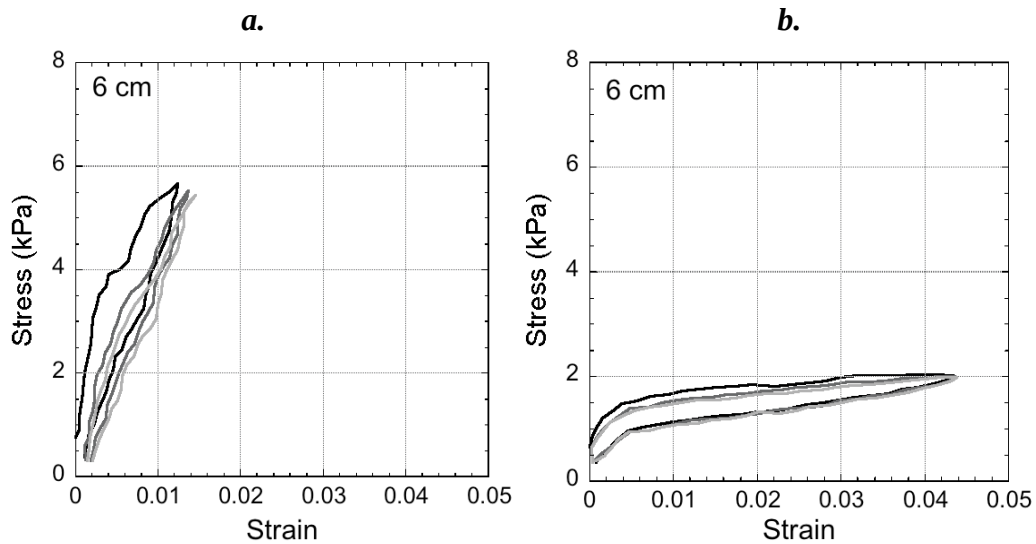


Figure 2. Stress-strain behaviour of sediment from Willapa Bay, Washington. Stress-strain behaviour from the tidal flat (a) and from the channel (b) are drastically different with the flats behaving much more elastically and the channel sediments behaving much more viscously. The channel sediments behaviour is typical of a fluid while the sediments on the flats behave as solids.

Fracture toughness: Measurements on cores collected on the transect across a channel in Willapa Bay showed that the middle of the channel had an anomalous fracture toughness profile. This profile (figure 3) appears to confirm the stress-strain measurements, i.e., indicating that the sediment is not elastic.

Willapa - 356854
(February 27, 2010)

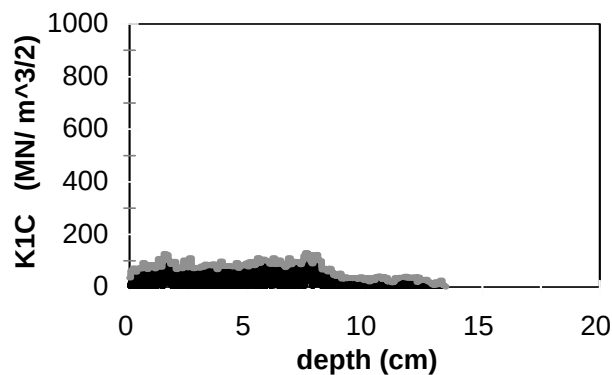


Figure 3: fracture toughness profile in core sample taken from the middle of the channel in Willapa Bay.

None of the profiles of fracture toughness in other cores taken across the channel showed a decrease in fracture toughness with depth and several showed dramatic increases, e.g., figure 4 showing a profile in a core taken from the flat.

Willapa - 356831
(February 27, 2010)

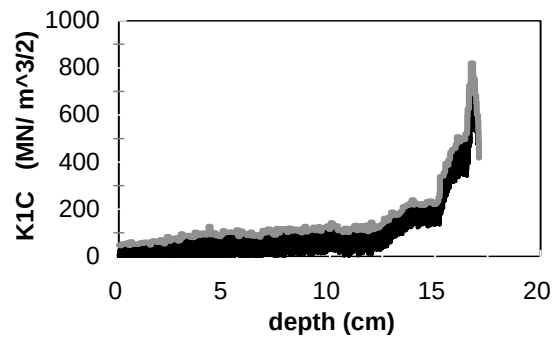


Figure 4: fracture toughness profile in core sample taken from the flat above the channel in Willapa Bay.

Erodibility: Testing of the portable flume in the lab showed that creating an initial flaw at the surface of the sediment results in a decrease in the shear stress required for failure by fracture to occur (figure 5). As theory predicts for elastic fracture, stress for failure decreases with increasing flaw size. What could also be seen in lab experiments is the ability of near-surface sediments to “self-heal” on very rapid time scales after a flaw is introduced. This behaviour reflects the ease at which deeper sediments tended to fail by fracture during erosion tests with the flume in July of 2009.

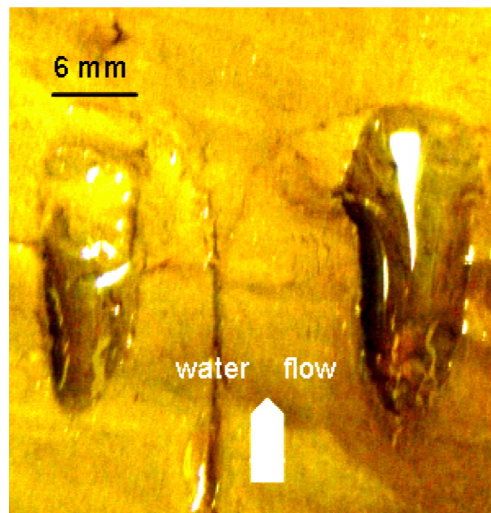


Figure 5: In studies of erosion of muddy sediments in a flume we have demonstrated that fracture occurs where small cracks have been initiated artificially. Two such fracture sites are shown.

IMPACT/APPLICATIONS

Our results will lead to better prediction of tidal flat stability (fracture toughness and erosion flume) and other relevant geotechnical information, like trafficability (stress-strain behaviour).

RELATED PROJECTS

None.

PUBLICATIONS

Johnson, B.D. and M.A. Barry (2010), Is fracture toughness an indicator of sediment erodibility? Eos Transactions, AGU, 91(26) Ocean Sciences Meeting Supplement, Abstract GO35C-15. [published]

Johnson, B.D., M.A. Barry, B.P. Boudreau, P.A. Jumars, and K.M Dorgan (2010), Profiling Fracture Toughness in Cohesive Sediments, Geotechnique. [submitted]

Barry, M.A. (2010), Elastic and fracture behaviour of marine sediment in response to free Gas, PhD Thesis, Dalhousie University, Halifax, Nova Scotia, Canada. [published]

Barry, M.A., B.P. Boudreau, and B.D. Johnson (2010), A new instrument for in situ measurement of Young's modulus in shallow cohesive sediments, Geotechnique. [submitted]

PATENTS

We are in the process of patenting the fracture probe. [pending]