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Three Dimensional Finite Element Analysis of the Influence of Wood and Steel Mixed Static Pressure Single Pile Penetration on Adjacent Underground Pipeline

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Abstract:

The static pressure single pile of light wood structure shows good seismic performance in previous earthquakes. In this paper, the theoretical calculation method of four side clamped plate is simplified. In this paper, the circular hole expansion theory is used to analyze the soil squeezing effect of pile in the process of pile sinking. The test data show that the dead weight of jacked pile machine, static earth pressure and pile tip squeezing effect are the main forces of underground pipeline engineering. Based on this, this paper analyzes the mechanical model, finds the dangerous section and monitors it. In this paper, the ANSYS finite element simulation analysis of soil and supporting structure is carried out to verify the consistency between the displacement distribution and stress distribution of the underground structure and the actual engineering monitoring results.

Keywords: *Wood and Steel Single Pile, Underground Pipeline, Finite Element Analysis, Data Fusion*

I. INTRODUCTION

Underground engineering structure refers to the underground civil engineering built below the ground, mainly for the development and utilization of space resources deep into the ground, mainly including underground houses and underground structures, subway, highway, passage, tunnel, civil air defense engineering and so on [1-2]. Underground space engineering has an important impact on our survival and development. Through the use of underground space, we can solve the problems of soil scarcity and traffic congestion. Making full use of underground space has gradually become a new trend of international energy conservation. In this trend, it has become one of the urgent problems to study the influence of soil changes (such as earthquake, pile sinking, etc.) on underground engineering structure [3-4].

Pile foundation is an ancient form of foundation [5]. Due to its high bearing capacity, good stability, excellent seismic performance, small and uniform settlement, it is widely used in high-rise buildings, seismic areas, low-grade soft soil and public buildings with large live load. At present, the pile foundation at home and abroad is mainly high-strength reinforced concrete pile [6]. According to its construction method, it can be divided into cast-in-place pile and precast pile. The cast-in-place pile needs to drill holes in the construction site first, and then put in reinforcement and pour concrete. Precast pile is to use vibration method, hammer method or static pressure method to sink the precast pile into the ground. Because the advantage of static pile pressing method used in precast pile is no noise and no pollution, the static pile pressing method is used in most urban infrastructure construction.

II. CALCULATION MODEL AND STRESS ANALYSIS OF UNDERGROUND ENGINEERING

2.1 Cross section calculation model

The mechanical behavior of underground engineering in the process of bearing load is the basis of underground structure design and research, and the mechanical model of underground engineering should fully consider the stress characteristics of underground structure

(1) Load in normal use (such as the weight of equipment, the weight of vehicles in the tunnel, etc.);

(2) The interaction between surrounding rock, soil and groundwater is often the main load of underground structure;

(3) Due to the arching effect of the stratum, the vertical pressure of the structure is mainly the self weight pressure of the overlying stratum;

(4) The load of surrounding environment during construction.

As shown in Fig. 1 and Fig. 2, there are two common cross-section stress and deformation characteristics of underground structures.

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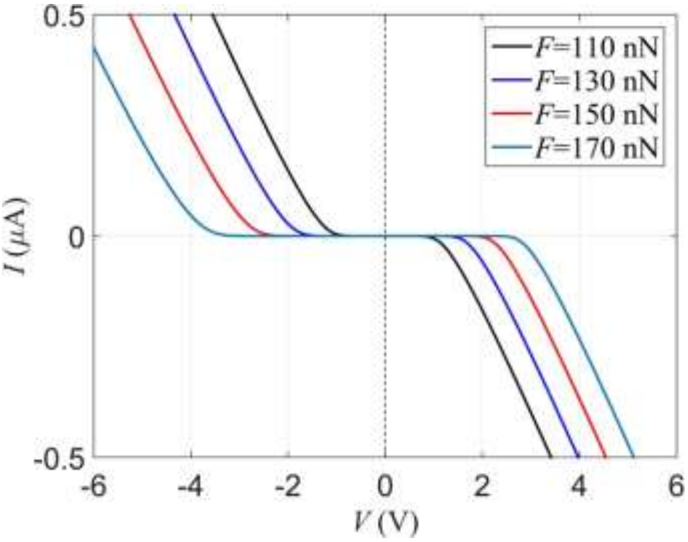

Fig 1: Stress characteristics and deformation curve of rectangular underground structure

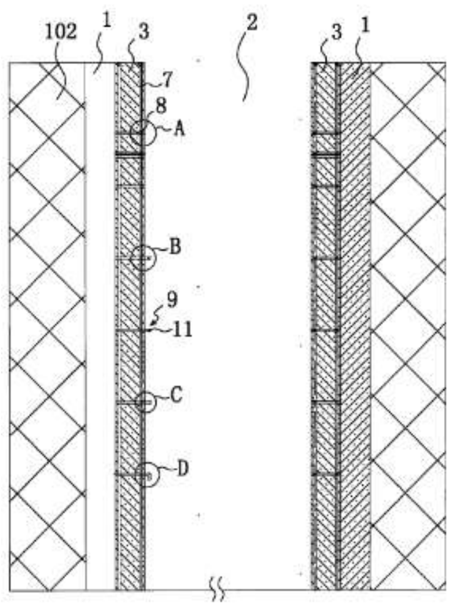

Fig 2: Mechanical characteristics and deformation curve of horseshoe-shaped underground structure

The vertical load of the upper part of the underground structure is mainly the self weight pressure of the overlying strata, and the lateral horizontal load is mainly the surrounding rock pressure, which is manifested as active surrounding rock pressure and passive surrounding rock reaction. The active surrounding rock pressure is the force acting on the structure due to the constraint of the structure when the surrounding rock deforms and loosens towards the underground structure, while the passive surrounding rock reaction is the binding force when

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the structure deforms towards the surrounding rock.

It can be seen from the figure that two kinds of common underground structures (rectangular and horseshoe underground structures) are subjected to the horizontal load of surrounding rock pressure or soil compaction force produced by surrounding construction, and the vertical pressure of white weight of overlying strata during arching effect. The deformation curves are similar, which are the top structure bending downward, the side structure bending outward in the upper direction and bending inward in the lower direction.

There are many kinds of cross-section shapes of underground structures. Because of the representativeness of rectangular cross-section, the calculation model of underground structures can be approximately equivalent to a rectangular section.

2.2 Lateral calculation model

If the common cross section is equal to the rectangular section, the calculation model is an axisymmetric plane. Generally speaking, in the process of pile sinking, the influence of pile foundation on one side of underground engineering structure (underground passage) is greater than that on the other side. Therefore, the main calculation plane can be concentrated on one half of the symmetrical cross section for calculation, and the wall of underground engineering structure is generally composed of reinforced concrete wall, beam and column. If a single wall is regarded as a precast reinforced concrete slab with four sides supported on beams, columns or bottom plates, the wall composed of multiple walls can be regarded as a multi span continuous four side fixed supported slab structure, and the column structure is regarded as the supporting point of the continuous slab, so that the calculation is simple. This is shown in Figure 3.

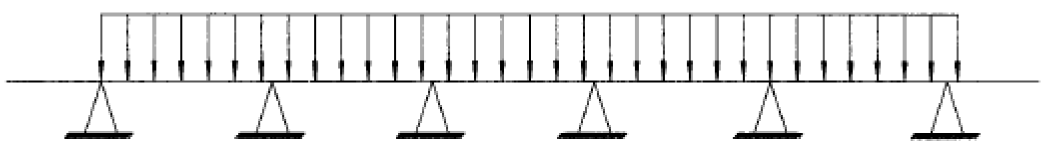

Fig 3: Schematic diagram of simplified wall model

In the process of pile driving, the force on the wall (continuous plate) of underground engineering structure is mainly composed of static earth pressure, dead weight of static pile driver and squeezing earth pressure in the process of pile driving.

III. ENGINEERING EXAMPLES

3.1 Project overview

A library is planned to be built in a certain area. The library inclines from east to south, u is a road, the north side is close to the central square, and the underground civil air defense project is under it, which is usually used as an underground parking lot. The underground civil air defense project is an integral cast-in-place reinforced concrete structure. The total length of the South exterior wall is 125m from east to west, and the column spacing is 6.6m-8.8m. It is

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parallel to the @ axis of the new library building, and the distance is 6.2m. The center of the outermost pile of the library axis @ axis is 5.74m away from the exterior wall of the civil air defense project.

The pile foundation of library adopts prestressed pipe pile, phc500abl00, and the pile sinking method is static pile pressing method. The natural ground elevation of the library pile foundation construction site is basically the same as that of the North Square.

The underground civil air defense project is a C30 reinforced concrete structure. The total height of the civil air defense project is about 4.75m, the width of the passage is 8.4m, the thickness of the top plate is 250mm, the thickness of the bottom plate is 450mm, the thickness of the south wall is 300mm, and the thickness of the overlying soil layer is 0.5m. According to the height of the underground civil air defense project, the soil condition of the proposed library site with a buried depth of 0-10m is mainly investigated.

3.2 Monitoring principle and purpose

The failure of reinforced concrete flexural members is mainly due to the cracks in the concrete in the tension area, and then the steel bars yield, and finally develop to the edge of the concrete in the compression area to reach the ultimate compressive strain, and the concrete is crushed, which is the ultimate bearing capacity of reinforced concrete structure.

For the underground engineering structure, the stress is more complex, and belongs to the building structure in use, if the general monitoring method is still used. That is to say, the allowable deflection of l_0 flexural members is limited to l_0 / 200 (l_0 < 7m) and l_0 / 250 (7m ≤ l_0 ≤ 9m) (3.4.3 of code for design of concrete structures (GB 50010-2010)) [7-8]. The shortest span of underground civil air defense project is 6.6m, and the allowable deflection is about 33mm. When the deflection of the wall panel structure of the civil air defense underground project reaches the allowable value, cracks have already appeared in the concrete tension area. Because the structure is under the surface, cracks and other situations will lead to the leakage of the wall and floor, which can not be used normally. Therefore, for the underground engineering structure, the general monitoring method is no longer applicable.

Based on the stress analysis of underground engineering structure, it is proposed that the crack resistance of underground engineering structure is taken as the control quantity, that is, the design value of axial tensile strength of concrete is used as the ultimate strength for calculation, rather than the yield strength of steel bar as the ultimate strength for calculation. The main monitoring method is whether the surface stress of underground engineering structure reaches the design value of reinforced concrete tensile strength, or whether the deflection reaches the deflection when the concrete is about to crack. At this time, the concrete tension area of underground engineering structure is about to crack or just appear crack, which can avoid the underground civil air defense engineering can not be used normally due to the pile foundation construction of underground engineering structure.

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3.3 Observation on surface cracks of exterior wall and floor in the south of civil air defense project

The surface cracks of the South exterior wall of civil air defense project mainly depend on the appearance observation. If cracks are found on the wall before pile sinking, the surface plastering layer should be removed to observe whether the cracks are structural cracks. If there is no crack on the reinforced concrete surface after removing the plastering layer, the crack does not belong to the structural crack, but should be the crack of the plastering layer. If the structure crack is determined, the crack width value d_0 is recorded by the electronic crack width observation instrument, and the crack width ratio is monitored during pile sinking, then the difference $\triangle d = d_a - d_0$ is the crack change value. When the value is about to reach the warning value, the construction will be stopped.

The cracks in the floor mainly use the existing cracks (expansion joints) in the floor of the civil air defense project which is divided by the beam grid. When the measuring points are buried, the impact drill is used to drill holes on the floor of the basement of the civil air defense project, and then the measuring nails are hammered in. The crack measuring points are selected on both sides of the existing expansion joint of the bottom plate between axis 6 and axis @ of the civil air defense project, and the width is measured by vernier caliper. Before pile sinking, use vernier caliper to tightly clamp the center of cross wire of measuring nails on both sides, read out the initial value d_0 ', and the monitoring value is d_a' when pile sinking, and the difference $\triangle d' = d'_a - d'_0$ is the change value of cracks. A total of 7 crack observation points are arranged, as shown in Figure 4.

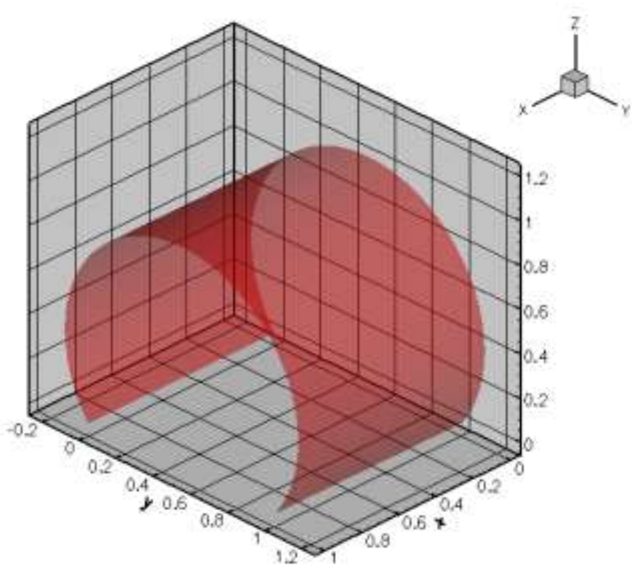

Fig 4: Location of observation points for ground cracks in basement of civil air defense project (unit: m)

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IV. CALCULATION OF FLOOR OF UNDERGROUND ENGINEERING STRUCTURE

Because the circular hole expansion only calculates the plane internal stress of the soil with the depth of Z, and the main pressure on the floor of the underground civil air defense project is the upward uplift of the soil caused by the squeezing effect, which causes the vertical pressure on the floor, so the stress value of the floor of the underground civil air defense project can only be estimated.

Similarly, assuming that the soil is in equilibrium, the soil element is selected.

According to the calculation method of static earth pressure, the horizontal stress is the stress caused by pile tip expansion.

The results are as follows [9-10]:

$$\sigma_3 = K_0\sigma_1 = \sigma_L \quad (1)$$

Therefore, the stress in the vertical direction is:

$$\sigma_1 = \frac{\sigma_L}{K_0} \quad (2)$$

It remains to be verified whether it is correct to estimate the deflection or stress at the bottom plate according to the above formula.

To calculate the stress caused by soil squeezing effect at the bottom plate, the depth z of the calculation point is taken as 5.25m, and the stress caused by pile end expansion at this depth is 652.0Pa The bottom plate of civil air defence works lies in the second soil layer, i.e. clay Q4, and the coefficient of static earth pressure is about 0.18 when the Poisson's ratio of soil is 0.15.

At this time, the vertical stress σ_1 is 28.583kPa.

It is also considered that the vertical stress at any point in the earth can be obtained from the fixed point L. For the floor of the underground project, it is considered that the load action form is still triangular, that is, the maximum value is near the pile sinking site, and the far-end load is 0. Take two slabs with width 1 at the deflection or stress observation point of the floor of the civil air defense underground project for calculation, as shown in Figure 5.

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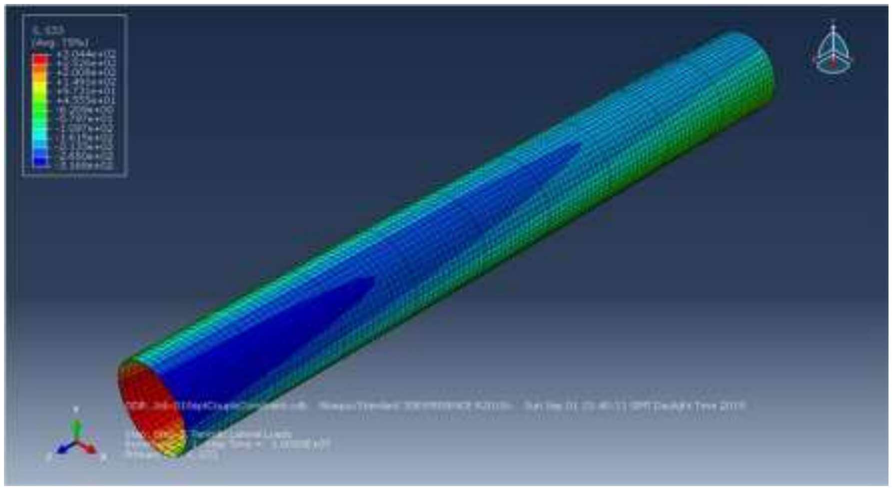

Fig 5: Schematic diagram of civil air defence works floor calculation

Through the comparison between the measured value and the theoretical value, it is found that except for the small difference of the stress in the center of the floor in the east-west direction, the difference of the stress in the center of the floor in the north-south direction and the vertical displacement of the floor are large. The reason may be that the stress calculation method can not accurately calculate the pressure value at the bottom plate, resulting in a larger deflection value. The north-south direction, that is, the width direction of the civil air defense engineering channel, is affected by the ground expansion joint. The ground expansion joint can effectively reduce the stress value in the north-south direction, but the influence of the ground expansion joint is not considered in the theoretical calculation.

V. CONCLUSION

Based on the mechanical model stress analysis of the underground engineering structure in the process of pile sinking, this paper puts forward a calculation method for calculating the stress and deflection of the retaining wall structure of the underground engineering, and according to the characteristics of the underground engineering structure, it puts forward the crack resistance as the monitoring control quantity of the underground engineering, so as to avoid the cracks of the underground engineering structure due to the excessive influence in the process of pile sinking. The stress analysis of underground engineering structure mainly focuses on the calculation of the earth pressure caused by the self weight of soil, the uniform surface load caused by the self weight of static pressure pile machine and the stress caused by the soil squeezing effect. In practical engineering, the initial value of each point needs to be recorded in the monitoring, although there is no pile machine and pipe pile on the retaining wall at this time. But the static earth pressure always exists, so in the later calculation, it can be considered that the static earth pressure does not act on the underground engineering structure.

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