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The State of the Art and Science of Coastal Engineering

Recession of Predominantly Sandy Bluffs

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Outline

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3.Experimental Setup

4.Results and Discussion

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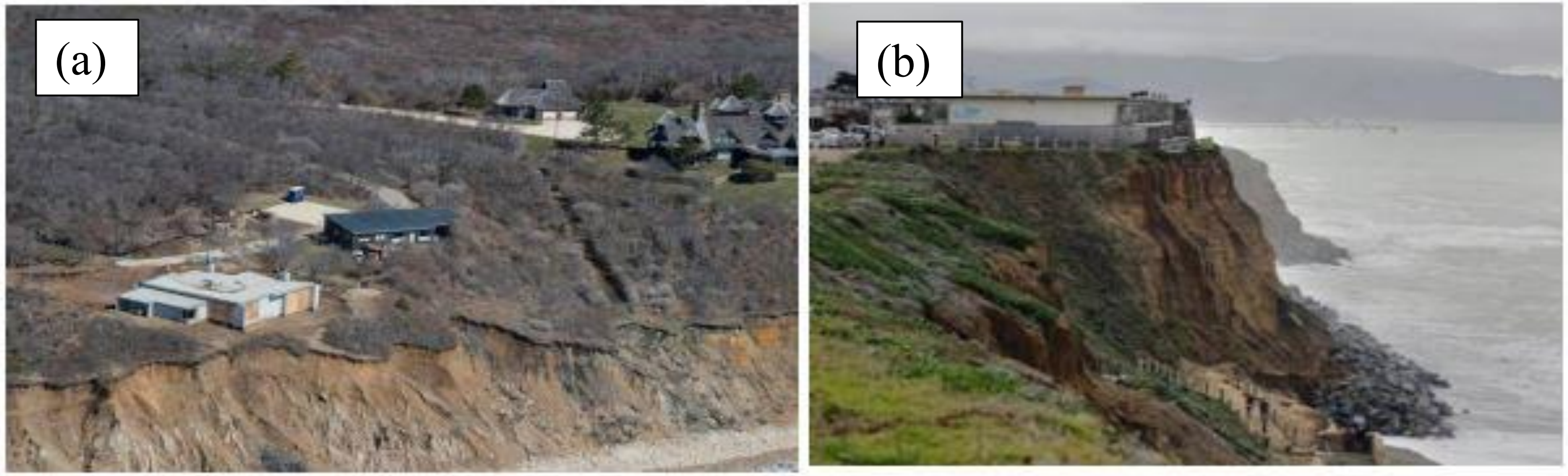
INTRODUCTION

Coastal Bluff Recession

Involve a broad range of factors including both sea-based morphodynamic activities as well as land-based processes.

- Impossible to Recover
- Poses substantial risk to the safety of nearby structures and infrastructures
- Has many social, environmental and economic impacts on coastal communities, states, and nation



Bluff Recession in Montauk, NY (image Credit: Photo Credit: Doug Kuntz, Newsday); (b) Pacifica, CA (Image Credit: Credit Eric Risberg/AP)

Location	**Bluff portion of total shoreline length (%)**
Great Lakes	12
Mid-Atlantic and New England	7
California	72
Oregon	58
Washington	22

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Some of existing methods rely on historical bluff recession data and others are highly empirical.

	Experimental Studies
Skafel et al. (1994)	Cohesive beach-bluff profile erosion by waves
J. S. Damgaard and P. Dong(2004)	Soft cliff recession under oblique waves
Bastien Caplain et al.(2011)	Cliff retreat and sea bed morphology under monochromatic wave forcing

OBJECTIVES

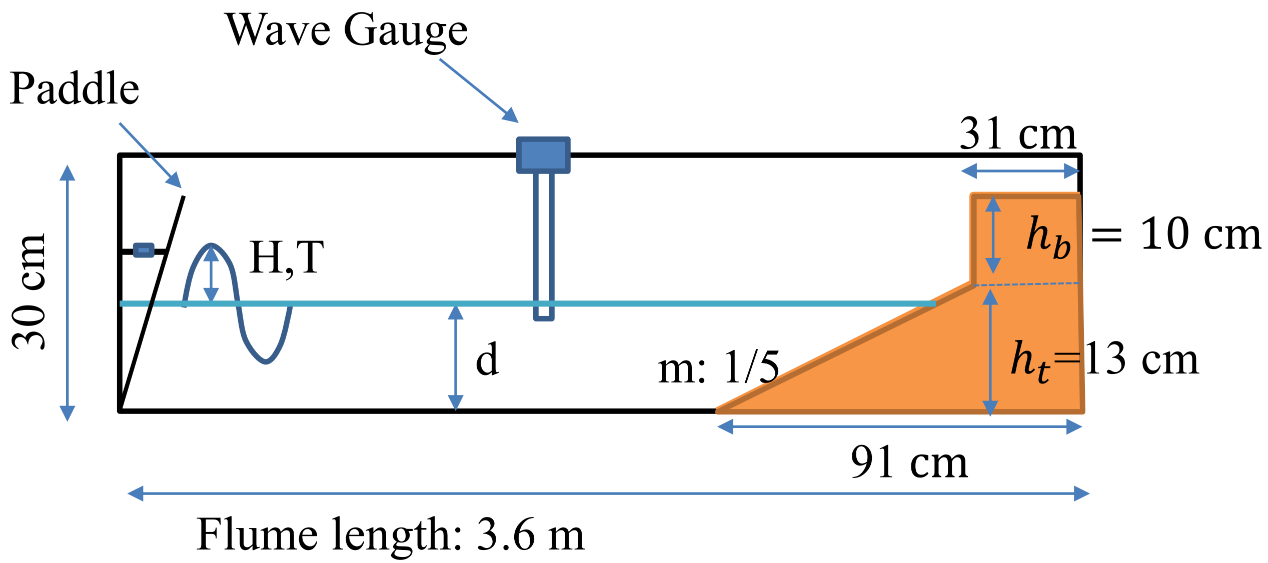
Explanatory experiment is conducted to investigate the influence of geotechnical parameters of predominantly sandy bluffs on their responses to sea-based forcing

Two parameters are considered here:

- Shear strength of the material
- Fraction of clay

EXPERIMENTAL SET UP

- Monochromatic waves generated using flume's flap-type paddle
- Instantaneous water surface elevation measured using a resistive wave gauge
- Beach and bluff profile Evolution recorded using GoPro Hero 5 Black



Schematic of Experimental Setup

Material for Testing

- Sample materials were taken from a bluff site on south shore of Long Island, NY.
- The Montauk bluffs are predominantly sandy, steep or event vertical with a height ranging from about 6 m to more than 30 m.
- Bluffs are constantly being eroded by wave and surge attacks from Atlantic Ocean.

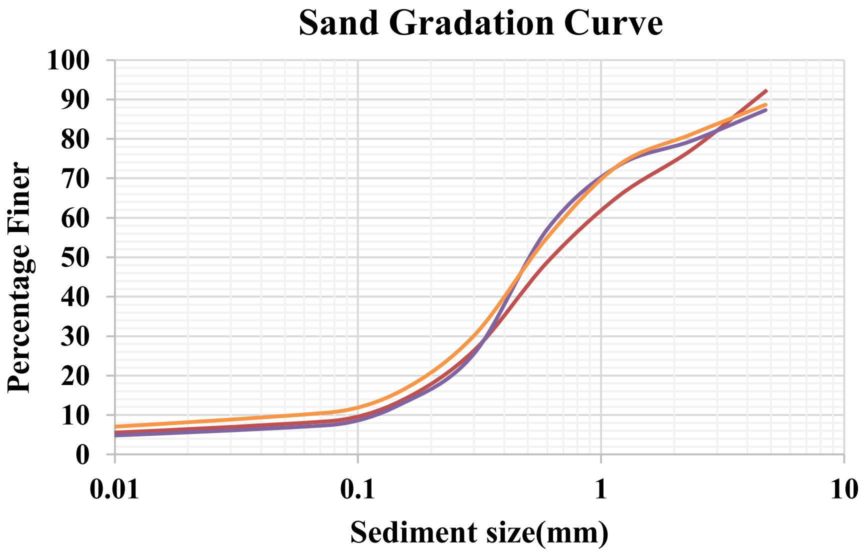
Montauk Point Bluff

Materials Properties

- Field materials were analyzed in the lab for their geotechnical properties.

Field sample properties

Gs	2.52-2.56
Water content	4-17%
Void ratio	0.36-0.64
Dry Density	1.43(gr/cm^3)
e_{min}	0.30
e_{max}	0.68
I_D (Relative Density)	0.1-0.86
w_{opt}	11-13%
PL	18.2-21.1%
LL	35.7-36.7%
PI	14.6-18.5%



Sieve analysis of three different field sample (D_{50}:0.5mm)

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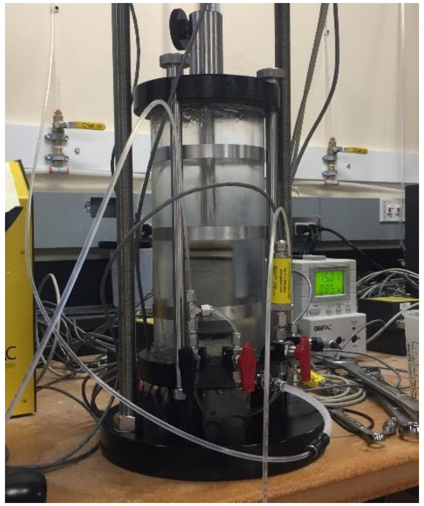
Sample Preparations for Flume Tests

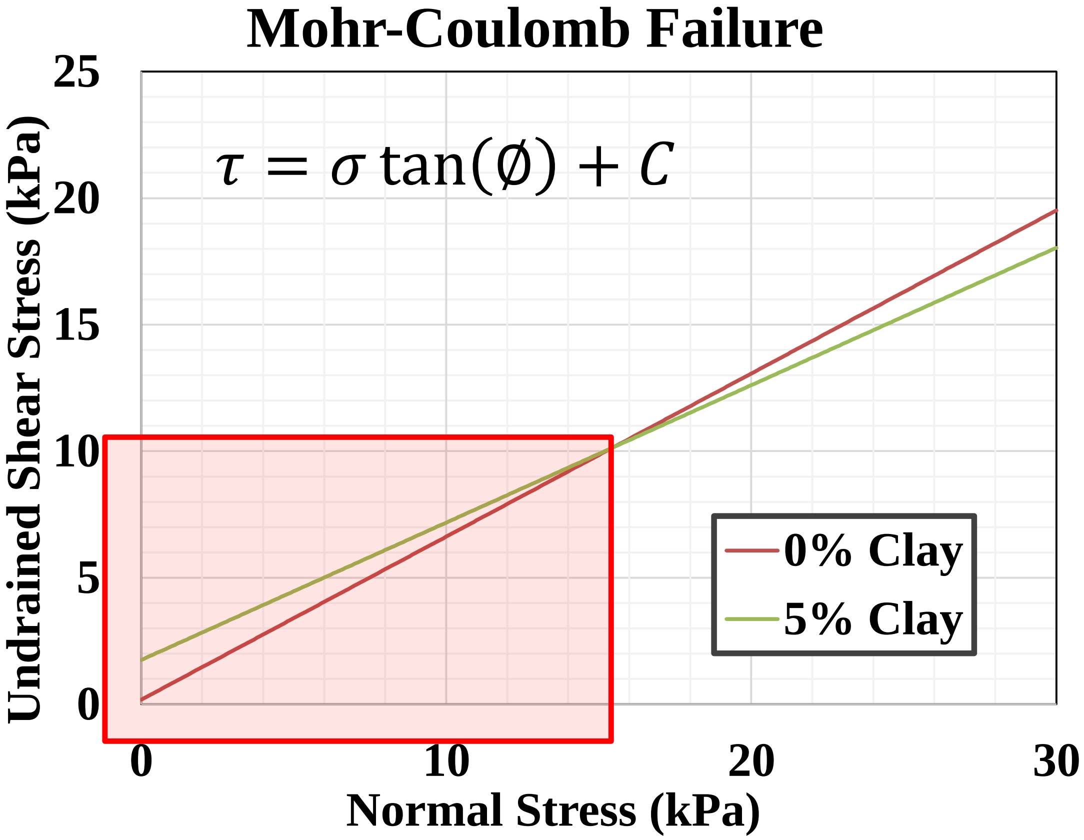
- Test samples were prepared based on field sample properties with two different clay content(0 %and 5 %)
- Samples were made by volume control method to reach the target density.

Target sample properties for small flume experiments

Target Samples	Properties
Void Ratio	0.51
I_D (Relative Density)	0.39
Water content	0.07

- Triaxle tests were conducted to obtain sample materials strength indices.





Undrained Shear strength parameters

Sample No.	Clay Content (%)	C'(kPa)	Φ'	C (kPa)	Φ
1	0	0.15	33.3	0.18	32.8
2	5	1.01	28.8	1.75	28.5

- Clay content increases undrained shear strength under normal stresses lower than 15.5kPa
- Clay content reduces undrained shear strength under normal stress higher than 15.5kPa

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Molding Beach-Bluff Sample

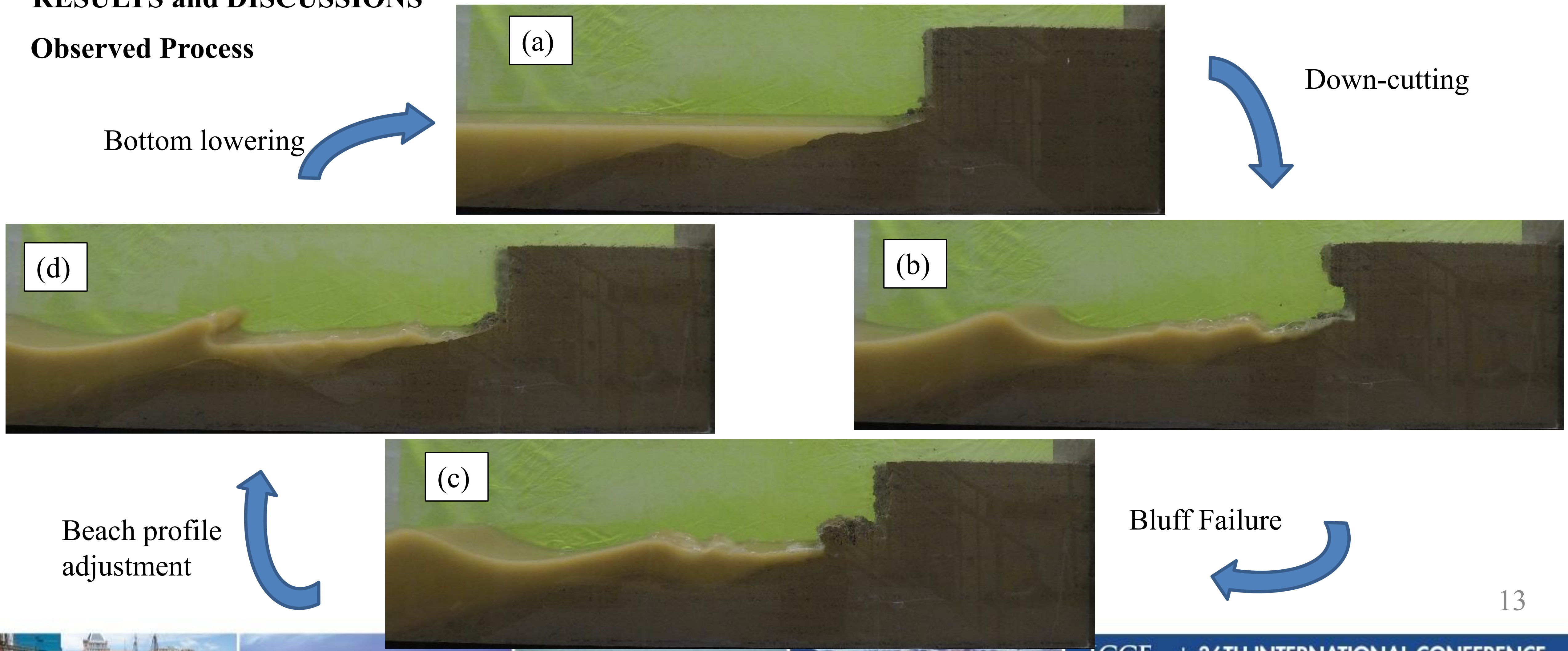
- Soil was mixed with specific amount of water to reach the target water content
- Soil compacted layer by layer based on volume control method for the target density (A-D)
- Water level was gradually risen to target level
- Pictures were taken for profile measurements (E)

Water Levels and Wave Characteristic

Wave and water level at toe of 1/5 slope	Stage 1	Stage 2	Stage 3
Water depth (d, cm)	12.5	13.5	14.5
Wave height (H, cm)	5.6	6.3	7.4
Wave period (T, s)	0.51	0.51	0.51
Wave length (L, cm)	39.1	39.5	39.8
Wave Steepness (H/L)	0.14	0.16	0.19
Surf similarity (ξ)	0.53	0.5	0.46
Breaker type	Plunging		

RESULTS and DISCUSSIONS

Observed Process



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Time laps of bluff failure

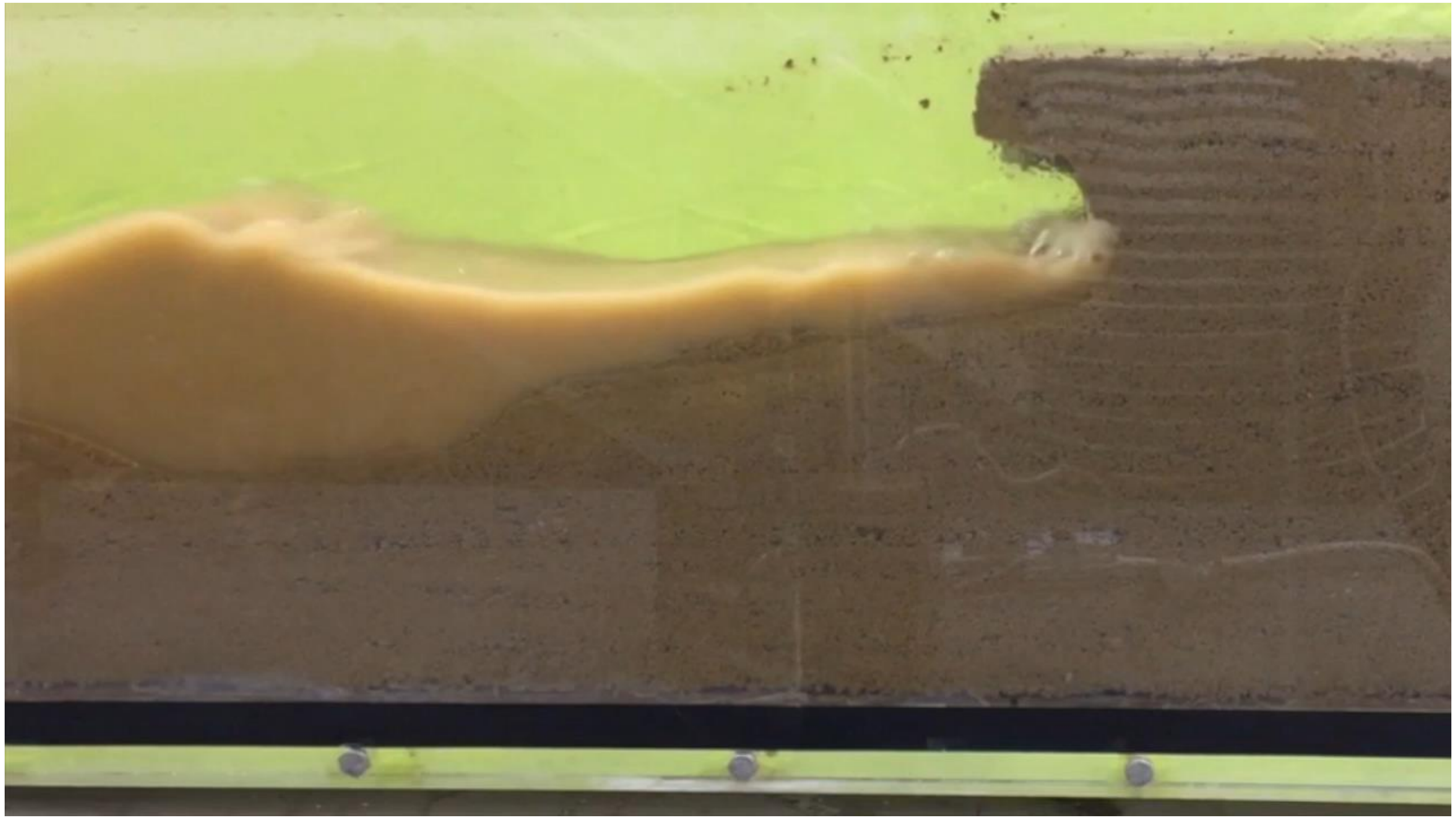

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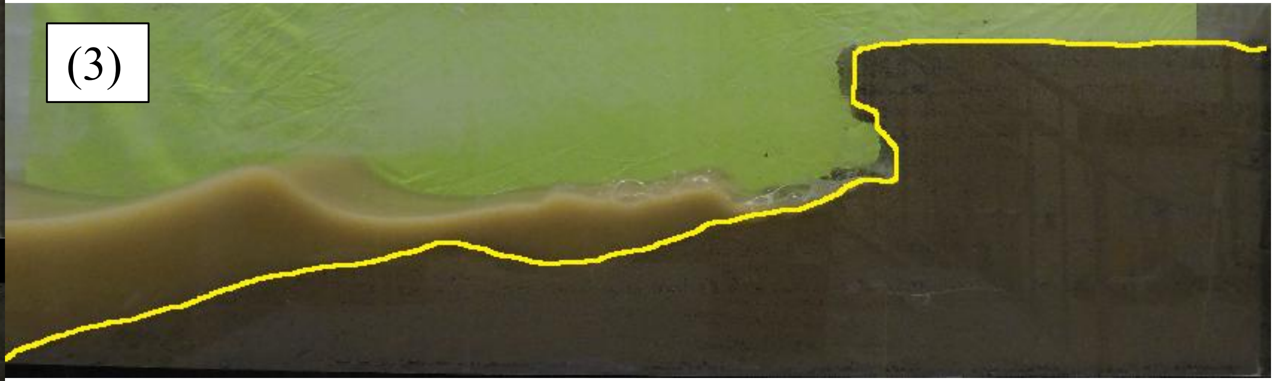
Image Processing

- Image Processing utilized by three different toolbox in MATLAB R2017a.
- First camera has been calibrated and then images were wrapped.
- Secondly, beach and bluff edges were captured using a color threshold technique (1).
- Then, image region analyzer used to delete the noises, and,
- Finally, Image segmentation technique was used to eliminate farther edge of the bluff visible due to camera angle relative to the bluff (2).



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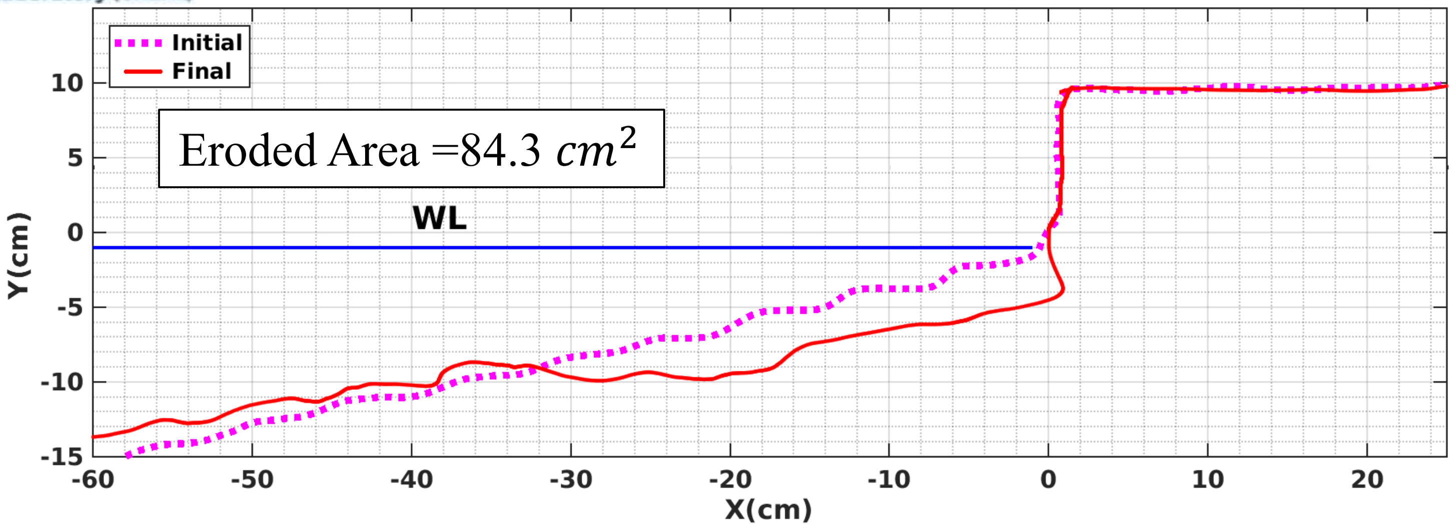
Stage 1: Initial and final profile of beach and bluff

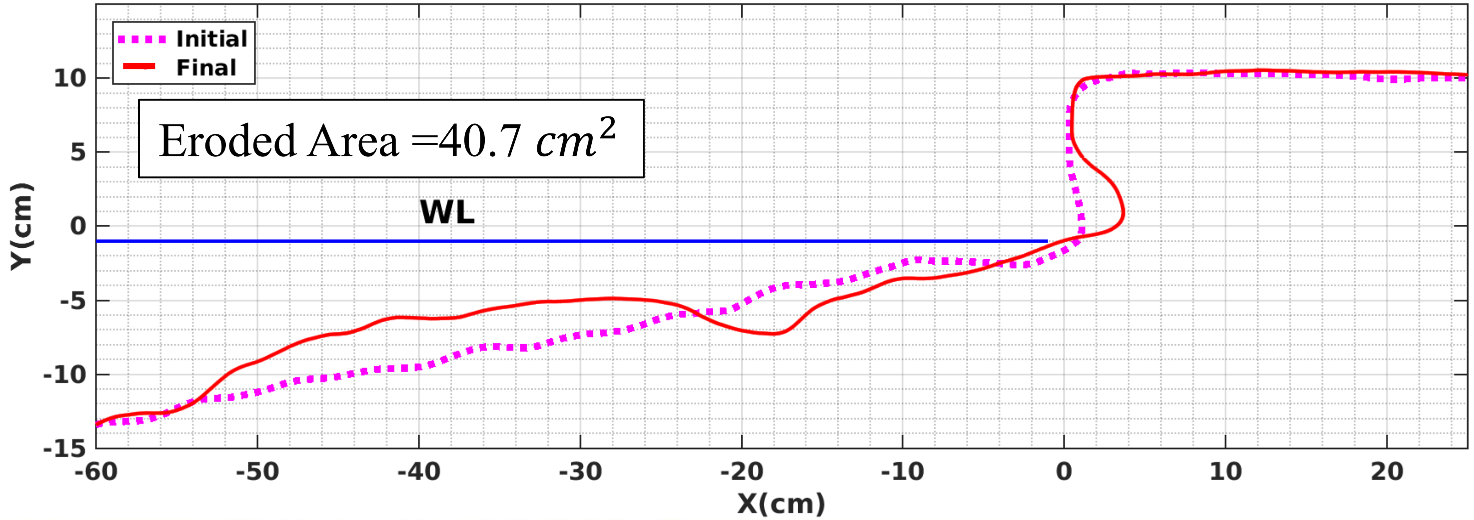
d=12.5 cm
H=5.6 cm
T=0.51 s
Test duration: 24 hr

Eroded Area
Sample with pure sand: A_e= 84.3 cm^2
Sample with 5% clay content: A_e= 40.7 cm^2

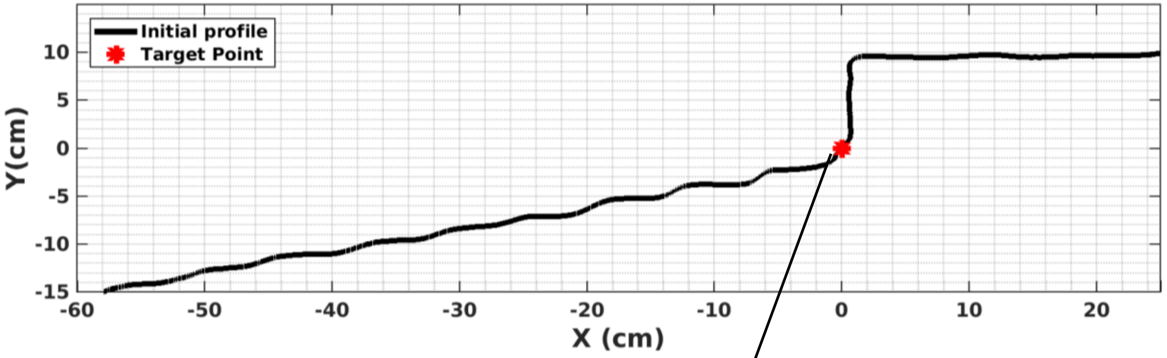
Clay Content: 0%



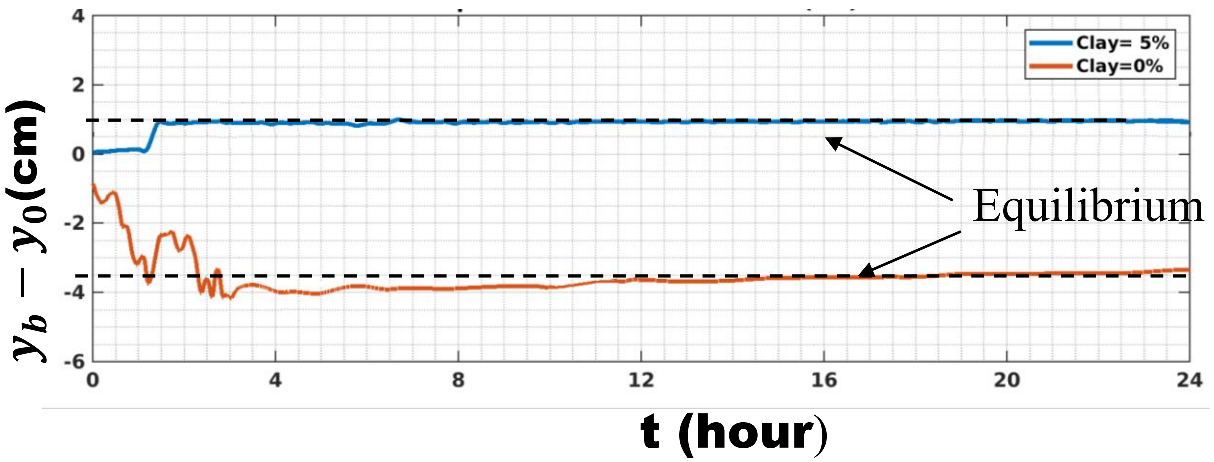
Clay Content: 5%



Stage 1: Rate of Bottom Change



Time history of bottom variations at the toe of bluff for the samples with pure sand and that with 5% clay content



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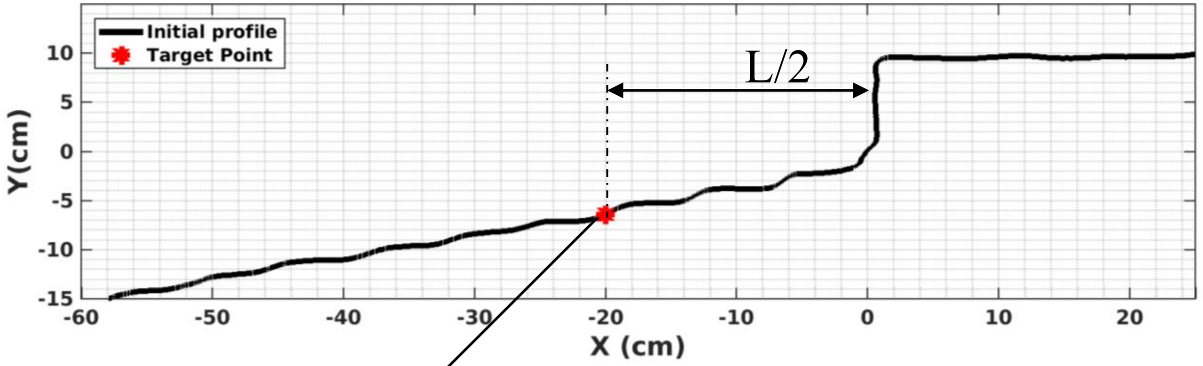
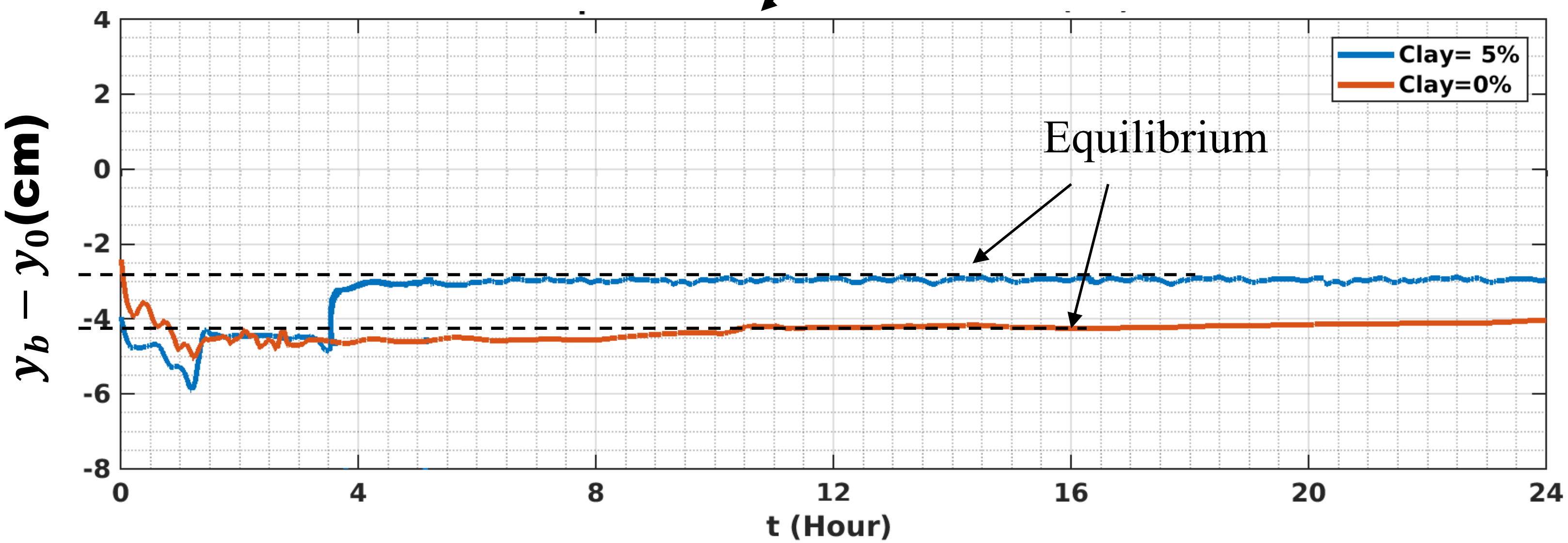
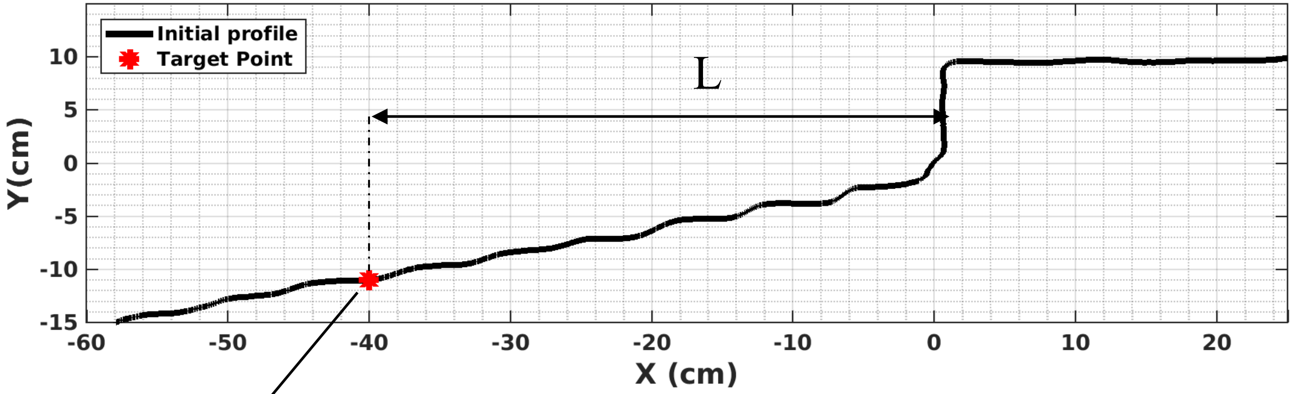


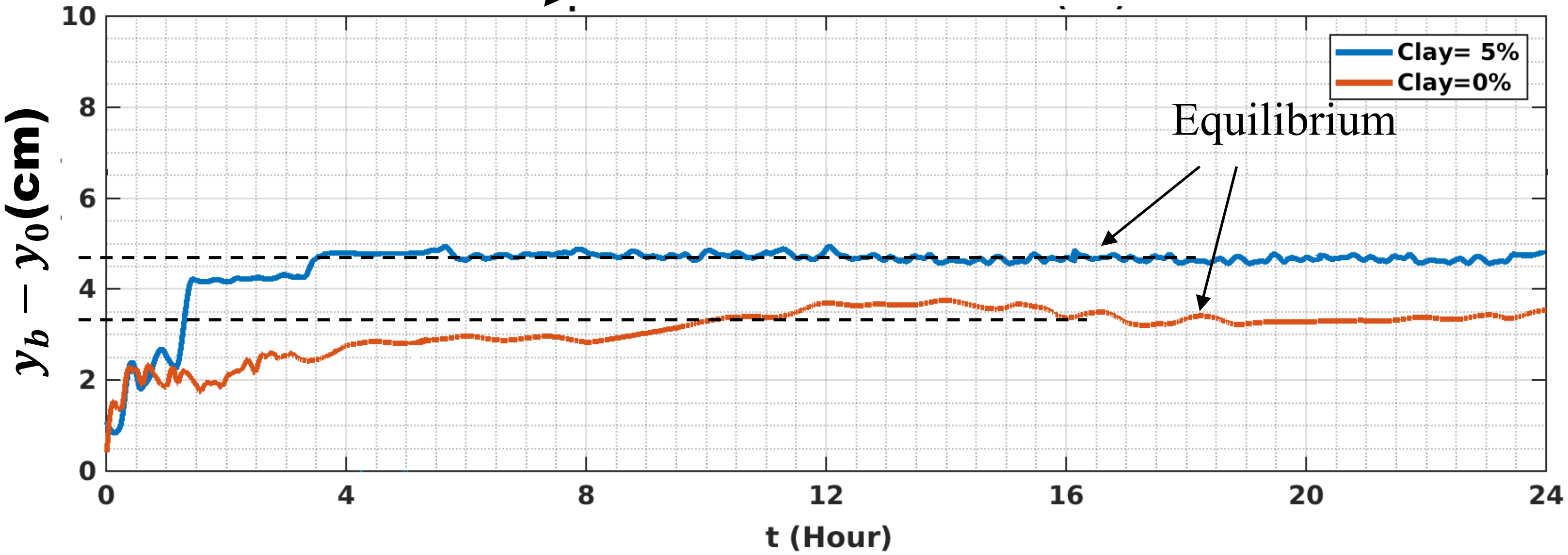
Time history of bottom variations at a distance equal to half-wave length from the toe of bluff for the samples with pure sand and that with 5% clay content



Stage 1: Rate of Bottom Change

Time history of bottom variations at a distance equal a wave length from the toe of bluff for the samples with pure sand and that with 5% clay content





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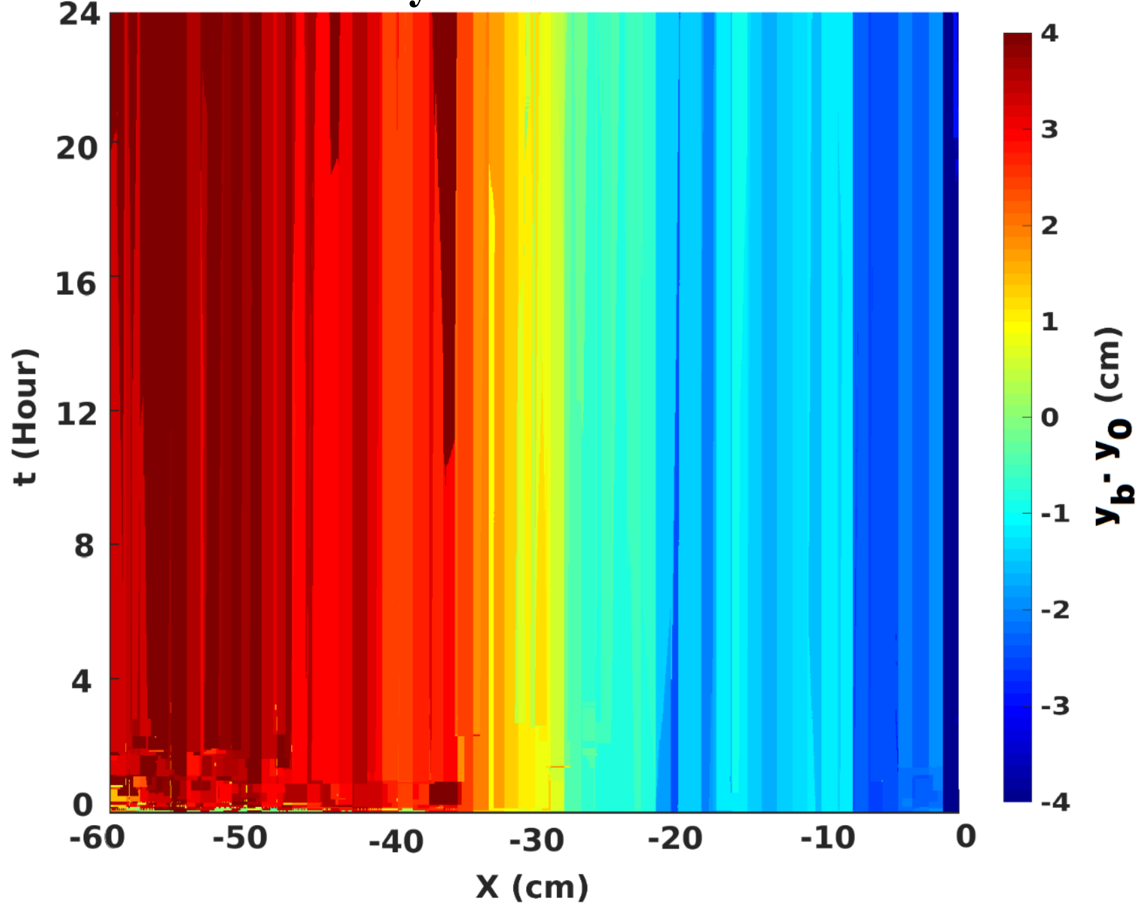
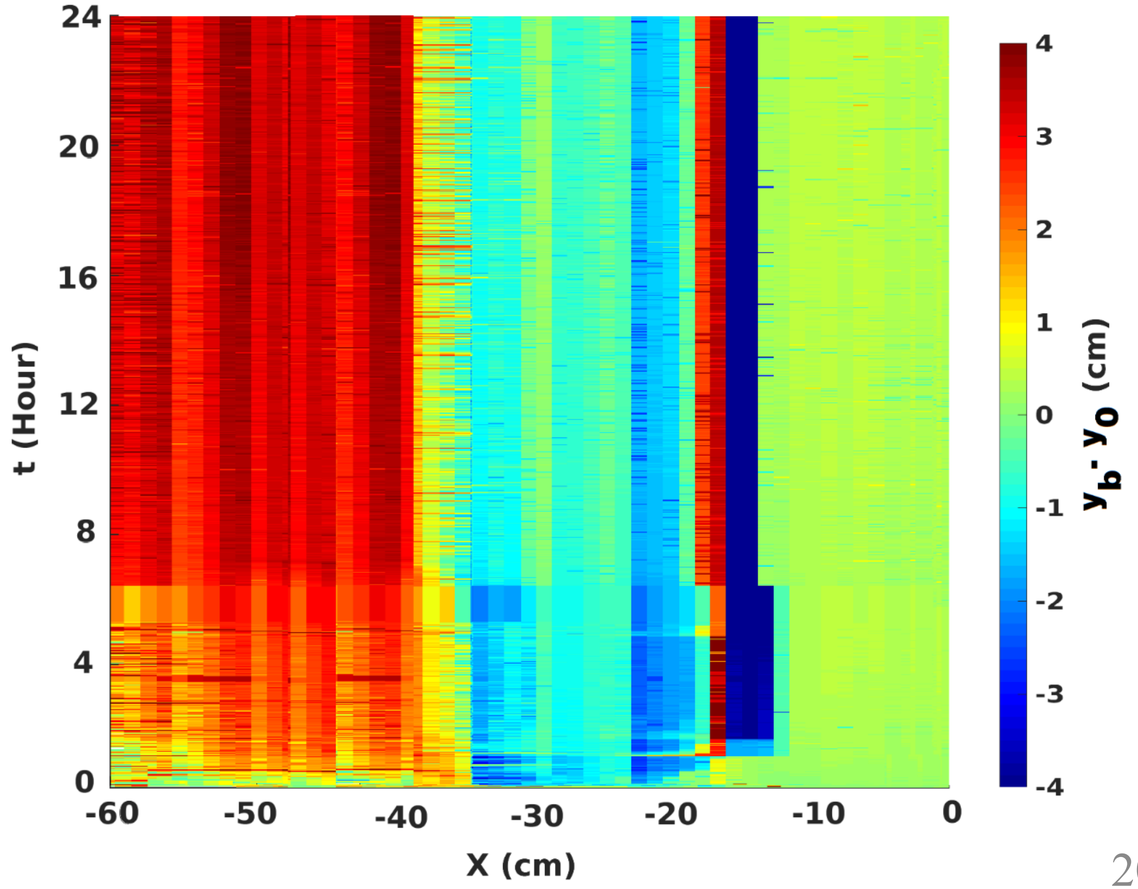
Time-stack of Bottom Elevation Variation

Clay Content: 0%



Clay Content: 5%



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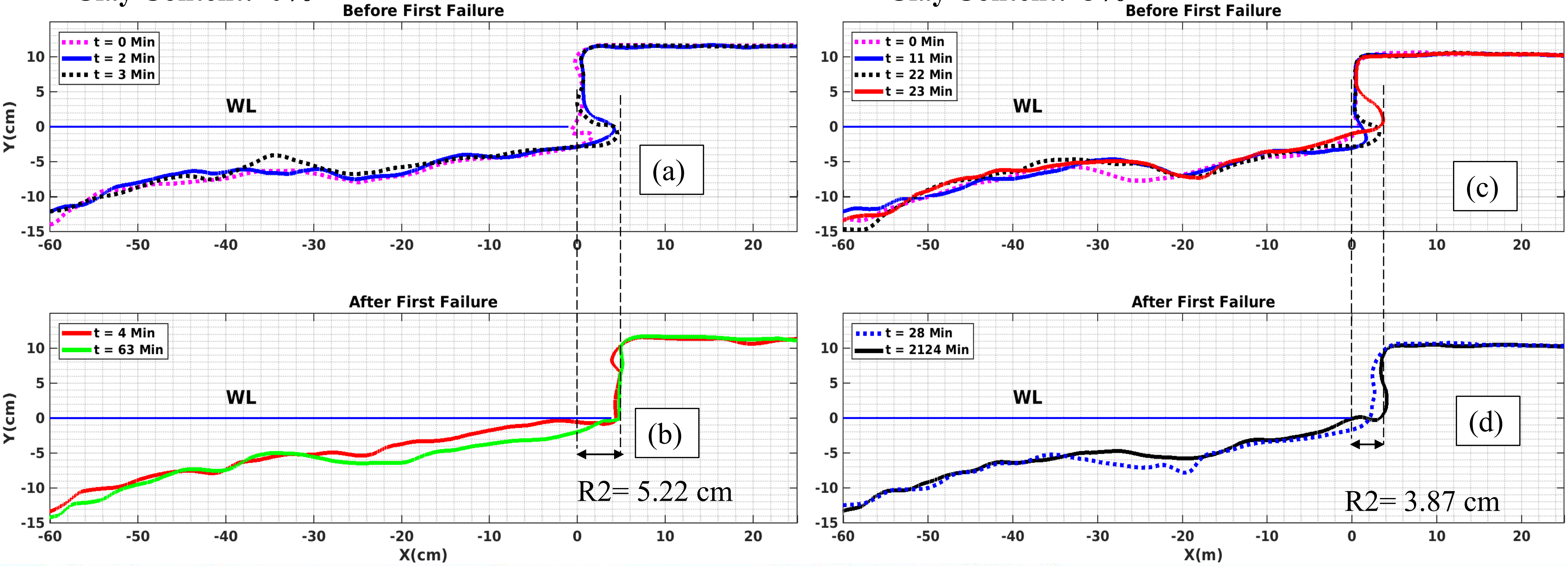
- **Stage 2: Beach and Bluff Erosion: First Failure**

Clay Content: 0%

Clay Content: 5%



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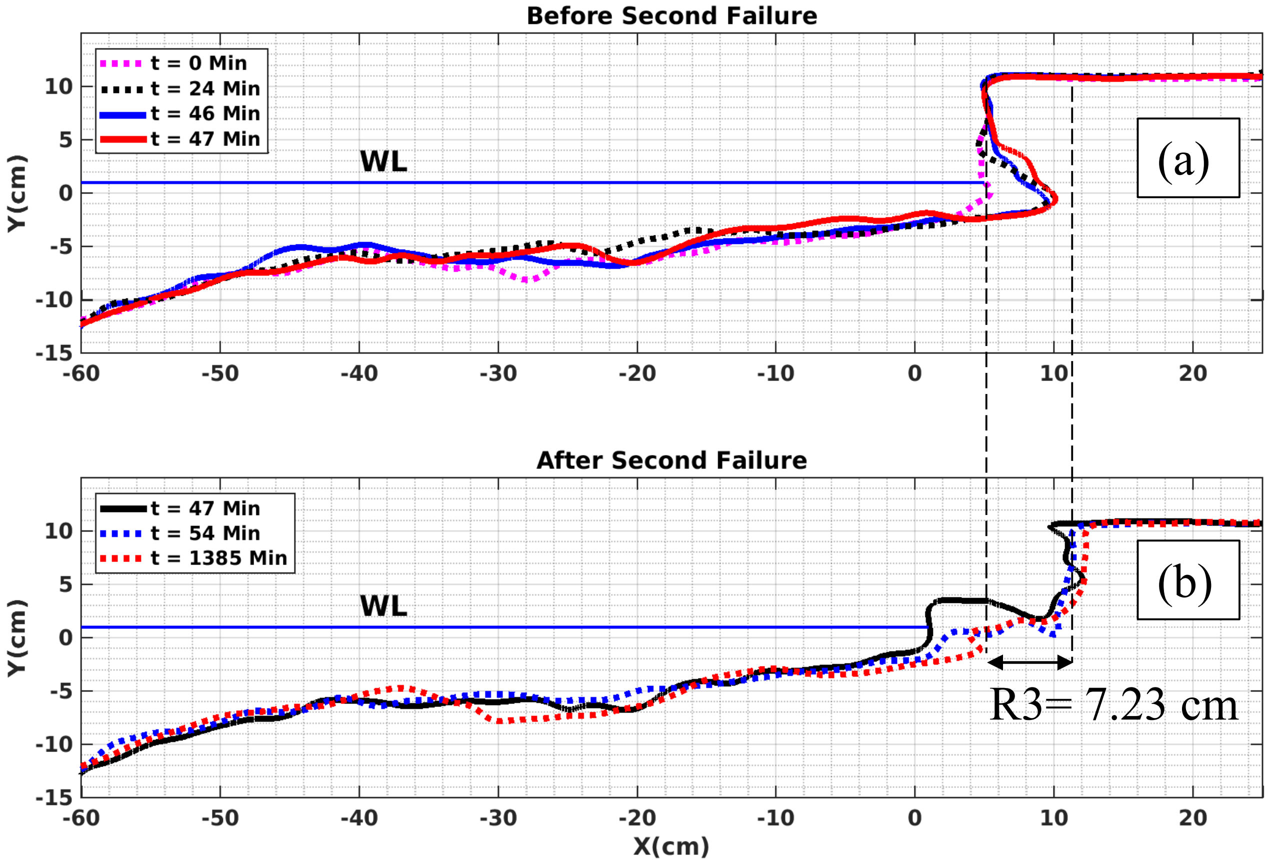
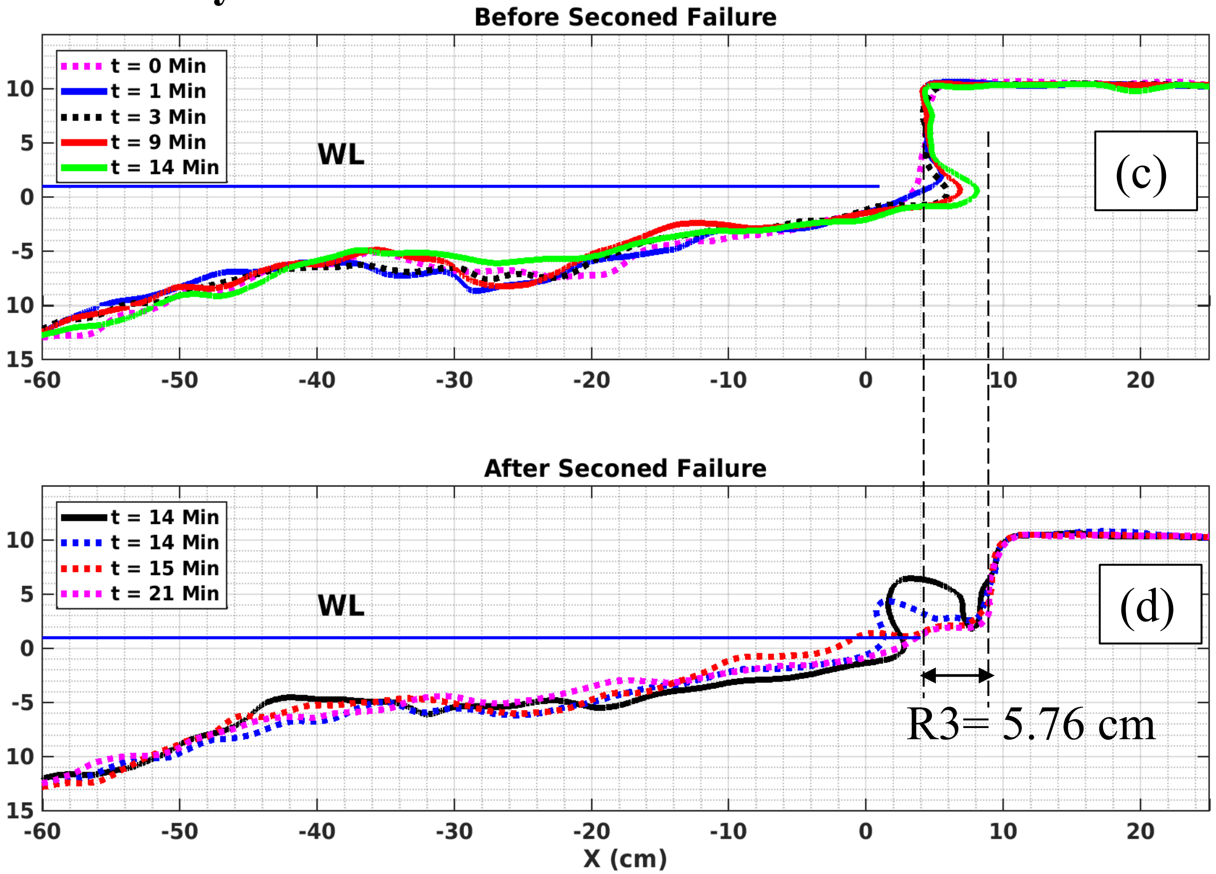
- **Stage 3: Beach and Bluff Erosion: Second Failure**

Clay Content: 0%



Clay Content: 5%



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Summary of Recession and Eroded Area

	Stage						Total Bluff Recession and Area Loss	
	1		2		3			
Clay Content	R1 (cm)	A_{e1} (cm^2)	R2 (cm)	A_{e2} (cm^2)	R3 (cm)	A_{e3} (cm^2)	R(cm)	A_e(cm^2)
0%	0	84.4	5.2	44.2	7.2	62.2	12.4	106.41
5%	0	40.7	3.9	20.3	5.8	44.3	9.7	74.75

Note: A_{e1} is beach cross-sectional area loss

A_{e2} and A_{e3} are bluff cross-sectional area losses

CONCLUSIONS

- Beach erosion for purely sandy bluff was more than double that with 5% clay content.
- In First stage, sample with no clay shows bottom lowering at the toe(2.5 cm). However, the second case with 5% clay content shows a small deposition due to bluff downcutting (less than 1 cm).
- During Stage 1, the bottom elevation at L/2, for the sample with 5% clay content rose by 1 cm following an erosion due to the bluff failure.
- Total crest recession for purely sandy bluff was 27 % higher than that with 5% clay content.
- The amount of bluff volume loss are 50 % and 100% higher during Stage 3 for sample without clay and with 5% clay, respectively. Perhaps this is due to large waves more directly attacking the bluff front.
- Final eroded area of the bluff for the pure sand sample was 43% higher than the that with 5% clay content.
- The purely sandy beach reaches an equilibrium condition during Stage 1, in less than 2 hour; however the beach with 5% clay content takes more than 4 hour to reach the equilibrium condition.
- Unlike for the purely sandy bluff, the down cutting (10.4 cm^2) happened for the bluff with 5% clay content during Stage 1 which can be because of the stiffness of the beach which allows plunging waves runup to reach the bluff more energetically as opposed to the sandy beach where breaking wave energy is spent on the transport of sands on the beach.

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Thank you.

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