Analysis and Treatment of Limit Invasion of Retaining Piles in Deep Foundation Pit of a Subway Station

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Abstract. This study delves into the limit intrusion of retaining piles in deep foundation pits of subway stations, analyzing the bearing capacity after the removal of over-limit retaining piles. Drawing upon a specific engineering case, it proposes a systematic solution to address the intrusion of retaining piles beyond the structural boundary during excavation. The research reveals that factors such as stratigraphic characteristics, construction seasons, equipment precision, and personnel operations can contribute to the intrusion. Corresponding remediation measures are outlined for varying degrees of intrusion, along with the implementation of reasonable load-transferring components to ensure the safety of subsequent excavation. This study provides valuable insights for similar engineering projects.

Keywords: Deep foundation pit; Breach limit of retaining piles; Pile filling; Force transmission member

1 Introduction

In the process of subway deep foundation pit construction, according to the stratum characteristics, the retaining pile and internal support can be used for foundation pit support. In order to avoid the limit invasion of retaining piles, the pile location will be considered in the construction process of retaining piles. However, due to the criticality control of strata, equipment and machines during construction, the criticality of retaining piles deviates, which leads to the situation that retaining piles invade the structural sideline after foundation pit excavation. Meiyuan uses the Gauss function model to predict land subsidence in the Xi'an area[1]. Han Xuefang acquires the deformation data of foundation pit through on-site monitoring [2-5]. In order to ensure that the stress of the main structure meets the requirements, it is necessary to chisel out the over-limit retaining piles. After the reinforced bars of the retaining piles are cut off, the bearing capacity of the retaining structure will be greatly reduced, and even the foundation pit will be destroyed. Therefore, it is necessary to analyze the bearing capacity of the chiseled retaining piles and take economical and reasonable remedial measures.

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2 General Situation of the Project

2.1 Station Overview

A subway station is an island platform station with two floors underground, with a length of 198.8m, a width of 19.7m and a depth of about 18 m. The surrounding environment of the station is relatively simple, and only one residential building is 12.27m away from the foundation pit of the station, which is relatively close.

2.2 General Situation of Engineering Geology

Within the excavation depth of foundation pit, the soil layers are filled soil layer, silty clay layer and medium coarse sand layer from top to bottom. See Table 1 for the physical and mechanical parameters of each soil layer.

Table 1. Physical and Mechanical Parameters of Rock and Soil Layer

Number	Soil layer name	Redundancy/ (kN/m^3)	cohesive strength /kP$_a$	Friction angle/ (°)	Permeability coefficient k/(m/d)
①2	plain fill	16.0	8.0	10.0	0.45
④4	Silty clay	19.4	27.0	17.0	0.39
④2	Medium coarse sand	20.0	0	32.0	0.35

2.3 Overview of Envelope Structure

The foundation pit of the station adopts 800mm@1200/1300mm retaining piles, and there are three supports, all of which are steel supports. The section of the retaining piles is calculated by Lizheng deep foundation pit calculation software, and the retaining piles are divided into four types. The reinforcement of retaining pile is C25, C20 and C12, as shown in Figure 1.

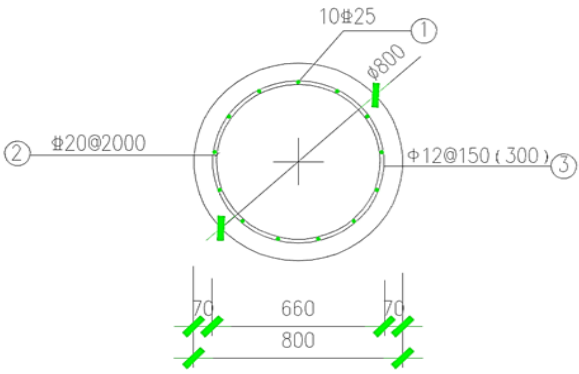

Fig. 1. Reinforcement Diagram of Retaining Pile

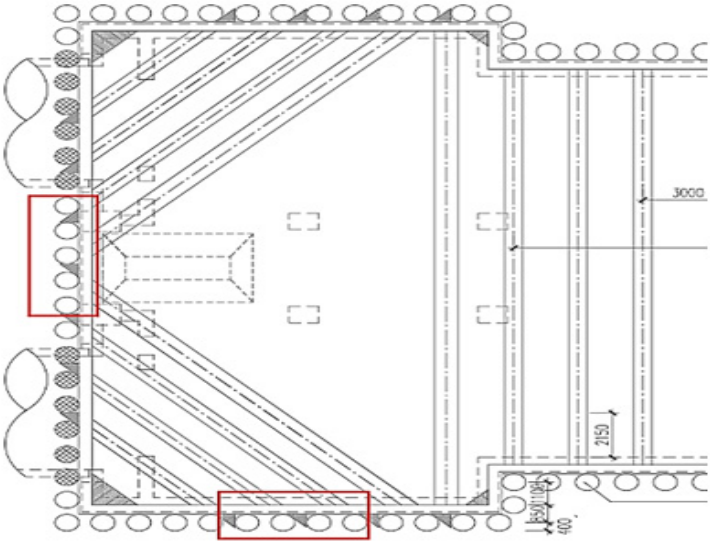

Fig. 2. Schematic Diagram of Invasion Location

3 Damage Limit of Retaining Piles

During the excavation of the last layer of soil in Axis 1-3 of the foundation pit, it was found that the enclosure structure was invaded, and the location of the invasion was shown in Figure 2.

According to the actual measurement on site, there are 6 pile foundations that have been invaded, which are located at the west and south sides of the head well at the north end. The pile length is 23.38m, and the pile foundation has been invaded at the position of 16m, and the degree of invasion is 130 ~ 21 mm. In this range, the station floor has been completed, and the side wall reinforcement has been reserved. The overrun part of the retaining pile from the third steel support to the floor has been chiseled. There are three reinforced bars chiseled out, and there is a condition of dismantling support in the subsequent main structure construction, which further increases the instability risk of the whole supporting system. Therefore, it is necessary to analyze the bearing capacity of the chiseled retaining pile and take reasonable and effective remedial measures.

4 Stress Analysis of Retaining Piles After Local Chiseling

4.1 Analysis of the Reasons for the Limit Invasion of Retaining Piles

During the construction of retaining piles, considering that the criticality deviation of cast-in-place piles should not be greater than 0.5%, the cost of interjecting concrete between piles in the later period and the cost of digging piles after the pile is invaded, the construction unit is used to putting 150mm outside the pile of the main structure

during the construction, but the pile is still invaded due to various reasons in the actual project. Based on a lot of construction experience of cast-in-place piles in foundation pits, it is concluded that the invasion of cast-in-place piles is often caused by the following reasons:

(1) Formation influence. There is a sand layer of 5 ~ 6 m underground and dry hole construction technology is adopted, and the retaining wall is not in place during the hole-forming process of cast-in-place pile, resulting in deviation of retaining piles.

(2) Construction season. The original municipal road was constructed in winter, and many gaps were formed in the filled soil layer due to the melting of the expanded frozen blocks, so the filled soil layer could not be uniform and dense. For example, if a large frozen block was back filled, the frozen block pad around it could not be compacted. During the construction of bored retaining piles in the following year, due to the heavy weight of the drilling rig, the one-sided track of the drilling rig was biased during the rotary slag dumping, resulting in deviation of the criticality of the drill pipe, and some retaining piles were inclined after being piled.

(3) The drilling rig alignment error is large. There is an error in measuring setting or drilling rig positioning, which leads to inaccurate alignment, deviation of the center of the retaining pile and limit invasion of the retaining pile.

(4) Equipment and personnel problems. Because the drill bit is badly worn and can't be replaced in time, or the rig driver's improper operation, it often causes the drill bit to stagnate, which will disturb the soil locally, causing the soil to loosen and collapse, resulting in the expansion of the lower part of the pile hole. In the process of hoisting the reinforcing cage, the lower part is too large and offset, which increases the space for the reinforcing cage to move freely at the lower part of the pile hole, thus affecting the criticality control during hoisting and lowering, resulting in the invasion limit of the pile.

4.2 Force Analysis of Shield Shaft Position

The position of shield well is calculated and analyzed, and the depth of foundation pit is 18.218m m. The ground overload of 20kP$_a$ and the building load of 85kPa should be considered in the calculation. The calculation overview is as Figure 3.

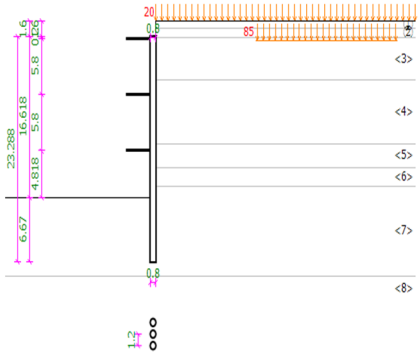

Fig. 3. Schematic Diagram of Force Analysis

4.3 Force Calculation of Shield Shaft Position

Through calculation, it is known that the safety of foundation pit can be ensured when the reinforcement area of main reinforcement is greater than 8125mm². During the invasion, 3 main reinforcement of enclosure structure are treated, and the remaining 17 main reinforcement, with the reinforcement area of 490.1 * 17 = 8331.7mm, can ensure the safety of foundation pit. The specific data are shown in Table 2.

Table 2. Design data sheet

Standard value of bending moment (kN·m)	Bending moment design value (kN·m)	Standard value of bending moment outside the pit (kN·m)	Design value of bending moment outside the pit (kN·m)	Reinforcement grade	Reinforcement center to margin (mm)	Reinforcement area As(mm^2)
566.9	708.6	498.9	623.7	HRB400	50	8125
Real collocation root number	Shear design value Md(kN·m)	Corresponding axial force Nd(kN)	Stirrup grade	Stirrup area calculation value As(mm2/m)	Maximum allowable spacing of stirrups (mm)	
0	677.7	0	HPB300	1311.9	250	

5 Treatment Scheme

According to the actual situation on site, the treatment is divided into two working conditions, and the treatment methods are as follows.

5.1 The Treatment Method of Invading the Structural Sideline ≤70mm:

Because the protective layer thickness of the enclosure pile is 70mm, and the enclosure pile with an invasion limit of 70 mm or less, the concrete with an invasion limit is chiseled without affecting the main reinforcement of the enclosure pile, and the concrete with an invasion limit is chiseled directly, as shown in Figure 4.

Fig. 4. On-site chiseling of pile foundation protective layer

5.2 The Treatment Method for the Invasion of Structural Sideline >> 70mm:

(1) manually remove the concrete to the uninhibited position, remove the concrete after the reinforcement of the main retaining pile, bend the original main reinforcement inward, and repair weld the upper and lower uninhibited positions with Φ 25 reinforcement, and the double-sided welding length is >>125mm.

(2) The reinforcement nails between piles will be lengthened from 1m to 1.5m, and the vertical spacing will be encrypted from 1.2m to 0.6m, so that the confined area can be closed quickly, as shown in Figure 5.

Fig. 5. Reinforcement nail lengthening encryption diagram

(3) Construction monitoring

As of June 27th, the monitoring conditions of surface monitoring points 30-1, 30-5 and 29-1, steel support monitoring points 22-1, 22-2, 22-3, 24-1, 24-2 and 24-3, and pile foundation in-clinometer points 29 and 30 were stable, and no early warning occurred. The monitoring positions are as follows figure 6.

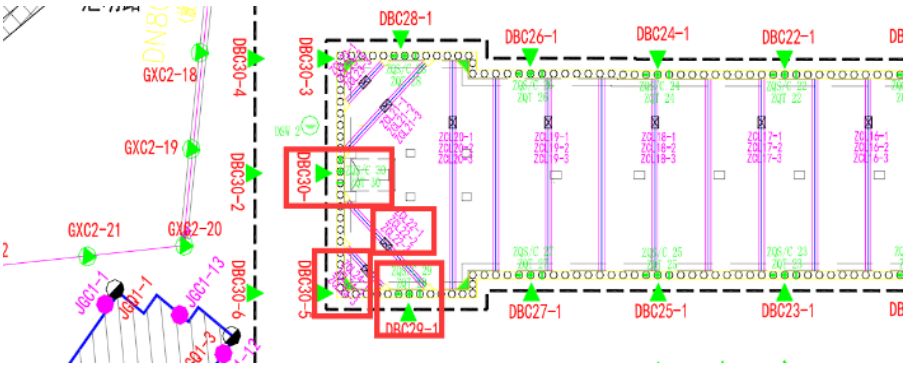

Fig. 6. Monitoring point bitmap

6 Conclusion

There are many reasons that lead to the limit invasion of retaining piles. Before construction, the construction unit should put the retaining piles outside according to its own construction management level, control the quality of finished piles as soon as possible during construction, and adjust them in time when the criticality deviation is too large. In this paper, the bearing capacity of retaining piles after excavation is analyzed, and the safety of subsequent excavation is ensured by adding piles and setting reasonable load-transferring members, it provides a new solution for dealing with similar engineering cases in the future.

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