Study on Earth Pressure Behind Separated Barrel Structural Wall

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Abstract. With the development of port shipping industry in China, barrel foundation structure is gradually applied in port engineering, especially in the case of large water depth and soft soil foundation under the sea. With the less scene workload, simple construction and short construction period, the structure has broad application prospects. The earth pressure distribution of barrel wall surface of double barrel structure is complex, so reasonably determining the barrel structure wall earth pressure calculation has a great significance for the stability of the structure. Through the numerical analysis of finite element method, establish the upper and lower barrel separation type barrel foundation finite element model, and conduct the finite element analysis of the model of barrel structure. Considering the influence of different backfill earth parameters on the earth pressure behind the wall, the corresponding earth pressure distribution curve is obtained, which is compared with the theoretical value and the reference used in Lianyungang project. The analysis results show that the barrel foundation with rubble machine tool connecting upper and lower barrels can be used in engineering, and the method of multiplying the theoretical value of earth pressure by the correction coefficient can be used to simplify the calculation. The correction coefficients of earth pressure under different soil conditions are given, which can be used as a reference for the design of barrel structures.

1. Introduction

It is of great significance for engineering design to study the distribution of barrel foundation and pressure under different geological conditions and the calculation method of barrel foundation which can be applied to practical engineering. Li Wu et al.[1] studied the stability of integral barrel foundation is analyzed by experiment and numerical simulation. In similar breakwater projects, Wang Yuanzhan et al.[2] carried out the finite element analysis of the earth pressure characteristics of cylindrical foundation breakwater. Earth pressure on Jiang Minmin[3] on the barrel foundation breakwater is analyzed with finite element method. Liu Zhenwen et al.[4] studied the earth pressure distribution of barrel foundation by model test. Liu Jianqi et al.[5] used model tests to measure the earth pressure acting on the barrel foundation structure, and analyzed the interaction between the barrel structure and backfill soil and foundation. Li Huarong[6] studied the influence of soil parameters, height-diameter ratio of barrel on horizontal bearing capacity of barrel foundation and distribution law of earth pressure outside barrel by finite element method. Earth pressure is the core content of barrel foundation structure stability calculation, and its distribution law and size play a controlling role in the
calculation results\[7\] In this paper, the earth pressure of barrel wall is calculated by finite element analysis. At present, the research on barrel foundation is mostly homogeneous soil, while the research on stratified soil with different properties is relatively less. The layered earth around barrel foundation structure has different properties. The calculated results from the theory of earth pressure are obviously different from the actual situation, which affects the structural design. Therefore, the different nature of the earth layers earth is established by using this model, using the method of theoretical calculation and numerical simulation, the distribution of earth pressure.

2. Finite Element Model

New type of barrel foundation by barrel, machine and barrel under the rubble, the barrel diameter of 8.9 meters, diameter of 8.1 meters and consisting of 1 meters long and 0.6 meters wide connecting wall, 12 meters high. The barrel and the lower barrel is arranged between 1 meters of rubble bed. The barrel is an oval barrel, 30 meters long axis, short axis of 20 meters, the barrel through the separator is divided into 9 compartments, the barrel wall 0.4 meters thick. Flat oval, 30 meters long axis, short axis of 20 meters, 0.6 meters thick, as shown in Figure 1.

When choosing the size of foundation soil, in order to effectively eliminate the effect of distant boundary constraint, the horizontal dimension of the barrel foundation structure is taken as the length of the soil calculation field at both sides before and after loading; the width of the calculation area is taken as half of the width of the structure; the height of the foundation soil is taken as six times the height of the lower foundation, and the foundation soil model is shown in Fig. 2.

![Figure 1. Barrel separating body finite element mesh](image1)

![Figure 2. Foundation soil mesh model](image2)

2.1. Research Conditions

According to the soil conditions of foundation soil by local land Elastic modulus E = 13MPa, Severe gamma γ=19.6 kN/m$^3$. Cohesion C = 18.8KPa, Poisson's ratio μ= 0.38.

In the case of different types of backfill, the mechanical characteristics of barrel foundation structure are studied. As shown in Table 1.

| working condition | φ(°) | C (kPa) | q (KN) |
|-------------------|-----|--------|-------|
| 1                 | 45  | 0      | 0     |
| 2                 | 37.5| 0      | 0     |
| 3                 | 30  | 0      | 0     |
| 4                 | 45  | 0      | 5     |
| 5                 | 45  | 0      | 10    |
| 6                 | 45  | 0      | 15    |
| 7                 | 15  | 5      | 0     |
| 8                 | 15  | 7.5    | 0     |
| 9                 | 15  | 10     | 0     |
Working conditions 1-3 are mainly to observe the influence of friction angle of cohesionless soil on earth pressure. Working conditions 4-6 are mainly to observe the effect of external loading on the earth pressure of cohesionless soil. Working conditions 7-9 are mainly to observe the influence of cohesion of cohesive soil on earth pressure.

3. Selection of analysis points and analysis of displacement results

3.1. Selection of Earth Pressure Point on Barrel Wall
In order to simplify the calculation, the hypothetical flat wall back along the axis of the barrel foundation structure is used instead of the arch wall back, and the earth pressure on the arch wall back is transformed into the earth pressure on the flat wall back. It will be more intuitive and simple to analyze the mechanical characteristics of barrel foundation structure after using the imaginary wall. The circumferential earth pressure caused by the arch wall back of the barrel is not considered on the imaginary wall back, but only the horizontal earth pressure on the imaginary wall back is considered, which can be more convenient to compare with the theoretical earth pressure. In the following studies, the earth pressure on barrel foundation can be transformed into the earth pressure on the imaginary wall on the shore, the earth pressure on the bottom barrel can be transformed into the earth pressure on the imaginary wall on the shore, and the earth pressure on the barrel on the shore can be transformed into the earth pressure on the imaginary wall on the shore.

3.2. Displacement Calculation Results
The displacement form of barrel foundation structure is that the upper barrel inclines to the sea, the horizontal displacement of the upper barrel is larger, and the lower barrel inclines to the shore. The horizontal displacement of the bottom of the lower barrel is the largest, and the overall horizontal displacement of the barrel foundation structure is relatively small. The vertical displacement on the shore side is larger than that on the sea side. Therefore, the overall displacement of barrel foundation structure can be seen as a movement mode that inclines to the shore side around the top of the barrel while moving horizontally toward the sea side. The distribution of earth pressure on the barrel wall is closely related to the displacement of the barrel. The calculation results of horizontal displacement and vertical displacement of the barrel are shown in the figure. (Displacement Cloud chart enlarged 200 times)
of the imaginary wall after the barrel is higher than the theoretical value, and the earth pressure of the backfill soil is different in different friction angles. Figure 6 reflects the variation of backfill earth pressure on the barrel under different friction angle and comparison with the theory of earth pressure, it can be seen from the figure, the greater the internal friction angle of backfill earth pressure is small. Figure 7 reflects the variation of the earth pressure behind the barrel under the applied load above the backfill and the comparison with the theoretical earth pressure. It can be seen from the figure that the earth pressure will increase with the increase of the applied load, but the earth pressure calculated by numerical method is generally larger than that calculated by theoretical method. Figure 8 reflects the contrast between the change law of the earth pressure behind barrel and the theoretical earth pressure when the backfill is clayey soil with different cohesion. From the figure, it can be seen that the cohesion of the backfill in the middle and upper part of the barrel depth has little effect on the earth pressure, while the law of the earth pressure increasing with the decrease of cohesion appears at the bottom of the barrel. The backfill soil is different in nature, and the calculated earth pressure is basically between the static earth pressure and the active earth pressure, so it has a small displacement, so it is shown as the active earth pressure.

4.2. Analysis of Vertical Earth Pressure Behind Barrel (Shore Side)

Figures 10 to 12 show the earth pressure on the hypothetical wall on the bank. The earth pressure of the imaginary wall after the barrel is higher than the theoretical value, and the earth pressure of the
imaginary wall after the barrel is basically between the static earth pressure and the active earth pressure. Active earth pressure.

4.3. Characteristic Analysis of Vertical Earth Pressure at Sea Side (Lower Barrel)

![Figure 13. Different friction angles](image)

![Figure 14. Different external loads](image)

![Figure 15. Different cohesion](image)

Figure 13 reflects the variation of friction angle of backfill under the barrel of vertical earth pressure and comparison with the theory of earth pressure, it can be seen from the figure, the internal friction angle increases under backfill earth pressure decreases the barrel. Figure 14 reflects the change of vertical earth pressure behind barrel under external loads on top of backfill. The comparison between the variation law and theoretical earth pressure shows that the earth pressure will increase with the increase of external loads. Figure 15 shows the comparison between the vertical earth pressure behind barrels and the theoretical earth pressure when the backfill is cohesive soil and under different cohesive forces. The cohesion of backfill soil in the middle and upper part of the barrel depth has little effect on its earth pressure, but the law of increasing earth pressure appears at the bottom of the barrel with the decrease of cohesion. In the displacement diagram of the barrel, it can be seen that the displacement of the barrel under the barrel foundation structure is very small. Therefore, the numerical earth pressure in Figure 13 to 15 distributes around the theoretical static earth pressure and can be calculated according to the static earth pressure in the simplified calculation of the earth pressure.

4.4. Earth Pressure Value Analysis

In the simplified earth pressure distribution of barrel foundation structure, the results of finite element analysis and theoretical earth pressure calculation are compared. The table of correcting coefficient of earth pressure for barrel foundation structure and the table of correcting coefficient of moment of earth pressure for barrel foundation structure are obtained. Following the table.

| Table 2. Table of correction coefficient of earth pressure |
|----------------------------------------------------------|
| working condition                                      | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Static earth pressure on shore $\eta_0$                | 0.88 | 0.86 | 0.84 | 0.87 | 0.87 | 0.86 | 0.84 | 0.86 | 0.82 |
| Active earth pressure on shore $\eta$                   | 1.53 | 1.48 | 1.42 | 1.51 | 1.50 | 1.48 | 1.40 | 1.48 | 1.44 |
| Static earth pressure after uploading barrel $\eta_0$  | 1.01 | 0.88 | 0.76 | 0.99 | 0.96 | 0.94 | 0.63 | 0.65 | 0.76 |
| Active earth pressure after uploading barrel $\eta$    | 1.73 | 1.41 | 1.14 | 1.69 | 1.65 | 1.60 | 0.94 | 1.41 | 1.14 |
| static earth pressure at sea side $\eta_0$             | 1.43 | 1.46 | 1.49 | 1.31 | 1.26 | 1.15 | 1.57 | 1.61 | 1.54 |
| passive earth pressure at sea side $\eta$              | 0.31 | 0.32 | 0.33 | 0.29 | 0.29 | 0.26 | 0.35 | 0.35 | 0.34 |

| Table 3. Table of modified coefficient of earth pressure Torque |
|---------------------------------------------------------------|
| working condition                                      | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Static earth pressure on shore $\eta_0$                | 0.88 | 0.86 | 0.84 | 0.87 | 0.87 | 0.86 | 0.84 | 0.86 | 0.82 |
| Active earth pressure on shore $\eta$                   | 1.53 | 1.48 | 1.42 | 1.51 | 1.50 | 1.48 | 1.40 | 1.48 | 1.44 |
| Static earth pressure after uploading barrel $\eta_0$  | 1.01 | 0.88 | 0.76 | 0.99 | 0.96 | 0.94 | 0.63 | 0.65 | 0.76 |
| Active earth pressure after uploading barrel $\eta$    | 1.73 | 1.41 | 1.14 | 1.69 | 1.65 | 1.60 | 0.94 | 1.41 | 1.14 |
| static earth pressure at sea side $\eta_0$             | 1.43 | 1.46 | 1.49 | 1.31 | 1.26 | 1.15 | 1.57 | 1.61 | 1.54 |
| passive earth pressure at sea side $\eta$              | 0.31 | 0.32 | 0.33 | 0.29 | 0.29 | 0.26 | 0.35 | 0.35 | 0.34 |
5. Conclusion
(1) Considering the actual situation of structural stress and deformation, when calculating the overall earth pressure behind the barrel wall, the active earth pressure behind the barrel body and the static earth pressure in front of the barrel body are calculated according to the theoretical value. Then the correction is made and the reference value of the correction coefficient is given. The following table.

Table 4. Value table of correction coefficient of earth pressure

| Name                                           | correction factor |
|------------------------------------------------|-------------------|
| Correction coefficient of active earth pressure on shore | 1.55              |
| Active Earth Pressure Correction Coefficient after Uploading Barrel | 1.85              |
| Correction Coefficient of Sea-side Static Earth Pressure | 1.15              |
| Moment correction factor of active earth pressure on shore     | 2.15              |

(2) In the simplified distribution of the earth pressure of barrel foundation structure, it is assumed that the earth pressure resultant force on the back of the wall can be obtained by multiplying the theoretical earth pressure resultant force by the earth pressure correction factor by comparing the results of the finite element calculation with those of the theoretical earth pressure calculation.

(3) This correction factor is only applicable to this area. If barrel foundation is used in other areas, further calculation should be made according to the local foundation earth.

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