Design Analysis of Deep Foundation Pit Support for a Building in Xi'an City

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Abstract

With the rapid development of China's basic engineering, the use of urban underground space is becoming more and more sufficient. Due to geological disasters such as ground fissures in Xi'an, it is necessary to formulate support schemes in the process of foundation pit support.Taking the foundation pit supporting project of a high-rise building in Xi'an as an example, this paper adopts various techniques such as anchor cable, shotcrete and drainage, and discusses related mechanical problems in engineering design, providing experience for similar projects in the future.

Keywords

Underground Space, Ground Fissure, Engineering Design.

1. Introduction

With the rapid development of China's economic construction, the demand for high-rise buildings is also growing, and deep foundation pits of more than 7m become very common.At the same time, the collapse of foundation pits is also common, causing huge casualties and property losses. The accidents are mainly caused by two aspects.First, the design is unreasonable, mainly reflected in the large error in the slope stability calculation process, without comprehensive consideration of various working conditions, ignoring the damage of groundwater to the foundation pit, and secondly, mainly due to the fact that during the construction process, it is not completely in accordance with the relevant The specification is carried out. In the selection of the anchor cable, the strength of the concrete is shoddy, resulting in a foundation pit accident.

Through the related research on the composite rock slope of the Carpathian Mountains, some scholars have analyzed the stability of the sliding failure mechanism of complex strata, and calculated the reliability index of the relevant safety factor[1].Fully investigate the relevant data to ensure the stability of the slope. There are many ways to support the slope of the foundation pit, and the application of the foundation of the soil nail support is more and more extensive, but the existing theories and methods are not mature enough.Some scholars in China have used FLAC to establish a simulated soil-fitting composite soil nailing support model. Through numerical analysis and horizontal displacement distribution law, the vertical settlement, axial force and anchoring displacement of the soil are obtained, and the slope stability is quantitatively calculated[2].Through the actual investigation and numerical simulation of the slope stability, the optimal scheme is selected to avoid the instability of the slope and cause engineering accidents.

2. Project Overview

A commercial building construction project in Xi'an is located in the Economic Development Zone of Xi'an. The proposed site is now a wasteland with overgrown weeds, the site is basically flat, and

the landform is in the middle of the first terrace of the south bank of the Weihe River. Earth excavation is the overall excavation of the foundation pit of the underground garage of the community. The foundation pit is 167m long and 139m wide. The excavation depth is 6.7m in the commercial building area, the residential building area is 7.4m, and the supporting area is about 4330m2. The plan is as follows: Figure one. The absolute elevation of the project is 352.125m.

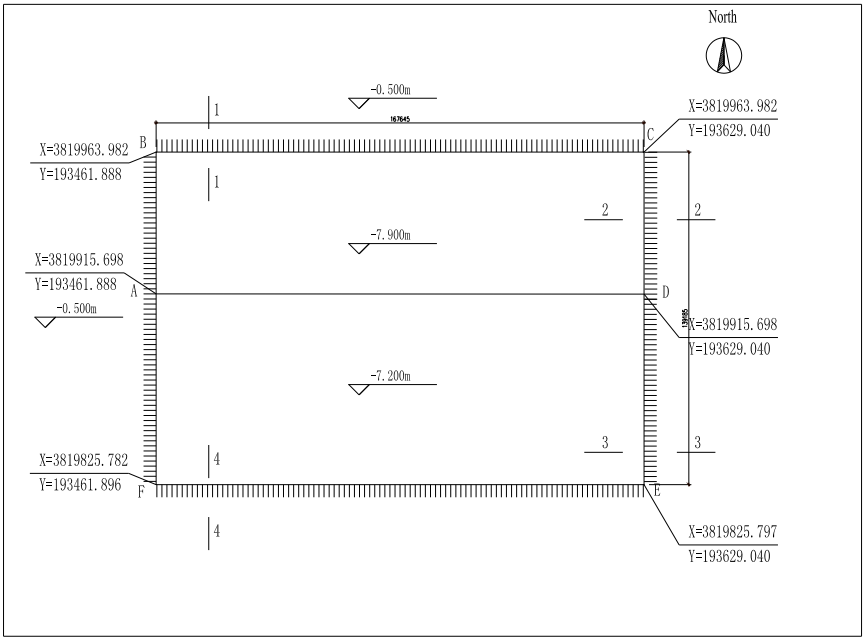

Figure 1 Foundation pit support plan design

3. Project Overview

3.1 Stratigraphic Structure And Description

According to the data provided by the geotechnical investigation report of the project, the proposed stratum consists of mixed fill, loess-like soil, silt and fine sand from top to bottom. The top layer of the soil layer within the influence range of foundation pit excavation is described as follows:

①Filling: The lithology is mainly silt, slightly wet, slightly dense, including bricks, tiles, etc., the soil is uneven, and the engineering properties are poor. The layer thickness is 0.30 to 3.60 m, and the bottom depth of the layer is 0.30 to 3.60 m.

②Loess:The lithology is mainly silty clay, brownish yellow, slightly wet-wet (=19.1%), medium density (=0.885), the soil is relatively uniform, the needle wormhole is developed, and the rust yellow markings are visible at the bottom. The layer thickness is 3.20~8.20m, the bottom depth of the layer is 5.70~8.20m, and the bottom level of the layer is 343.88~345.57m.

③Silt:yellow-brown, slightly wet (=16.4%), medium-density (=0.738), soil is relatively uniform, iron-manganese plaques, mica and sporadic snail shells and calcareous tuberculosis. The layer is distributed throughout the site, thickness: 0.50 ~ 2.60m; buried depth of the bottom of the layer: 6.30 ~ 9.30m; elevation of the bottom of the layer: 341.98 ~ 345.06m.

④Fine sand: grayish yellow, wet-saturated, medium-density, uniform particles, the main components are feldspar and quartz. According to the in-situ test data: the measured average number of hits was 19.4 hits. The layer is distributed throughout the site, thickness: 5.00 ~ 8.50m; buried depth of the bottom of the layer: 14.20 ~ 14.80m; elevation of the bottom of the layer: 336.42 ~ 337.68m.

3.2 Groundwater

The groundwater type belongs to the Quaternary loose rock type pore diving. It mainly accepts precipitation infiltration replenishment and lateral runoff recharge. In the flood season, it also accepts the supply of the Weihe River water. Generally, the runoff is directed to the Weihe River. The

drainage method is mainly based on artificial mining and drainage. During the survey period, it is the flat water period, and the groundwater stable water level of the site is buried at 13.21~14.10m (elevation 337.89～338.13m). The water level has changed by about 3.00m for many years.

4. Foundation Pit Support Design And Soil Mechanics Calculation

According to the relevant design drawings and project survey reports provided by the construction unit, the foundation pit support of the project is divided into three types of foundation pit support. According to the depth of the foundation pit and the surrounding environment of the foundation pit, the safety level of the foundation pit support structure is determined as For the second level, the importance coefficient of the support structure is 1.0; the design life of the foundation pit is 1 year. The stacking is not allowed within 2.0m from the top of the foundation pit, and the stacking within the range of 2.0m to 10.0m shall not exceed 20kPa. The support design is:

Foundation pit ABC section, excavation depth 7.4m, three-layer soil nailing wall support, grading 1:0.3, hole diameter 120mm, soil nail length 6m, 8m, 5m, Φ16 third-grade steel bar , the inclination angle is 15°.

Foundation pit CD section of foundation pit, excavation depth 7.4m, two layers of soil nailing wall + one layer of bolt support, grading 1:0.3, soil nailing hole diameter 120mm, anchor hole diameter 130mm, soil nail length 6m The anchor length is 9m, and the ribs are all made of one φ16 three-grade steel bar with an inclination of 15°.

Foundation pit DE section of foundation pit, excavation depth 6.7m, two layers of soil nailing wall + one layer of bolt support, grading 1:0.3, soil nailing hole diameter 120mm, anchor hole diameter 130mm, soil nail length 6m The anchor length is 9m, and the ribs are all made of one φ16 three-stage threaded steel bar with an inclination of 15°.

Foundation pit EFA section, excavation depth 6.7m, three-layer soil nailing wall support, grading 1:0.3, hole diameter 120mm, soil nail length 6m, 8m, 5m, the rib body adopts 1 φ16 third-grade steel bar , the inclination angle is 15°. The matching table of foundation pit support scheme is shown in Table 1.

Table 1 Support plan matching table

Support plan matching table				
Supporting part	Support selection	Vertical height H	Slope	Section
ABC	Soil nail wall	7.40m	1:0.3	1-1
CD	Soil nail wall+Anchor	7.40m	1:0.3	2-2
DE	Soil nail wall+Anchor	6.70m	1:0.3	3-3
AFE	Soil nail wall	6.70m	1:0.3	4-4

The basic parameters of the foundation pit are shown in Table 2.

Table 2 Foundation pit basic parameter table

Foundation pit basic parameter table							
Supporting part	Foundation pit depth	Groundwater depth in the foundation pit	Groundwater depth outside the foundation pit	Foundation pit importance coefficient	Soil nail load partial coefficient	Soil nail tensile resistance partial coefficient	Overall sliding partial coefficient
Full range	7.40m	13.0m	13.0m	1.0	1.25	1.30	1.30

According to the Technical Regulations for Building Foundation Pit Support JGJ 120-2012, the basic parameters in the foundation pit are as follows: the depth of the foundation pit of the ABC section

and the CD section is 7.400m, and the depth of the foundation pit of the DE section and the EFA section is 6.700m.In addition, the relevant parameters of all ranges around the foundation pit are the same, wherein the depth of the groundwater in the foundation pit is 13.000m, the depth of the groundwater outside the foundation pit is 13.000m, the importance coefficient of the sidewall of the foundation pit is 1.000, and the partial factor of the soil nail load is 1.250, the soil nail tensile resistance partial coefficient is 1.300, and the overall sliding partial coefficient is 1.300. The slope parameters of the foundation pit are shown in Table 3.

Table 3 Slope line parameter table

Bench slope parameter table for each pit				
Supporting part	Number of slope segments	Horizontal projection(m)	Vertical projection(m)	inclination(°)
ABC	1	2.262	7.400	73.0
CD	1	2.262	7.400	73.0
DE	1	2.048	6.700	73.0
EFA	1	2.048	6.700	73.0

According to the geotechnical geological survey report, the ABC, CD, DE, and EFA sections have passed through four soil layers, which are mixed filler, cohesive soil, silt and fine sand, and the soil thickness of the ABC section is 0.600m. , 6.000m, 1.730m, 6.600m, the soil thickness of the CD section is 0.600m, 6.400m, 0.960m, 6.900m, and the soil thickness of the DE section is 0.600m, 6.000m, 1.730m, 6.600m, respectively. The soil thickness of the EFA section is 0.600m, 6.000m, 1.730m, 6.600m, respectively. Among them, the soil layer parameters of each section of the foundation pit are shown in Table 4. The overload parameters of each pit are shown in Table 5.

Table 4 Soil parameter table

Soil layer parameter table of each pit							
number	Soil type	Bulk weight(kN/m^3)	Saturated bulk density(kN/m^3)	Cohesion(kPa)	Internal friction angle(°)	Nail resistance(kPa)	Anchor soil friction(kPa)
1	Miscellaneous fill	18.0	20.0	5.0	10.0	20.0	20.0
2	Clay soil	17.0	18.0	37.7	25.9	73.0	70.0
3	Silt	18.3	18.0	20.0	25.0	60.0	60.0
4	Fine sand	19.0	19.0	0.0	27.0	60.0	63.0

Table 5 Overload parameter list

Overload parameters of various pits						
Supporting part	Overload type	Overload value(kN/m)	Effect depth(m)	Effect depth(m)	Distance from the edge of the pit(m)	form
ABC	Partially uniform	15.000	0.000	3.000	1.738	Strip
CD	Partially uniform	15.000	0.000	0.500	1.238	Strip
	Partially uniform	330.000	6.000	30.000	7.738	Strip
DE	Partially uniform	15.000	0.000	0.500	1.452	Strip
EFA	Partially uniform	15.000	0.000	0.500	1.452	Strip

The foundation pit support selects soil nails as the supporting equipment, and there are 3 soil nails in the ABC and EFA sections. The specific soil nail parameters are shown in Table 6. The CD and DE sections have 2 soil nails. The specific soil nail parameters are shown in Table 7.

Table 6 Soil nail parameter table

ABC, EFA section soil nail parameter table						
Serial number	Horizontal spacing(m)	Vertical spacing(m)	Angle of incidence(°)	Drilling diameter(mm)	Length (m)	Reinforcement
1	1.600	1.800	15.0	120	6.000	1E16
2	1.600	1.800	15.0	120	8.000	1E16
3	1.600	1.800	15.0	120	5.000	1E16

Table 7 Soil nail parameter table

CD, DE section soil nail parameter table						
Serial number	Horizontal spacing(m)	Vertical spacing(m)	Angle of incidence(°)	Drilling diameter (mm)	length(m)	Reinforcement
1	1.600	1.800	15.0	120	6.000	1E16
2	1.600	3.600	15.0	120	8.000	1E16

Taking the ABC section as an example, the internal stability calculation is carried out for each area of the foundation pit. The supporting elevation of the ABC section is shown in Fig. 2, and the profile of the soil nail of the section is shown in Fig. 3.

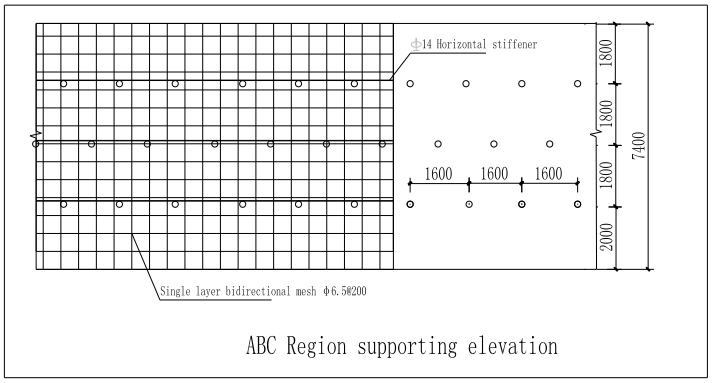

Figure 2 Supporting elevation of the ABC section

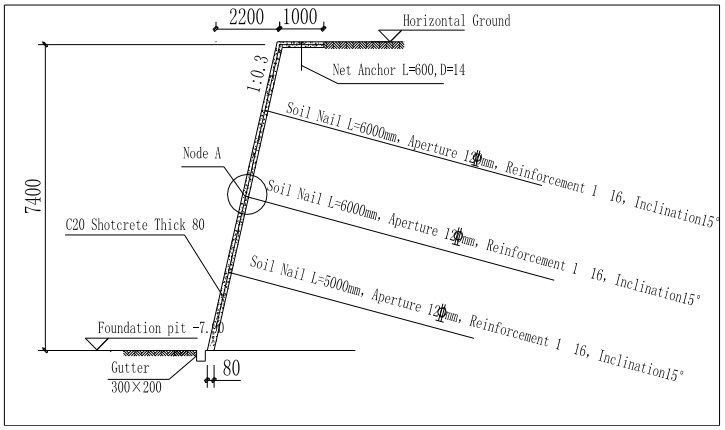

Figure 3 Profile soil nail design

Because there is groundwater in the project area, the total stress method is used to calculate the local tensile check, and the reduction factor of the resistance generated by the soil nail pull on the slip surface should be 0.500. The calculation results are shown in Table 8.

Table 8 Support plan matching table

Local tensile test result table							
Working condition	Excavation depth(m)	Burst angle(°)	Soil nail number	Soil nail length(m)	Tensile load standard value Tjk(kN)	Pull-out bearing capacity design value Tuj(kN)	Tensile capacity design value Tuj(kN)
1	2.300	47.4	0				
2	4.100	48.3	1	6.000	0.0	103.2	72.4
3	5.900	48.6	1	6.000	0.0	85.2	72.4
			2	8.000	0.0	145.9	72.4
4	7.400	48.8	1	6.000	0.0	70.3	72.4
			2	8.000	0.0	130.8	72.4
			3	5.000	20.6	84.2	72.4

When the internal stability of the foundation pit slope is to be considered, it should be considered comprehensively from different working conditions. The calculation results are shown in Table 9.

Table 9 Internal stability check result table

Internal stability check result table				
Working condition	Safety factor	Center coordinates x(m)	Center coordinatesy(m)	Radius (m)
1	3.768	-1.425	14.919	10.263
2	2.799	-2.198	12.309	9.563
3	2.285	-3.553	11.580	10.849
4	1.755	-1.312	6.284	8.387

According to the "Code for Design of Foundations for Building Foundations" GB50007-2011, when calculating the external stability of the ABC section, the parameters selected are shown in Table 10. The calculation results of the external stability of the area are shown in Table 11.

Table 10 External stability calculation parameter tablee

ABC segment external stability calculation parameters								
Soil nail wall calculation width (m)	Dip of the ground behind the wall (°)	Wall back angle(°)	Friction angle between soil and wall back(°)	Coefficient of friction between soil and wall	Wall toe distance from the foot of the slope(m)	Wall foundation bearing capacity(kPa)	Resistance to horizontal sliding safety factor	Anti-overturning safety factor
10.000	0.0	90.0	10.0	0.300	0.000	150.0	1.300	1.600

Table 11 External stability calculation result table

ABC external stability calculation result table									
gravity (kN)	Barycentric coordinates	Overload (kN)	Overload point x coordinate(m)	Earth pressure (kPa)	Earth pressure pointy coordinate(m)	Baseline average pressure design value (kPa)	Maximum pressure design value at the edge of the substrate (kPa)	Anti-sliding safety factor	Anti-overturning safety factor
1130.7	(5.539,3.529）	45.0	5.500	-113.1	2.516	115.6<150.0	164.5<1.2*150.0	34680848.000>1.300	63143904.000>1.600

5. Foundation Pit Engineering Monitoring

According to the requirements of the specification, from the beginning of the construction of the supporting works to the completion of the bottom plate, the construction monitoring of the whole

process should be carried out and the information construction should be carried out.Through construction monitoring, timely grasp the surrounding structure of the whole process of construction and the stress and deformation of the surrounding soil, timely grasp the impact of foundation pit excavation on the surrounding environment, in order to effectively guide the construction, timely adjust the construction plan, and take effective measures. Along the 20m in the longitudinal direction of the enclosure structure, the horizontal displacement and settlement monitoring points of the wall top are set at the top of the retaining retaining body, and the cross mark is marked with the red oil on the top surface and numbered. The monitoring point at the top of the slope of the foundation pit is 1000mm with Φ25mm steel bar, and 1.5 horizontal displacement and surface settlement monitoring points are set at the top of the surrounding body around the foundation pit. The number of daily monitoring during the excavation of the foundation pit shall not be allowed. Less than 1 time, the design of deformation detection of foundation pit engineering is shown in Figure 4.

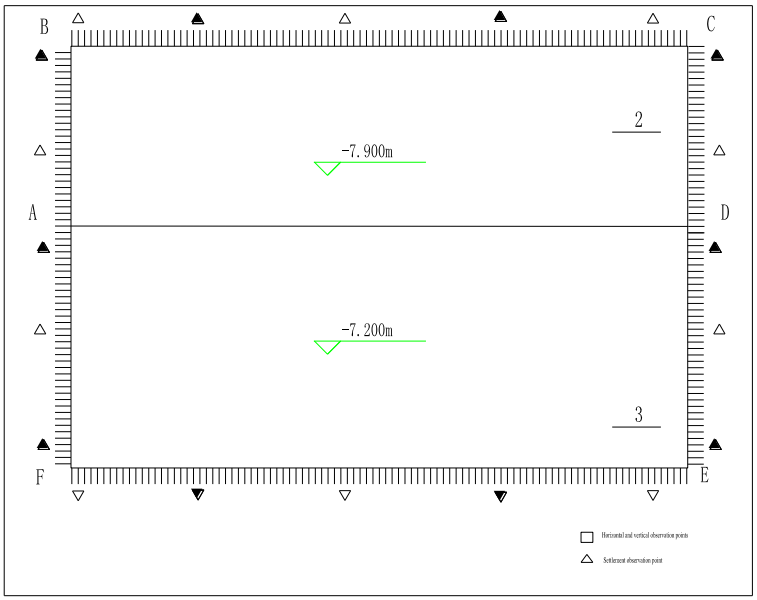

Figure 4 Foundation pit deformation detection design

When the horizontal displacement cumulative value reaches 60mm, or the horizontal displacement reaches 10mm, an early warning should be issued. When the vertical displacement cumulative value reaches 60mm, or the horizontal displacement reaches 10mm, an early warning should be issued.

References

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