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Kingdom Built on a Pile of Sand:Slow and Steady

Contents

1 Introduction

1.1 Problem Background

Sunshine, clear blue sea and golden color sand always seem to leave people in a happy state of mind. And a beach is where these three are combined, drawing people all around towards it. Sand, the granular matter formed by constant brushing of flowing water, however, can react with water in a different way, despite the fact that people refer to it as non-stable or unreliable. On a beach, where the already formed granular sand and the rise and fall of sea wave lies together, a new buff can be added to our flowing friend, the wet state.

1.2 Our Work

2 Assumptions & Nomenclature

2.1 Assumptions

2.2 Nomenclature

3 Modeling Under Waves and Tides

¡¡¡¡¡¡¡ HEAD

The 3-dimensional shape constructing problem is divided into two subproblems. We first establish the model using the **Mohr-Coulomb Criterion** to decide the shape of the slope. We then construct another model with a modified version of **Cellular Automata** to determine the best shape viewed from the top,...

3.1 Shape of the Slope: Mohr-Coulomb Criterion

We begin by determining the Side shape of the sand castle fundation. Before Approaching the problem, we will briefly address the property of sand as a granular media.

In our assumptions, sand particle are considered as a simplified model of identical tiny spheres. If we zoom in to observe a pile of wet sand, there are the so-called liquid bridges formed between sand particles.

Various water contents produce different liquid bridge distributions, which will influence the properties of sand.

Table 1: States of Sand

Liquid Content	State	Description	left for future use
No	Dry	000	000
Small	Pendular	000	000
Middle	Funicular	000	000
Almost saturated	capillary	000	000
More	Slurry	000	000

When the wave hits the foundation, the surface area is in slurry state and there exists no cohesive interaction between the particles, which makes it very hard, if not impossible, to prevent sand loss. Nevertheless, collapses after the wave resides can cause more harm to the foundation, which can be avoided by alternating the shape.

For dry sand, the failure criterion is given in terms of the shear stress τ, the normal compressible stress σ and the internal friction μ as

$$\tau > \mu\sigma$$

This is simply the friction formula with different notations. Now we consider a sandpile with a normal adhesive stress s_A across every plane, in addition to the stress caused by weight. The equation(1) is then modified as

$$\tau > \mu(\sigma + s_A)$$

This criterion is the so-called **Mohr-Coulumb criterion**.The stress resulting from the weight above the plane is shown in figure (1). Denote τ_f and μ_f as the shear stress and normal compressible stress at the failure plane,they can be written as

$$\tau_f = \rho g D sin\theta_c \qquad and \qquad \sigma_f = \rho g D cos\theta_c$$

where θ_c is the critical angle, D is the height of the sandpile and ρ is the density of sand. Therefore, to solve for θ_c is to solve the equation

$$\mu = tan\theta_c(D)\left(1 + \frac{s_A}{\rho g D cos\theta_c(D)}\right)$$

The only unknow factor is s_A, the adhesive stress across the plane. According to (Thomas C.H and Alex J.L -fix later)'s study, the value of s_A is determined by water content and there are three regimes as a function of the added-fluid volume. We now focus only on the state where the water content is close to saturated.

3.2 Top View Shape

3.3 Calculating Results

3.4 Simulating Results

3.5 Refer to Footnote

4 Modeling Under Rain

5 Determine the Best Sand-to-water Proportion

6 Other Ways to Make Our Sand Castle Last Longer

7 Sensitivity Analysis

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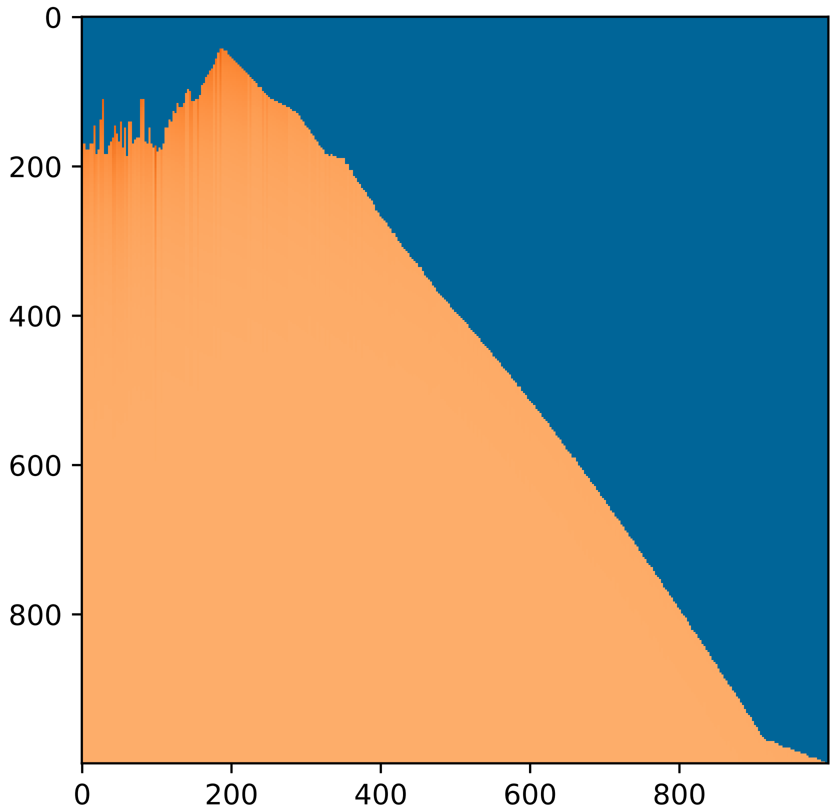

Figure 1: A Windows Terminal.

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Random citation [**LeeRice-4**] embedded in text. This is some example text[1].

I'm referring to footnote 1.

[1] Hello footnote

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