

# Numerical Study on Treatment of Weak Groundsill with Method of Extruding Slit by Dumping Rockfill

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**Abstract.** The process of constructing breakwater project is a course of dumping rockfill. And the slit is squeezed out. The simulation of dumping rockfill is mainly by Lagrange or Euler algorithm. But these two algorithms have disadvantages in the process of simulating. The course of extruding slit is a dynamic contact process of rockfill, seawater and silt. This paper studies the basic principle of Coupled Euler Lagrange algorithms (CEL). The course of extruding slit is simulated by CEL with ABAQUS. This paper studies the course of extruding slit by dumping rockfill in the project of Haiyang harbor. The size effect of rockfill on extruding depth is put forward. The research results can be used for reference in other engineering.

## Introduction

In the process of constructing breakwater, the silt is squeezed out with the weight of rockfill to achieve the purpose of replacing silt. After the treatment of weak foundation, the second settlement of breakwater can be avoided. As shown in Figure 1, constructing breakwater is a very complex process. The whole process involves theoretical analysis, GPS geological scan, static simulation of extruding slit and dynamic simulation of constructing process. Determining the construction scheme is extremely difficult using the traditional method because of the lack of definite quantitative analysis. With the rapid development of numerical simulation technology, the numerical simulation has become the effective means of breakwater construction process simulation.

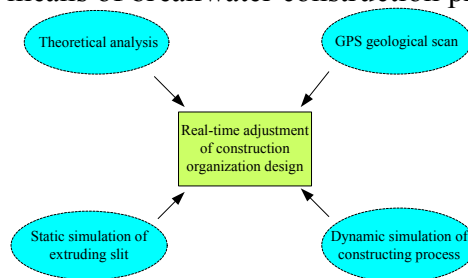


Fig. 1 Research Framework

This paper studies dynamic physical movement process of rockfill, sea water and silt using the finite element method. The research results can be a feedback to the construction. And it is a basis of determining construction scheme to meet the construction plan. The final achievement has an important significance on evaluating the stability of breakwater.

## The Coupled Euler-lagrange Based on Abaqus

In the course of extruding slit by dumping rockfill, the key point is the dynamic contact between fluid and stone. And the fluid motion is the difficulty of this research. The fluid is a continuum composed of an infinite number of fluid particles. So the fluid motion is the comprehensive motion

of fluid particle. There are two main methods of studying the fluid motion: Lagrange method and Euler method.

The Lagrange algorithm has advantages in describing solid-state medium. And Euler algorithm is excellent in simulating fluid. CEL combines the advantages of both. In the process constructing breakwater, stone and silt substratum are defined as Lagrange body. And the sea water and silt are described as Euler body. Finally, the dynamic coupling process of solid and fluid is achieved in the entire course of breakwater construction.

### The Algorithm of Coupled Euler-lagrange

In the traditional Lagrange FEM analysis, material determines the node. So when the material changes, the element changes at the same time. The element is often with a single material. So the boundary of element and the material is consistent. But nodes are fixed in space and the element will not deform in the Euler algorithm. And the material can flow in the element. Euler element may have no material in part of the region. So in each incremental material boundary are required to calculate. Usually the boundary of materials and element is not consistent. Element mesh offers space for the flowing material. When the material runs out of the element, it no longer involved in Euler calculation.

In order to overcome defects of Lagrange and Eulerian method, the coupled Lagrange Euler finite element method (CEL) is put forward in recent years. CEL can take advantage of both Lagrange and Eulerian finite element method. the finite element mesh is independent of particle and space motion. The nodes can vary with the particle motion, also it can be is fixed in space. So on the one hand, it can avoid the distortion problem without the need for remeshing of Lagrange method. The other hand, it can accurately describe the free surface motion because node movement can be freely choosed. More importantly, if the solid surface node is Euler node the phenomena of load oscillation can be eliminated. So boundary conditions can be accurately described without updating boundary condition. So the CEL is an effective method for simulating complex solid mechanics especially in the large deformation problem.

### Application of CEL in Abaqus Software

The coupled Euler-Lagrange is the key technical in calculating coupled fluid-solid in ABAQUS. CEL takes the advantages of Eulerian and Lagrange. In the process of calculation, the grid is fixed and the material can flow freely in the grid. And this method can effectively solve the singularity problem in the analysis of large deformation problem. So it can effectively simulate the fluid flow, liquid sloshing, penetration and other large deformation problems.

The CEL is adopted to simulate the process of extruding slit by dumping rockfill in the course of constructing breakwater. To verify the validity of the method, extruding slit by single stone is studied. The mud was defined as Euler body with the size of  $6\text{m} \times 6\text{m} \times 5\text{m}$  ( $b \times w \times h$ ). The size of stone is  $0.5\text{m} \times 0.5\text{m} \times 0.5\text{m}$  ( $b \times w \times h$ ). The density of mud and stone are  $15\text{kN/m}^3$  and  $22\text{kN/m}^3$  respectively. Other parameter of mud are elastic modulus  $10\text{MPa}$ , Poisson's ratio  $0.35$ , cohesive force  $8\text{kPa}$ , friction angle  $8^\circ$ .

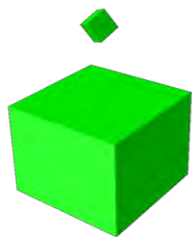


Fig. 2 Step 0

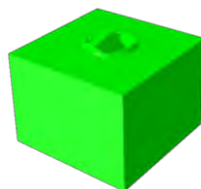


Fig. 3 Step 4500

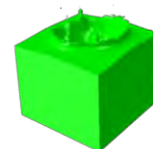


Fig. 4 Step 12179

12179 increments were carried out in the course of analysis. Several typical incremental steps are show below from Figure 2 to Figure 4. The postprocess result shows that the course of extruding slit was well simulated using the CEL method. In the process of stone movement, the contact sur-

face of rock and fluid was dynamic changed. The stone extruded silt under the action of impact. And the large deformation was occurred. It can fully reflect the effect of extruding slit by dumping rockfill in the course of constructing breakwater.

### Dynamic Simulation of Extruding Slit by Dumping Rockfill

This paper will study the construction of break water in Yantai Haiyang port. A plurality of stone was dumped in the course of construct breakwater. This article will study dumping three stone at the same time. By this model, the impact of stone diameters on extruding effect was analyzed. The calculation model is composed of four parts: stone, sea water, silt and silt substratum. The stone and mud substratum are defined as Lagrange body. Sea water and mud are defined as Euler body. The rockfill diameter ranges from 0.1m to 1.0m. The size of Euler body is  $0m \times 10m \times 50m(b \times w \times h)$ . The sea water is 7m depth. Free flow region height of Euler body is 10m.

### Dynamic Simulation of Extruding Slit by Dumping Rockfill

According to the geological data, the parameters of rock and soil are shown in table 1:

Tab. 1 Soil Parameter

parameter object	Elastic modulus (MPa)	Poisson's ratio	Density ( $kN/m^3$ )	Cohesive force(kPa)	Friction angle ( $^{\circ}$ )
slit	2.17	0.35	16.6	8.9	10
silt substra- tum	23.6	0.3	19.2	19	29.5
rockfill	60	0.2	26	1.9	21.1

Analysis of 10569 increments was carried out. The results as shown in Figure 5~Figure 7. The calculation records the process of stones passing through water, the contacting of stone and slit. The contact surface of stone and the fluid dynamic changed. Eventually the slit was extruded.

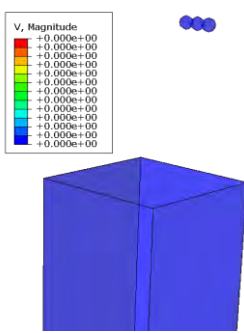


Fig. 5 Step 0

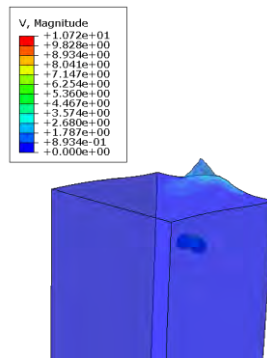


Fig. 6 Step 3000

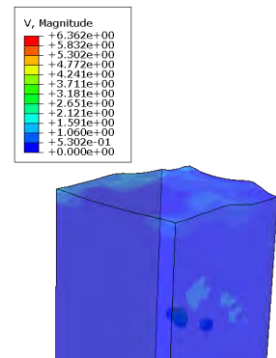


Fig. 7 Step 10569

### Effect of Rockfill Diameters on Extruding Slit

Ten different conditions is studied to analyze the effect of rockfill diameters on extruding slit. Rockfill diameters were taken as follows: 0.1m, 0.2m, 0.3m, 0.4m, 0.5m, 0.6m, 0.7m, 0.8m, 0.9m, 1.0m. Figure 8 and Figure 9 are the result of extruding slit with diameter of 0.4m and 0.8m respectively. Figure 10 is the fitting curve of diameter and extruding depth. And the fitting function

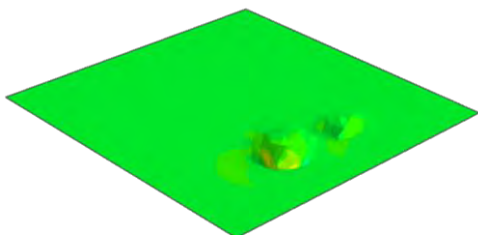


Fig. 8 Rockfill Diameter of 40 cm

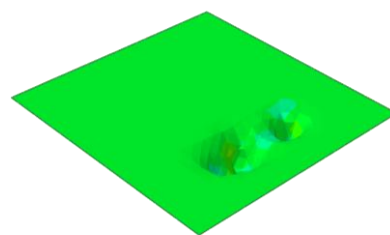


Fig. 9 Rockfill Diameter of 80 cm

As can be seen, the larger diameter of rockfill will bring greater depth of extruding slit.. The reason is that unit volume constraint is less with bigger stone. And then it is more easy to form concentration stress. There is a need to explain that the results can only be used for assessing effect of extruding slit with different rockfill diameter. It can't reflect the final form of silt.

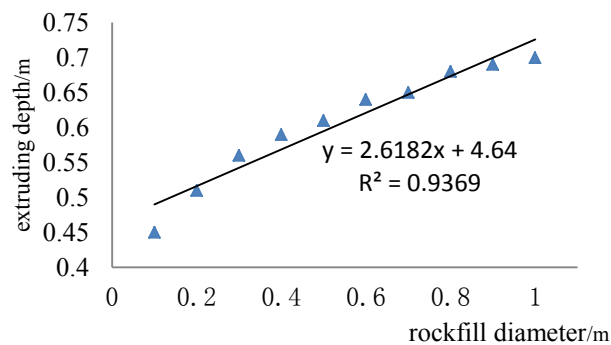


Fig. 10 Fitting Curve of Rockfill Diameter and Extruding Depth

## Conclusion

This paper analyzes the process of extruding slit under the weight of rockfill in the course of constructing breakwater. Coupling algorithm with Euler and Lagrange was used based on CEL method of ABAQUS software. The vices of Lagrange method and Euler algorithm could be shed by CEL. Through the simulation of single stone extruding mud, the effectiveness of CEL algorithm was verified. And this research simulates the process of extruding slit with rockfill for the first time. Using the research method in this paper, the construction process of breakwater is studied by numerical simulation based on Chinese Shandong Haiyang port. Physical contacting process of rockfill, sea water and silt was simulated. The size effect of rockfill on extruding depth is put forward by simulating different stone. The research method of this thesis breaks through the conventional simulation method of extruding silt. And it can provide good references for other related project.

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