

Analysis of 120m Circular Enclosed Coal Yard Based on Finite Element Mechanics

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Abstract. Large diameter circular closed coal yard has large coal pile, high coal pile height, and the cancellation of expansion joints, which has many adverse effects on the structure. The study of finite element analysis method, in view of the large stack on the effect of pile and pile of coal load and temperature effect on structure to do the analysis, the influence of material parameters was verified the correctness of the structure internal force under the condition of various loads is obtained as a result, the temperature effect may produce several times the pile of coal load internal force, provides reference for engineering design.

Key words: closed coal yard; Temperature action; The finite element

1 Introduction

Large diameter circular closed coal yard has the characteristics of small occupation, favorable to environmental protection, flexible operation and so on, and has been applied more and more. The early round coal yard usually set expansion joints along the retaining wall, using reinforced concrete retaining wall and reinforced concrete buttress scheme, similar to retaining wall, although the scheme is simple in calculation theory, but the amount of reinforced concrete, high cost. Laizhou power plant round coal yard retaining wall to cancel the expansion joint, make full use of ring tension resistance coal pressure, advanced technology, less floor area, unit area storage is larger, less reinforced concrete consumption, cost saving. However, the arrangement of the expansion joint will make the structure produce a lot of internal forces under the action of temperature, and the current specifications and commonly used engineering design software can not accurately analyze the effect of temperature on the structure.

Circular coal yard is rarely studied abroad, and almost all existing projects are analyzed and designed independently or with the participation of Wuhan University. With the application of circular coal yard, completing independent design has become an urgent requirement. The project uses the general finite element analysis software to analyze the circular coal yard under the coal load and various temperatures to obtain the internal force of the structure and complete the engineering design.

2. Comparison between finite element analysis and pile test results

Using numerical calculation based on the finite element software, especially as it comes to the elastic-plastic nonlinear calculation, the calculation results of real or not largely depends on the selection of calculation parameters correctly or not, therefore, using the finite element simulation test pile process, compared with pile test report again, to determine the selection of calculation parameters correctly or not is very necessary.

(1) Physical model and soil material parameters

The material of pile body is C40 concrete, which adopts linear elastic constitutive model without considering its cracking and plasticity. Ideal elastic-plastic soil layer, D-P yield criterion and associated flow rule are adopted. Table 3 shows the physical parameters of each soil layer. The interaction between pile and soil is simulated by contact attribute, friction coefficient is constant value 0.3, and the pile bottom and soil layer are coupled by node freedom. Large deformation effects are considered. As the extended D-P plastic yield criterion is used in the calculation, the c and values in the original physical parameters of the soil layer need to be transformed, and the transformation formula is as follows:

$$\tan \beta = \frac{6 \sin \phi}{3 - \sin \phi} \quad \sigma_c = 2c \frac{\cos \phi}{1 - \sin \phi}$$
$$K = \frac{3 - \sin \phi}{3 + \sin \phi}$$

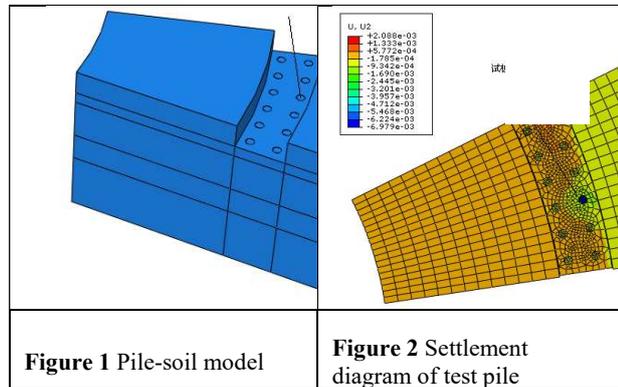
C Cohesion of materials
Material internal friction Angle

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The internal friction Angle of the transformed material
 Tensile limit of transformed material
 K flow stress ratio

(2) Geometric dimensions

Since there is only vertical load and no horizontal pressure in the soil during pile test, the local pile-soil model of 18° is selected for calculation according to the pile foundation construction situation in the coal yard of Laizhou Power Plant, as shown in Figure 1.



The radial length of the soil is 46.25m, the depth (thickness) is 20m, and the coal yard is divided into four layers both inside and outside the coal yard. In the coal yard: the thickness of crushed stone is 4.4m, the thickness of coarse sand is 5m, the thickness of strongly weathered rock is 3.5m, and the thickness of moderately weathered rock is 7.1m; Outside the coal yard: backfill soil is 4.4m thick, coarse sand layer is 5m thick, strongly weathered rock is 3.5m thick, moderately weathered rock is 7.1m thick.

The pile diameter is 1m, with one row every 3° along the circumferential direction and two rows of piles along the radial direction, with a distance of 3.2m. In this calculation model, there are 12 piles in total, and the middle pile is selected for pile test analysis, as shown in Figure 3.

(3) Load and boundary conditions

In the finite element model, the radial and circumferential displacements were constrained respectively around the soil, and the bottom was fully constrained, that is, the displacements in all three directions were constrained. The bottom of pile is coupled with the degree of freedom of soil, that is, the degree of freedom is bound, and the pile is in friction contact with the soil.

Firstly, the dead weight of soil is calculated without considering the pile (i.e. killing the pile), and the initial stress field of soil layer is obtained. Then the pile is activated and the test load of single pile is applied.

(4) Calculation results and analysis

According to the Test Report of Bored Pile Engineering in No.2 Round Coal Yard of Huadian International Laizhou Power Plant Phase I (2×1000MW) Unit Project, the maximum test load on a single pile is 7000kN, and the test pile number is 227. The test results are compared with the calculation results. The measured vertical maximum displacement value is 10.61mm, the maximum springback deformation is 5.96mm, and the springback rate is 56.2%.

The maximum vertical displacement calculated by finite element method is 6.41mm, the springback deformation is 6.01mm, and the springback rate is 93.8%. FIG. 2-2 shows the comparison of P-S curves between finite element calculation and pile test report.

The comparison between the above finite element simulation test pile calculation results and test pile report results can be obtained as follows:

The maximum settlement of pile obtained by field test is 10.61mm, and the maximum settlement of pile obtained by finite element calculation is 6.41mm, which is 60.4% of the maximum settlement of field test.

The springback deformation obtained by field test is 5.96mm, the residual deformation obtained by finite element calculation is 0.4mm, and the finite element calculation result is 6.7% of the field test result.

It can be seen from the above results that the maximum settlement of pile obtained in field test is 4.2mm larger than the calculated settlement, and the residual deformation is 4.46mm larger than the calculated result, and the residual deformation is mainly caused by the sediment at the bottom of pile, indicating that the sediment at the bottom of pile is 5mm~6mm. Removing the influence of the sediment at the bottom of pile, under the action of 7000kN load, The deformation of the pile in the field test is 5.96mm, while the deformation of the calculated pile is about 6.01mm. It can be seen that the calculation results are in good agreement with the field test results. It shows that the calculation model and material parameters can better reflect the actual engineering situation.

3.Foundation treatment analysis of retaining wall of coal yard

The diameter of the coal yard is 120 meters, and the height is 17 meters. The retaining wall of coal yard adopts the integral ring structure. In order to avoid the adverse effect of uneven settlement on the upper cylinder structure of the retaining wall foundation, bored piles are used in the retaining wall foundation of the whole coal yard, and the moderately weathered granite is used as the pile end bearing layer.

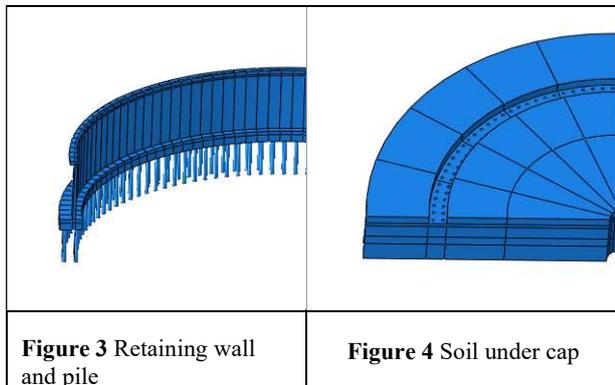
(1) Geometric dimensions

Since the structure of retaining wall has little influence on pile foundation, the size of retaining wall is simplified in calculation. The geometric dimensions of the coal yard are as follows:

Retaining wall: upper width 0.6m, lower width 0.8m, linear change in the middle, the total height of 18.2m;
 Cap: width 5.6m, height 1.8m. Retaining walls and piles are shown in Figure 3.

For pile foundation construction in coal yard, a local pile-soil model of 180° is selected for calculation. The radial length of soil is 180m, including 120m inside the retaining wall, 30m on both sides outside the retaining wall, 20m depth (thickness), and both inside and outside the coal yard are divided into four layers. In the coal yard: the thickness of crushed stone is 4.4m, the thickness of coarse sand is 5m, the thickness of strongly weathered rock is 3.5m, and the thickness of moderately weathered rock is

7.1m; Outside the coal yard: backfill soil is 4.4m thick, coarse sand layer is 5m thick, strongly weathered rock is 3.5m thick and moderately weathered rock is 7.1m thick, as shown in Figure 4.



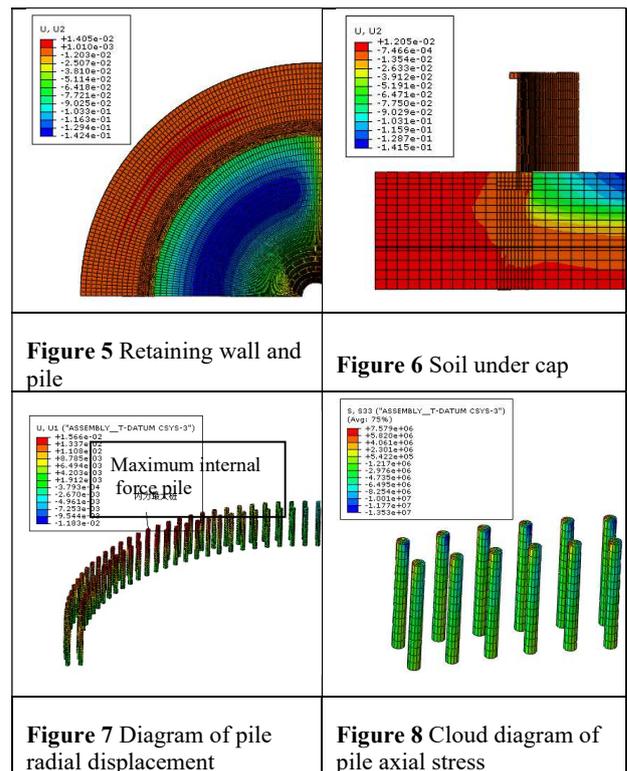
(2) Stress and deformation of soil
 In the result processing, the results show that the local coordinate system, namely the cylindrical coordinate system with the origin of the coordinate in the center of the silo, is adopted: Z direction is vertically downward (direction 3), R direction is radial direction (direction 1), T direction is circumferential direction (direction 2), and the following is the same, which will not be described again. In all figures, the unit of deformation is m and the unit of stress is Pa.

From Figure 5 to Figure 3-8, it can be seen that:
 A) Vertical settlement of soil
 In the range of 90° of the model coal pile, the soil has settlement, and the maximum settlement occurs at the top of the coal pile, the maximum settlement is 142mm. The settlement of 90° region without coal pile is very small.

B) Radial displacement of soil
 The maximum radial displacement of the soil occurs on the surface of the cap bed in the 90° region of the coal pile and is directed to the outside of the coal yard. In this region, the radial displacement of the soil around the pile is small and the maximum horizontal displacement is 28.9mm, indicating that the horizontal extrusion of the soil after dynamic compaction is limited.

Figure 6 is the vertical section of the foundation intercepted where the soil layer's radial displacement is large. It can be seen that the soil layer's radial displacement is large at a depth of 5m near the center of the coal yard.

Since this calculation model is a 180° model with a total of 120 piles, the axial stress distribution of the pile body is different. Therefore, the pile row with the maximum stress on the pile top is selected for analysis in the following result arrangement (as shown in Figure 7). The pile near the coal pile area is called the inner pile and the other one is called the outer pile), which are shown in FIG. 8.



4. Conclusions and Prospects

Based on the analysis of the round coal yard of Laizhou Power Plant, the following conclusions are drawn:

- (1) The model and material parameters used in finite element analysis and calculation can better reflect the actual engineering situation.
- (2) Soil mass in coal pile area has a great influence on pile stress. In the site with poor geological conditions, foundation treatment is needed to control pile stress. For the site where the bearing layer is not very deep, dynamic compaction method can better control the action of soil on pile in coal pile area.
- (3) The effect of environment and service temperature greatly exceeds the requirements of "Code for Design of Reinforced Concrete Silos" (GB50077-2003), and the empirical data provided by the code cannot be used. Because the meteorological conditions of different power plants are different, the effect of temperature must be analyzed separately.
- (4) The oxidation of coal pile will produce high temperature. Even if there is no spontaneous combustion, the local temperature inside the retaining wall will increase, and the temperature outside the retaining wall will remain unchanged. Therefore, the insulation material must be made inside the retaining wall to reduce the concrete temperature near the coal pile area.
- (5) The amount of reinforcement per unit volume of circular coal yard is much, so attention should be paid to the early stage of the project.

Outlook:

With the enhancement of environmental protection and the reduction of land resources, the application of circular coal yard will be more and more extensive. At present, the main reason for limiting application is first of all, the cost

is relatively high, followed by a relatively long period of time. In the future project, the following items can be considered to reduce the cost:

(1) In cooperation with the technology professionals, the elevation of the coal yard is lowered to the outdoor ground, and the lateral pressure of the soil is used to offset the load of the coal pile. Meanwhile, the seasonal temperature rise and temperature drop can be greatly reduced underground, thus reducing the engineering amount of the whole coal yard.

(2) retaining wall reinforcement is crack control, and the maximum amount of steel in the whole coal yard is retaining wall. The amount of reinforcement can be reduced by using prestressed concrete technology. This approach involves concrete theoretical analysis, design, construction and other aspects, whether the application remains to be studied.

References

1. xia guangzheng, xia dongtao, "finite element analysis of giant coal silo under ambient temperature", space structure, 2006,12(1):62-64.
2. wu dongping, xu yun et al., "stress characteristics and optimization design of a new circular coal bunker structure with ring beam" [J]. Journal of wuhan university (engineering science), 2008,42(2):78-80.
3. peng xueping, "internal force analysis of giant coal silo structure based on different foundation calculation models", journal of wuhan university (engineering science), 2005,38(4):63-67.
4. fan zhenzhong, "some problems in structural design of circular closed coal yard", [J] journal of wuhan university (engineering science), 2007,40(sup)158-161.
5. "Investigation Report of Geotechnical Engineering in Construction Drawing Design Stage of Huadian International Laizhou Power Plant (2×1000MW)".
6. Test Report on Bored pile Construction in No.2 Round Coal Yard of Huadian International Laizhou Power Plant (2 × 1000MW) Unit Engineering. Shandong Base Arrow Engineering Quality Inspection Co., LTD.