Research on the Initial Settlement Depth of Artificial Reef on the Clay Seabed

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Abstract. The artificial reef is an artificial structure that simulates some characteristics of a natural reef. Its penetration depth in the seabed soil affects the stability of the reef on the seabed. In this paper, based on the CEL (Coupled Eulerian-Lagrangian analysis) method, a finite element model is established for the process of artificial reef entry and penetration, which simulates the speed change law of the artificial reef in the water and the penetration depth in the clay seabed, and The study analyzed the influence of different reef weights, penetration speeds, and seabed soil properties on the penetration depth of artificial reefs.

Keywords: Artificial reef, Clay seabed, Speed Variations, Submarine soil.

1. Introduction

In the construction of marine ranches, artificial fish reefs, as artificial structures that simulate some of the characteristics of natural reefs, can fundamentally repair and optimize the existing marine ecological environment, so that the environment can reach a benign cycle state. Artificial reefs are of great significance in the construction of marine pastures. At present, most scholars at home and abroad are focusing on the stability of artificial reefs. After installation, artificial reefs mainly have stability problems such as settlement, erosion, overturning and slippage [1][2]. The methods to solve these problems mainly include: 1. The optimization of artificial reef structure and materials; 2. The optimization of seabed address conditions; 3. The improvement of site selection standards. Many excellent results have been published in the field of artificial reef stability: Kageyama Y et al. [3]studied the influence of different opening ratios and upflow angles on the stability of artificial reefs; Yun et al.[4] proposed the use of ground nets and ground net bamboo mats to reduce The settlement and erosion of the ground; Hyun-Min Yang et al. [5]improved the durability of artificial reefs by adding L-arginine to cement mortar. In terms of numerical simulation, Fujihara et al.[6] applied numerical simulation to the field of artificial reefs for the first time, studying the distribution range and characteristics of upwelling in front of the artificial reef; Jinho Woo et al. [7]studied the effects of different up-flow angles on the drag coefficient of the artificial reef influences; Li Xin et al.[8][9] used data mining methods to study the stability of marine engineering construction and successfully applied them to GIL engineering

Although many excellent methods have been proposed, few people consider the effect of the initial settlement on the stability of artificial reefs. When the artificial reef is installed on the seabed by free fall, it will have a certain amount of kinetic energy when it reaches the surface of the seabed due to the effects of gravity, buoyancy and drag force of the sea. Therefore, the artificial reef will have an initial settlement depth on the seabed after installation; and when the seabed soil is too soft, or the artificial reef has a large accumulation density, the initial settlement depth will be very obvious. Moreover, considering the initial settlement depth is conducive to optimizing the structural design of artificial reefs. In summary, this article selects the common 3m artificial reef as the representative reef type, and uses the cel method to study the influence of artificial reef weight, placement height, and different seabed soil properties on the initial settlement depth, which is an effective prediction for artificial reefs in actual projects. The initial settlement depth of the reef provides a basis.

2. Calculation model

2.1. Artificial reef model

This paper uses a 3m×3m×3m square round hole artificial reef to carry out analysis and research, as shown in Figure 1. The thickness of the six sides of the cube fish reef is 0.2m. At the center of the top surface of the reef, there is a circular hole with a diameter of 0.8m. The four sides have four circular holes with a diameter of 0.8m. The volume of the reef is 6.363m^3. The reef is made of concrete, and artificial reefs with three densities of 1950kg/m^3, 2400kg/m^3, and 2800kg/m^3 are selected for research, as shown in Table 1.

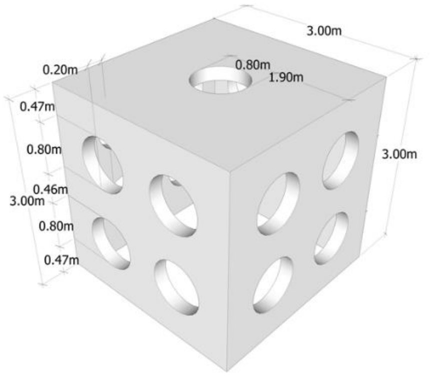


Figure 1. Artificial reef model

Table 1. Artificial reef size parameter table

Number	Side length(m)	Opening diameter(m)	Material	Density(kg/m^3)	Reef weight(kg)
1	3.0	0.8	Lightweight concrete	1950.0	12407.85
2	3.0	0.8	Ordinary concrete	2400.0	15271.2
3	3.0	0.8	Heavy concrete	2800.0	17816.4

The deformation modulus of concrete is large and the deformation of the reef is small. It can be assumed that the reef is not deformed during the penetration process. Therefore, the element type of the artificial reef is selected as the discrete rigid body (Discrete Rigid). The characteristic of the discrete rigid body is that the load The unit body will not deform under the action.

2.2. Fluid-structure coupling numerical model

① Water model

The water model in this paper is a finite cuboid of 30m×30m×20m. When the reef enters the water, the flow of the water medium can be regarded as an incompressible, viscous laminar flow. The water material adopts the Mie-Gruneisen equation of state in the linear Us-Up Hugoniot form.

The basic parameters of the real water medium Us-Up Mie-Gruneisen equation of state are: $\rho = \frac{1025\text{kg}}{\text{m}^3}$, c_0=1450m/s, s=0, $\Gamma_0 = 0, \mu = 0.001 Pa \cdot s$.

② Soil model

The soil model is a finite cuboid with a size of 30m×30m×3m, as shown in Figure 2. The boundary condition of the model is non-reflective. The clay material adopts the Mohr-Coulomb plastic model, and the parameters of the clay material are shown in Table 2.

Table 2. Clay parameter table

Soil type	Density(kg/m^3)	Internal friction angle(°)	Cohesion(10^{3}Pa)	Young's modulus(10^{6}Pa)
Soft clay	1400	18	81	21
Medium clay	1500	20	70	24
Hard clay	1700	24	60	28

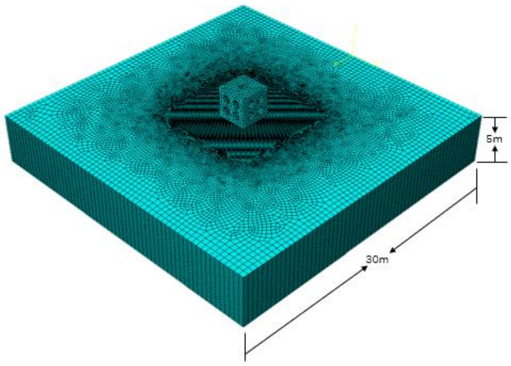


Figure 2. The finite element model of the soil

3. Analysis of numerical results

3.1. Water sports characteristics of artificial reefs

Since the resistance of the seawater during the movement is proportional to the descending speed of the artificial reef, the artificial reef will not keep accelerating. When the speed of the artificial reef reaches a certain value, the resistance of the seawater will be the same as that of the artificial reef. Its gravity and buoyancy reached a state of equilibrium, and the artificial reef began to move at a constant speed. Therefore, when the release height of the artificial reef reaches a limit value, increasing the release height will not obtain a greater initial penetration speed. Therefore, it is of great significance to analyze the movement laws of artificial reefs in seawater. Figures 3 show the relationship between the time, speed, and the height of the artificial reefs of three different reef weights.

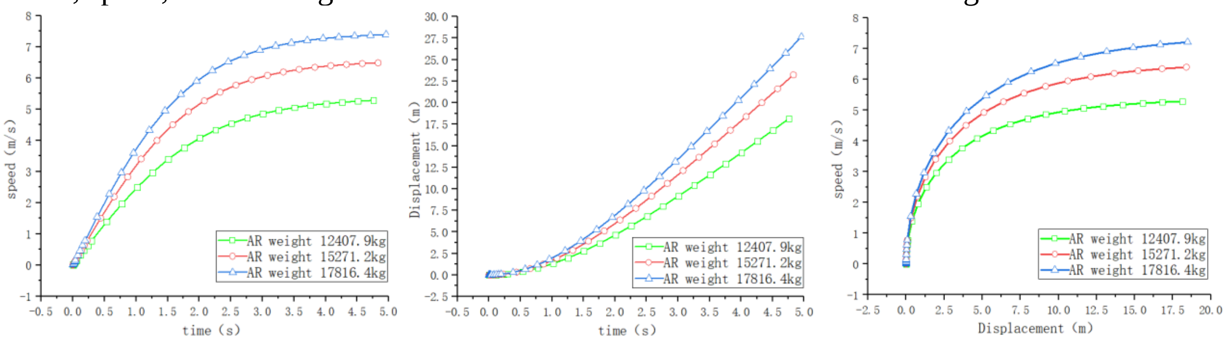


Figure 3. Relation curve of ARs moving in water

It can be seen from the figure above that with the increase of time, under the action of gravity, buoyancy and drag force, the speed and displacement of the artificial reef gradually increase, but its acceleration gradually decreases to 0m/s. As shown in the figure, as the release height increases, the initial penetration speed of artificial reefs also gradually increases, but the rate of increase is not constant. In the range of 0s to 3s, the speed of the artificial reef increases rapidly. When the time is greater than 5s, the artificial reef becomes a uniform motion.3 Factors affecting penetration depth of artificial reefs

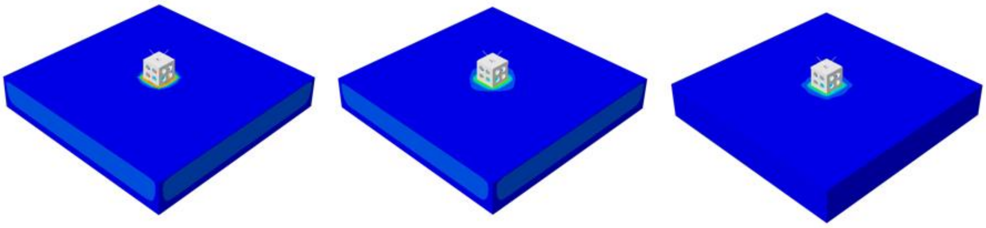


Figure 3. The initial settlement of ARs under different clay shear strengths

①The impact of reef weight

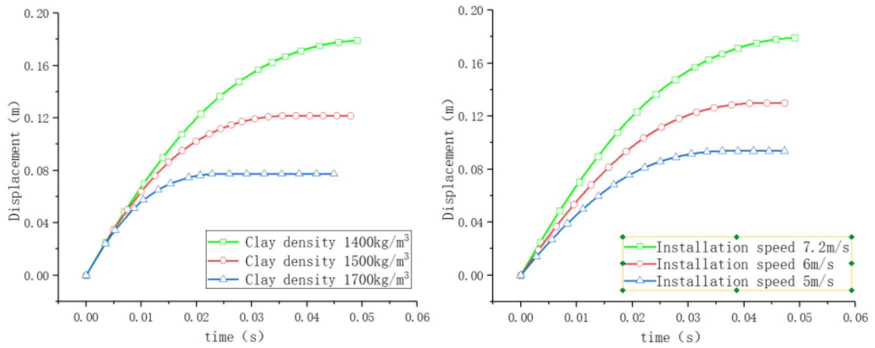
Analyzing the water movement process of artificial reefs shows that weight is one of the important factors affecting the penetration depth of artificial reefs.According to the principle of energy conservation, the greater the kinetic energy of the artificial reef, the deeper the penetration. From the initial kinetic energy $\mathrm{E}=\frac{1}{2}mv^2$, it can be seen that the kinetic energy of the artificial reef is proportional to the weight of the reef. Moreover, the difference in weight will also affect the maximum speed of artificial reefs in the water. Therefore, a reasonable choice of the weight of the artificial reef can not only control the initial settlement depth of the artificial reef, but also save costs.

②The influence of clay shear strength

Analysis of the numerical simulation results shows that the hardness (shear strength) of the seabed soil directly affects the settlement depth of the artificial reef. In this paper, three seabed soils with different shear strengths are selected for numerical simulation. It can be seen from Figure 4.(a)that when the density of clay changes from 1700kg/m3 to 1500 kg/m3, the settlement depth of the artificial reef increases from 7.9cm to 12.2cm, and the settlement depth increases by 54.4%. When the density of clay changed from 1500kg/m3 to 1400kg/m3, the settlement depth of the artificial reef increased from 12.2cm to 17.9cm, and the settlement depth increased by 46.7%. It can be seen that the penetration depth of the artificial reef decreases with the increase of clay hardness (shear strength).

③Impact of initial installation speed

Numerical results show that the initial installation speed directly affects the initial settlement depth of the artificial reef. The greater the speed of the artificial reef on the surface of the seabed soil, the greater the kinetic energy of the artificial reef, and the depth of penetration into the seabed soil. The deeper. It can be seen from Figure 4(b)that when the initial installation speed of the artificial reef increases from 5m/s to 6m/s, the settlement depth of the artificial reef increases from 9.3cm to 12.4cm, and the settlement depth increases by 33.4%. When the initial installation speed of the artificial reef increased from 6m/s to 7m/s, the settlement depth of the artificial reef increased from 12.4cm to 17.9cm, and the settlement depth increased by 44.3%. It can be seen that the initial installation speed of the artificial reef on the surface of the seabed soil has a great influence on the initial settlement depth of the artificial reef, and the initial installation speed of the artificial reef is related to the weight and the height of the artificial reef. . Therefore, the selection of artificial reef placement height is very important for the installation of artificial reefs.



(a) **(b)**

Figure 4. (a)Time-displacement curve under different seabed soil conditions (b) Time-displacement curve under different installation speed conditions

4. Conclusion

The installation process of the artificial reef on the clay seabed was numerically simulated by the cel method, and the movement law of the artificial reef in the water and the initial penetration depth of the artificial reef on the seabed soil under different conditions were mainly explored. Get the following conclusions:

(1) Under the action of gravity and sea water, the artificial reef first accelerates in the water, and after reaching a certain depth, the artificial reef begins to move at a constant speed;

(2) The heavier the artificial reef, the greater the initial settlement. Therefore, a reasonable choice of artificial reef weight can not only save costs, but also ensure the beneficial effects of initial settlement on the stability of artificial reefs;

(3) The greater the shear strength of the seabed, the greater the initial settlement. Therefore, reasonable selection of artificial reef placement or optimization of the artificial reef structure according to engineering geological conditions can increase the stability of the artificial reef;

(4) The artificial reef will move at a constant speed after reaching a certain depth. Therefore, a reasonable selection of the artificial reef stocking height can control the initial settlement of the artificial reef.

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