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Application of composite soil nailing support for the deep excavation based on FLAC^{3D}

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ABSTRACT

Through an elastic-plastic analyse of FLAC^{3D} program which based on the explicit difference method,and from the case of urban complex of the third space deep excavation project in Tangshan on composite soil nailing combined with general soil nail and prestressed anchor.Numerical simulation is carried out the horizontal displacement on the top of pit foundation,which with measured date is discussed.The analysis shows that the composite soil nailing can largely restrain the pit foundation deformation. The successful application supplies some reference to similar projects in future.

KEYWORDS

Deep excavation; Composite soil nailing; Prestressed anchor; Numerical anchor; Horizontal displacement.

INTRODUCTION

In the 1990s high-rise buildings in Shanghai, Shenzhen and other coastal high water levels, the rapid development of soft soil layer, the pit excavation and shoring techniques involved in the typical strength of soil mechanics, stability and deformation, but also involves soil and supporting structure of the joint action of other issues, making it a focus of the current geotechnical engineering, Tongji University research group in 1997 proposed a composite concept of soil nailing, and applied to the actual project. In recent years, with urban development, high (high) multi-story building basements, underground stations, underground parking, underground streets, underground shopping malls, underground civil defense fortifications and other development and utilization of underground space, resulting in a large number of deep foundation pit design and construction problems, composite soil nailing technologies, greatly expanded the application of soil nailing range, because of its savings in project investment, improve efficiency and shorten the construction period has been widely used in engineering[11]. At the same time, composite soil nailing in theory, research results are also quite good, but the composite soil nailing is still the current status of theoretical research lags behind the development of engineering practice[5]. In order to estimate because of the soil caused by excavation and shoring system deformation, on the one hand depends on the finite element method and other modern analytical tools; the other hand, depends on the correctness of the parameters of the soil, lack of routine laboratory tests have been to reasonably determine the stress-strain soil parameters, only the results of laboratory tests and field tests in order to combine a more satisfactory solution to this problem. In this paper, practical engineering, the use of FLAC3D software, programming, selection and reasonable model parameters, create a composite soil nailing structure of the finite difference model to simulate the process of excavation pit, combined with on-site monitoring data, the stress state and its supporting structure to conduct a study of displacement for the composite soil nailing design and calculation of theoretical research and provide a basis to further improve the composite soil nailing theory and analysis[1-3].

PROJECT OVERVIEW

The third spatial complex compound project location located at the Hebei Province Tangshan Municipal party committee Party school south side, constructs east side the north road, ground 25, underground 3, the hole excavated for building foundation plane size approximately for 169m×68m, the cutting depth most as depth of 16.1m. According to the location "Ground Project Reconnaissance Report", the location respective landform unit Lushan flushes the proluvial plain before Yanshan south, the Dou River modern river valley Ⅱ The stage spot, various soil layers physical mechanics target see Table 1.

TABLE 1: Physical and mechanical properties of soils

Soil No.	Soil name	Thickness /m	Gravity γ/ kN·m^{-3}	Cohesive strength c/ kPa	Friction angle φ/(º)	Elastic modulus E/ MPa	Poisson's ratio μ
(1)	Mixed earth fill	1.0	16.0	12.0	18.0	4.17	0.25
(2)	Silty clay	4.0	18.8	20.7	13.0	2.82	0.35
(3)	Granulated sugar	1.2	18.0	0.0	28.0	12.42	0.25
(4)	Silty clay	1.0	18.6	20.9	12.3	2.52	0.35
(5)	Granulated sugar	2.2	18.0	0.0	32.0	14.83	0.25
(6)	Silty clay	1.6	19.1	20.2	12.8	3.58	0.25
(7)	Granulated sugar	1.2	18.4	0.0	34.0	15.67	0.25
(8)	Silty clay	1.0	18.8	20.9	12.3	3.72	0.25
(9)	Granulated sugar	1.8	18.4	0.0	34.0	16.67	0.25
(10)	Silty clay	1.8	18.9	20.5	13.4	6.67	0.25
(11)	Granulated sugar	4.0	19.0	0.0	36.0	19.08	0.25
(12)	Round gravel	4.0	19.0	0.0	36.0	23.33	0.25
(13)	Silty clay	2.2	19.2	20.3	13.2	4.06	0.25

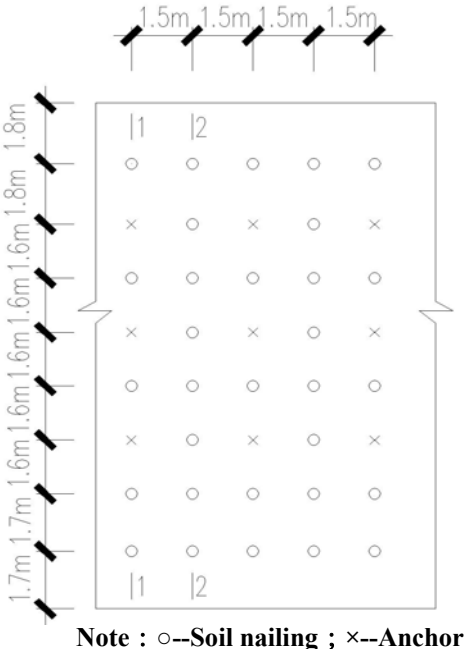
THE SUPPORTS AND PROTECTIONS OF EXCAVATION AND PRECIPITATION DESIGN

The supports and protections plan of excavation

This excavation belongs to the deep big hole excavated for building foundation, (JGJ 120-99) stipulated according to "Construction Hole excavated for building foundation Supports and protections Technical schedule", this project belongs to the first-level hole excavated for building foundation project, the hole excavated for building foundation sidewall security

rating for first-level, the building yard category is Ⅱ The kind, the earthquake resistance fortification intensity is an octave[6]. In order to save the building cost of projects, upside passes through the technical economy and the field condition generalized analysis, east the hole excavated for building foundation, west the both sides uses the earth nail, lower part the stake anchor supports and protections, west the hole excavated for building foundation south side and the hole excavated for building foundation north side uses the earth nail + pre-stressed anchor cable's compound earth nail supports and protections plan. Below this article south main analysis hole excavated for building foundation, north side compound earth nail supports and protections[4,10].

The excavation according to 1:0.3 puts the slope, the lamination partition excavates, the earth nail and the anchor cable construction uses the machinery to become the hole, in the hole the note thick liquid uses the water ratio is 1:0.5 cement only thick liquid. The earth nail altogether supposes eight row, uses the diameter 22 and 25 twisted steels, horizontal spacing 1.5~3.0m, vertical spacing 1.6~1.8m, length 9.0~14.0m, becomes the hole diameter is 110mm, with the horizontal plane included angle angle 15°, leaves leeway the lapped joint in the slope face, in order to with the slope face cross link steel bar and the mat reinforcement connects in together. The anchor cable altogether supposes three row, 2 bunches of ϕs15.2 steel bars tie, horizontal spacing 3.0m, vertical spacing 3.2~3.6m, length 23.0m, becomes the hole diameter is 150mm, with horizontal plane included angle angle 15°, with 2nd, 4th and 6th row of earth nail gap arrangement. The earth nail supports and protections slope face lays down the spacing 200mm×200mmφ6.5 mat reinforcement, sprays 80mm again the thick C25 thin stone concretes. Anchor cable nose waist Liang is the 22a channel steel, the steel backing strip size for 150mm×150mm×15mm, the pre-stressed locking value is 350kN. Elevation of retaining structure as shown in the figure 1.



Note：○--Soil nailing；×--Anchor

Figure 1 : Compound soil nailing in the excavation of the elevation

Excavation precipitation

In the location the subsoil water level is apart from the natural ground approximately 5m, the subsoil water level is deep, the subsoil water level must fall approximately 11m deeply. The main water-bearing stratum is the sandy soil level, according to buries the condition is fourth is the hole diving, water-bearing stratum synthesis penetration coefficient K is 15m/d. Arranges the tube well precipitation around the hole excavated for building foundation, precipitation well tube outer diameter 400mm, well depth 28.0m, according to the well spacing 9.0m well placement.

NUMERICAL ANALYSIS MODEL

Uses FLAC^{3D} finite difference method to establish the compound earth nail numerical calculus model, after the pilot calculation, after this project excavated surface's boundary takes, in structure excavation depth H 2~3 times place, lower boundary when excavates below the bottom surface 0.6H is more reasonable, from excavates takes 0.6H face the hole excavated for building foundation inside, expands the computation scope again is not big to the horizontal departure and the earth nail pulling force computed result influence, this rule which promulgates with literature basic consistent. This article analyzes the hole excavated for building foundation side and below the hole excavated for building foundation excavated surface the 27m intersection spot hypothesis is the origin of coordinates, the slope Mother Earth body extends 65m along x axis direction, the width direction extends 45m along the y axis direction, the cutting depth extends 27m along the z axis direction[8].

In the model building, the soil body uses the misalignment elastoplasticity model, its failure criterion uses the Mohr-Colomb criterion, only considered that the earth nail, the anchor cable are pulled the function, neglects anti-curved its, anti-cuts the function, with the Cable unit simulation earth nail and the anchor cable, the compound earth nail wall concretes surface layer simulates with the entity unit. Model boundary condition: The hypothesis side boundary not horizontal departure, does not have the shear stress, the supposition is the roller support, the hole excavated for building foundation pit bottom stay still, uses the fixed hinged support, the top of slope surface is the free boundary, does not exert the boundary constraint, initial crustal stress field for dead weight stress field. Selects Table 1 various soil layers the physical mechanics parameter[7,9].

EXCAVATION HORIZONTAL DISPLACEMENT MONITORING MENTHOD

According to the related regulations and design requirements , unifies this project the special details, the monitor plan is as follows:

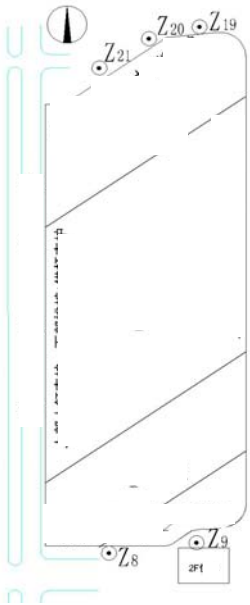


Figure 2 : Arrangement of protective structure for excavation and displacement observation points of foundation pit

(1) Observation point build: Uses the cement mortar in the earth nail wall crown to suppose the spot, the observation point center engraves “ten” the character thin, test point horizontal spacing 20m, and each side side slope observation point many in 3. the 8# test point located at the hole excavated for building foundation south the slope, 19#, 20#, the 21# test point located at the hole excavated for building foundation north the slope, the test point concrete position which the earth nail wall goes against see Figure 2 to show.

(2) Monitoring method: Uses the TOJ2E altazimuth observation, carries on the observation with the method of polar coordinates to calculate the top of slope displacement. Carries on the observation before various measuring points, first through the observation reference point checkup work stand position, is carrying on to various measuring points observation. With has the scale division rod to place in the observation point, the read value, the measuring accuracy is 0.1mm.

(3) Monitor process: In entire structure excavation supports and protections construction period, excavates one to observe 2~3 times every time. nearby

(4) South slope 8# and north nearby slope 21# supposes one to measure the slanting hole separately, through when measures in the slanting hole to arrange the slipper inclinometer which carries on the side slope different depth soil body horizontal departure's monitor, the survey inclinometer's group of guide wheels along measured that the slope tube guidance sliding way puts in the tube, has slipped into the base, every other 50 cm upward back guy reading, determines between the inclinometer and the perpendicular line inclination angle change, then obtains the different depth place horizontal departure.

(5) Side slope distortion monitor warning value: This project uses the earth nail and the pre-stressed anchor cable compound earth nail supports and protections, the hole excavated for building foundation side slope horizontal departure cumulative value achieves 0.2%H (30mm, H is hole excavated for building foundation depth), or the change speed achieves 3mm/d, must carry on the dangerous warning immediately, and takes the emergency procedures to the hole excavated for building foundation supports and protections structure and the peripheral environment's protection object.

MONITORING RESULTS AND NUMERICAL SIMULATION RESULT ANALYSIS

Draws a chart according to the horizontal departure monitoring result and the numerical simulation result 3-4, the concrete study is as follows:

(1) Figure 3(A-D) is south the hole excavated for building foundation the slope and north the slope measuring point numerical calculus and the actual top of slope horizontal departure along with the structure excavation process curve distribution. The result indicated: The soil body distorts along with structure excavation carries on has the obvious time effect, after structure excavation completes, distorts tends to be stable. The curve from August 4 to September 1 the time section, the hole excavated for building foundation top of slope horizontal departure change is not big, presents the obvious platform shape.

(2) Figure 3(A-C) respectively is 8#, 20# and the 21# monitoring result and the numerical simulation result contrastive analysis chart, this spot place hole excavated for building foundation pit goes against the horizontal departure to monitor the value slightly being smaller than numerical simulation value, the soil layer parameter which elects with the numerical simulation, the material parameter and so on concerns. But demonstrated as a whole the numerical simulation result and the construction monitoring result difference is not big, top of slope horizontal departure change tendency basic consistent, and value is relative size close. East the hole excavated for building foundation south side the establishment has the approach slopeway, carries on along with the project, the folk recipe excavates construction loads and so on vehicles in its side to pass through unceasingly, but from the 8# test point horizontal departure monitoring result and the numerical simulation result analysis, its horizontal departure change is quite stable, this can the good restraint supports and protections structure displacement not be able to separate with the earth nail and the pre-stressed anchor cable.

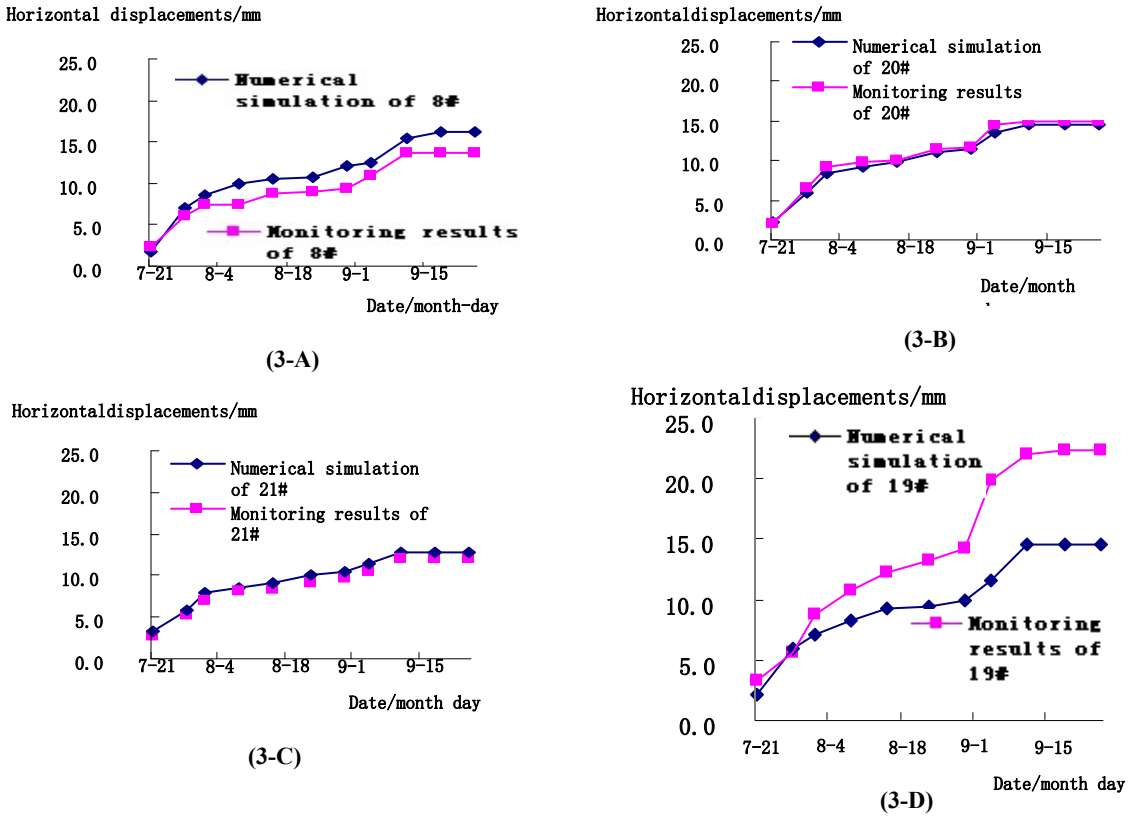


Figure 3: (A-D) Monitoring and numerical simulation results of each monitoring site horizontal displacements on the top of pit foundation

(3) Contrast figure 3-A, 3-B and the 3-C,20# test point the test point displacement is slightly bigger than 8# and 21#. Is mainly because 20# located at hole excavated for building foundation north side earth nail wall, also approaches the hole excavated for building foundation corner, and is prominent to the hole excavated for building foundation interior. Nearby the hole excavated for building foundation corner the spatial function is obvious, building enclosure horizontal departure and earth-pressure action of force complex.

(4) Hole excavated for building foundation excavates after July 11 starts starts to move monitors completes until structure excavation, the hole excavated for building foundation top of slope maximum horizontal departure is 22.3mm (sees

figure 3-B), is smaller than far 0.3%H (H is structure excavation depth) the biggest displacement monitors the value. The hole excavated for building foundation north side 19# test point horizontal departure is biggest, when is structure excavation to 10m about, the side seep is serious, the partial soil body landslide result, and encrypts the lengthen earth nail after the backfill and anchor cable processing, the distortion tends to be stable.

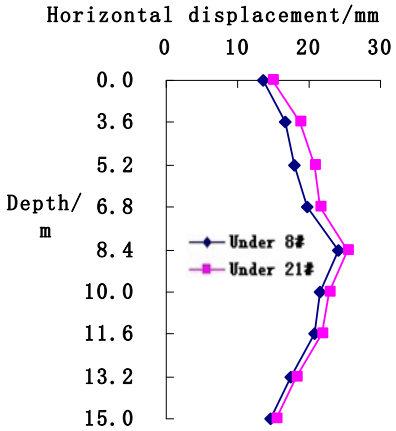


Figure 4 : Horizontal displacement curve of foundation pit after excavation along depth

(5) Figure 3 is the structure excavation supports and protections, south hole excavated for building foundation under north slope 8# test point and hole excavated for building foundation under slope 21# test point 1-1 section planes along hole excavated for building foundation depth horizontal departure's change curve. The traditional earth nail supports and protections side horizontal departure is big, and the maximum value occurs generally in the hole excavated for building foundation crown, to hole excavated for building foundation in sidelurch. May see from Figure 4, the pre-stressed anchor cable compound earth nail supports and protections and the traditional earth nail supports and protections' horizontal departure has obviously different, the pre-stressed anchor cable compound earth nail supports and protections side displacement reduces obviously, and the maximum horizontal departure is not occurs in the hole excavated for building foundation crown, but is being apart from the hole excavated for building foundation base to have certain distance. This is mainly because upside the pre-stressed anchor cable and lower part earth nail both form the unified stress whole, the earth nail's existence also enhanced the soil body integrity, reduced the function on the side active thrust of earth, also as a result of the anchor cable pre-stressed's function, improved the soil body stress, enables the soil body the performance parameter (cohesive force, angle of internal friction and so on) to be improved, in the soil body the biggest shearing stress reduces, has the enhancement equally in the soil body shearing strength, enabled in the earth nail wall structure the soil body stability to obtain strengthened the earth nail and the anchor cable union supports and protections, both supplemented mutually, the mutual influence resisted the load and the distortion together, effective control upside soil body levelDistortion.

CONCLUSION

(1)Unifies the Hebei Province Tangshan third space complex compound project practice, through to this compound earth nail supports and protections structure monitoring result and the numerical simulation result's analysis, this plan good control hole excavated for building foundation distortion, had guaranteed the hole excavated for building foundation security, has satisfied the construction request well. Obviously, applies the FLAC3D finite difference method, uses model which this article selects, can very good computation structure excavation cause the hole excavated for building foundation crown and the hole excavated for building foundation different depth's soil body's distortion, may use in instructing the project practice.

(2)The pre-stressed anchor cable compound earth nail supports and protections can the very good restraint side soil body distortion, and the maximum horizontal departure is not occurs in the hole excavated for building foundation crown, but is being apart from the hole excavated for building foundation base to have certain distance place. Investigates its reason, the pre-stressed anchor cable + earth nail's compound supports and protections technology has the more complex mechanics transmission rule, is worth carrying on a more thorough theory and the practice aspect research, with the aim of promoting the application well.

(3)Compares with the similar engineering geology condition's other supports and protections structure, the earth nail + anchor cable's compound earth nail wall supports and protections not only save the building cost of projects, moreover sped up the construction progress, reduced the time, in addition uses the machinery to be small, is small to the environmental effect. This project's success implementation indicated that uses the earth nail + anchor cable's compound earth nail supports and protections plan is reasonable, also has provided the experience which for the local similar project may use for reference.

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