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Study on the Establishment of Stable Sand Castle Model Based on Multi-Body Dynamics

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Abstract:Making sand castle is one of the most popular activities on the beach.How to make a more stable sand castle model has become a hot issue.In this paper,the optimal three-dimensional sand castle model in different conditions is studied.Compared with other similar studies,our model is more convenient for people to understand and give a more intuitive feeling.We study the relationship between various geometry and structural stability by controlling variables.In addition,we also set up a wave erosion model to compare the stability through the fluid flow equation. In order to find the best sand water mixture ratio which can make the sandcastle foundation most stable,we found that the slurry and sand water mixture have similar properties ingeniously,so we used the slurry to establish the slurry model,and found the most stable sand water proportion by comparing the viscosity,thus also reflecting the properties of the sand water mixture,which helped us to draw a conclusion. As for the problem of the optimal three-dimensional geometric model in rainy days,we have established a rain erosion model based on hydraulics and sediment kinematics.We judge the anti rain erosion ability of the geometry by the size of sediment carrying rate,find the data of similar experiments with the help of data,and then draw the corresponding image with the formula,and obtain the conclusion.Then we use the knowledge of structural mechanics,hydrodynamics and other aspects to discuss the method of using other strategies to prolong the service life of Sandburg from multiple angles and dimensions. In order to facilitate the calculation,we use MATLAB software to help us solve the calculation problem better.Finally,we provide several improvement ideas for the optimization of the model and the realization method under each optimization idea,and give an objective evaluation and analysis of the advantages and disadvantages of the model.

1. Introduction

We will find that whenever we go to a relaxing beach,there will always be many people making sandcastles on the seashore,and even some areas will hold sandcastle making competitions.Some people simply pinch out the shape of a sand dune,while others buy a set of complicated tools to build an exquisite sandcastle as much as possible.The only certainty is that everyone hopes that the sandcastles they build can be maintained for as long as possible without being destroyed by wind or waves[1].

Rising tides,corrosive waves,and even wind erosion can cause the sandcastle to collapse[2].To build a perfect sandcastle,we must consider every possible aspect:the type of sand,the total amount of sand,the sand-water mixing ratio,and so on.Taking the above factors into consideration,our first task is to build the best 3D geometry for sandcastle production.Based on this condition,we will study to determine the optimal sand-water mixing ratio that will stabilize the sandcastle and the impact of climate change on sandcastles.Finally,we will write an article in Vacation Magazine to teach people how to build a stronger sandcastle.

2. Principle Analysis of Wave Erosion Model

Fig.1 :3d Image of Each Geometry

First,we calculate the minimum surface area of each geometry in the case of equal volume,which does not include the bottom surface.

With reference to Navier Stokes equation,we can deal with the flow of incompressible[3]viscous fluid and list the continuity equation(1)and momentum conservation equation(2)in tensor form:

$$\frac{\partial \rho v_i}{\partial x_i} = 0 \tag{1}$$

$$\frac{\partial \rho v_i v_j}{\partial x_j} + \frac{\partial \rho v_i}{\partial t} = -\frac{\partial p}{\partial x_i} + \mu \frac{\partial}{\partial x_j}\left(\frac{\partial v_i}{\partial x_j} + \frac{\partial \rho v_j}{\partial x_i}\right) + \rho g \tag{2}$$

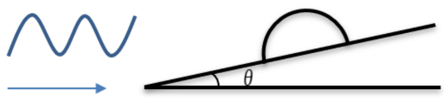

Fig.2 :Sand Castle Map of Sea Water Impact

Considering that the beach has a certain inclination,the angle is set asθ,then the pressure P of the fluid can be approximately calculated according to the equation,then the force on each geometry can be calculated through the formula F=S×P,and then the degree of erosion of the geometry can be calculated according to the magnitude of the force.When the degree of erosion is k,the geometry can no longer be maintained.Finally,by comparing different geometry,the The length of time needed to maintain the state,so as to obtain the optimal three-dimensional geometry shape[4].

3. Establishment of Rainfall Erosion Model

In this study,we need to consider the direction,size and duration of rainfall,and when the rainfall reaches a certain amount,water flow will be formed,which will also

have an erosion effect on the foundation.

The model will be based on hydraulics and sediment kinematics.Because the erosion of rainwater to the foundation is mainly the impact of the water flow formed on the sandcastle,and the erosion directly hit the foundation by raindrops only accounts for a small part,so our model will only consider the erosion of the foundation after raindrops form the water flow.First of all,because there will be a slight difference in the quality of different sands,we can know that the sediment carrying capacity of single width bed loadis:

$$m_a = \frac{k\tau U e_a}{tg\beta} \tag{3}$$

Then,we take the lighter sand taken away as a whole,and their center of gravity remains unchanged.By referring to relevant data,we can get the single width sediment transport rate of suspended loadas follows:

$$m_b = \frac{0.01\tau U^2}{\omega} \quad (4)$$

Combining equation(4.1.1)and equation(4.1.2),we get that the total sediment carrying capacityof the flow is:

$$m_c = \tau U\left(\frac{ke_a}{tg\beta} + \frac{0.01U}{\omega}\right) \quad (5)$$

Of which;

$$U = \frac{1}{n}R^{\frac{2}{3}}J^{\frac{1}{2}} = \frac{1}{n}(h_1 \cos\theta)^{\frac{2}{3}}(\sin\theta)^{\frac{1}{2}} \quad (6)$$

After a series of derivation,we can get w:

$$w = 1.73\sqrt{\frac{\gamma_1 - \gamma}{\gamma}gd} \quad (7)$$

Therefore,the maximum value ofcan be obtained.And the critical slopeis about42.

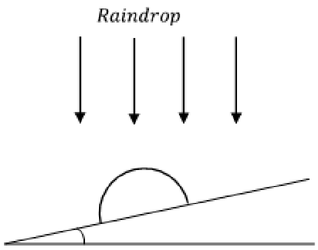

Fig.3 :Schematic Diagram of Rainwater Erosion

4. Model Solution Considering Hydraulics and Dynamics

We simply think that the larger the sediment carrying rate of different shapes of foundation, the weaker its resistance to rainwater erosion. So we need to figure out the relationship between slope ratio and sediment carrying rate and the image of slope ratio and sediment concentration. From the previous formula, we know that the critical slope is about 42.,and then according to the data given in the reference data, we can get Figure 6,Figure 7 and Figure 8:

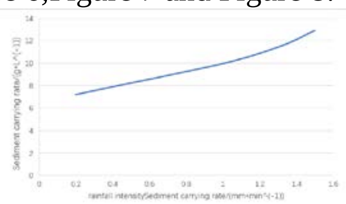

Figure 4 relationship between sediment carrying rate and rainfall intensity

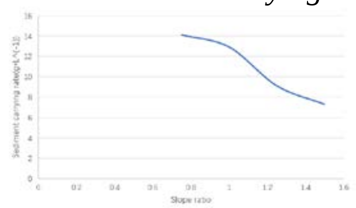

Fig.5 Relationship between Slope Ratio and Sediment Carrying Rate

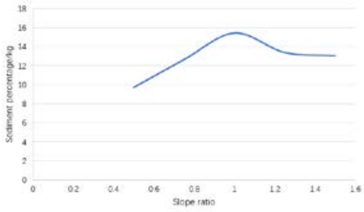

Fig.6 Image of Slope and Sediment Percentage

From Figure 4, we can see that the sediment carrying rate of rainfall increases with the increase of rainfall intensity, which is in line with our cognition. From Figure 5 and figure 6, we can know that when the slope ratio is less than the critical value, the amount of washed sand increases with the increase of the slope ratio, and when the slope ratio exceeds the critical value, the change is not so obvious.

5. Conclusion

In order to facilitate the calculation, we use MATLAB software to help us solve the calculation problem better.The best 3D sand castle model is roughly determined by changing the total amount of sand,but this is in the case of the same amount of sand.According to the research,the stability of the first simulation test will increase with the increase of sand,but we need to note that the stability will not improve indefinitely.Therefore,the amount of sand and gravel can be increased within a certain range.The daily erosion of sea water is one of the main reasons why the sand castle can not maintain its original shape.In order to keep the sand castle for a long time,we should move it as far as possible from the sea to build it.We can even consider the factor of wind erosion and build sand castles next to some buildings or trees so that they can withstand less wind.

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