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Analysis of Deep Foundation Treatment of Soft Soil Under Strong Corrosion Conditions

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ABSTRACT

In the design and construction process of the foundation treatment of an example power plant, the content of chloride and sulphate ions in the groundwater in this area is tens to hundreds of times the content of other normal areas, which makes the corrosion damage more rapid. The residual strength of concrete after 8-20 years is only 5% to 10% of the original design strength, which will be a terrible consequence, meanwhile making it no longer possible to use concrete drilled cast-in-place piles for foundation treatment. For the dynamic compaction-soil replacement foundation treatment method, first, dynamic compaction is applied for the treatment of foundation, then the soil under the foundation with a thickness of 2m is excavated, and backfilled with graded crushed stones, layered rolling is conducted so as to ensure the compactness. With this method, the requirement for the quality of the bearing capacity of the foundation can be met, and the cost is economical and reasonable. The overall construction period is not too long, the destructive effect of the saline soil is avoided, and there is no need to worry about the corrosion effect of chloride ions and sulphate ions.

INTRODUCTION

With the development of society, the scale of modern architecture becomes larger, which has caused corresponding changes in the foundation, resulting in deep foundation construction technology. The deep foundation construction technology is different from the traditional foundation technology. It has high requirements for soil mass stress, but China's geological environment is complex, and there are some geological environments with insufficient stress, such as soft soil environment with strong corrosion conditions. To ensure smooth implementation of the project, it is necessary to adopt the corresponding construction technology. This paper mainly analyses the deep foundation treatment method of soft soil with strong corrosion conditions by practical examples.

EARLIER STUDIES

With the increase of the depth and area of foundation pit engineering, the design method and construction technology are constantly updated and improved, which has formed many highlights of domestic foundation pit engineering construction projects in recent years and has produced good effects. Many kinds of retaining structures have been widely used. For instance, diaphragm wall, cement-soil mixing pile retaining, row pile retaining and SMW method, etc. occupy the main position in the foundation pit retaining. In addition, many kinds of retaining structures have been combined into the overall supporting structure in some projects. There are new theories and methods for foundation pit design and construction technology and verified by the actual project. With the development of enclosure structure, various forms of support emerge as the time requires. New materials begin to be applied to support structure, and reinforced concrete system and steel support system begin to be used in practical projects.

A study carried on the mechanical analysis of the foundation pit supporting structure and the results showed that the anisotropy of soil would increase the displacement of retaining wall and the settlement around the foundation pit (Yang et al. 2013, Nwankwoala et al. 2018, Cho 2017). The field observation data of several foundation pits in cohesive soil and found that the horizontal displacement of the surface support structure was related to the uplift resistance coefficient under the conventional construction conditions (Li & Zeng 2013, Kibria et al. 2018, Rawat & Singh 2018). Based on this discovery, some studies simplified the engineering experience by combining the finite element calculation and proposed a stability safety factor method used for estimating the maximum displacement of the ground behind the retaining structure and wall (Yang et al. 2016, Azeem et al. 2018, Nordin et al. 2018). Some scholars studied the stability of a foundation pit, which was located in a garbage filling

Fig. 1 (a): Example of collapsible loess.

Fig. 2 (b): Example of collapsible loess.

site, and analysed the effective stress of the foundation pit which was affected by the gas during the excavation by means of a two-dimensional and three-dimensional computer model. And through parametric study, they checked the soil behaviour under different parameters (Wang & Cao 2013, Ali et al. 2018, Khattak et al. 2018). A study analysed the monitoring data of a foundation pit project in a soft soil area and analysed the surface subsidence and foundation pit dewatering. When the foundation pit dewatering measures were adopted, the dewatering of aquifer would cause soil compression, foundation deformation, building cracking and inclination (Ishikura et al. 2016, Tahir et al. 2017). A research provided relevant parameters for foundation pit design and construction through field tests and laboratory tests. Geometric requirements for strengthening soft soil layers of foundation were also simulated by experiments (Hou & Li 2013, Hashemi 2017). The stability of diaphragm wall under the limit state and calculated the reliability index of transverse bearing diaphragm wall by using the limit state equation. The reliability index could be applied to some walls with larger wall displacement (Eskisar 2015, Wang & Xu 2017, Aziz & Hanafiah 2017). A study adopted Plaxis3d to simulate the influence of anchor rod on underground continuous wall. Through the simulation analysis, it could be seen that the soil layer on one side of diaphragm wall was subjected to earth pressure, and anchors were used to resist lateral loads and reduce deflection to a large extent. The cases of anchor and no anchor were compared and analysed. The modelling and analysis of how to arrange the anchor structure more favourably and reduce the cost input were also made and the research results were verified through practical engineering (Wang 2014a, Farasat et al. 2017). A research compared the soil movement behind the retaining structure, including the retaining wall with support and gravity retaining wall, proposed the soil displacement mode behind the multi-support retaining wall, and established the correlation curve of settlement, foundation pit depth and distance (Consoli 2015, Anjum et al. 2017). The rigid clay foundation pit was analysed by using the fully elastic Mohr-Coulomb model and the non-linear block model, and the stress of the foundation pit with and without support was calculated respectively (Wang 2014b, Omini & Akpang 2018, Dami et al. 2018).

In summary, the above studies mainly discuss the mechanical research of foundation pit supporting structure, and analyse the data of some specific geological conditions, such as garbage filling site, foundation pit in a soft soil area, data monitoring, modelling analysis, etc. However, there is very little research on deep foundation treatment for soft soil under strong corrosion conditions. Based on the above research status, dynamic compaction and replacement of the foundation treatment program is adopted to ensure that the quality of the bearing capacity of the foundation can meet the requirements. Under the reasonable conditions of construction period and quality, the destruction of saline soil is avoided, and the erosion of chloride and sulphate ions is prevented.

MATERIALS AND METHODS

Overview of the example: The geological conditions in this area are quite special, and the adverse geological phenomena are as follows:

***Collapsible loess*:** In the upper part of the plant area, the loess generally presents a denser state, it is the newly accumulated redeposited loess with vertical joints and horizontal bedding. There are developed pores and soluble salt crystals, initial collapse pressure is 78kPa; there is medium weight collapsible loess within 5m in local areas, and the plant area can be considered as a site of non-weight level-I (slight) collapsible loess. Figs. 1 and 2 are examples of collapsible loess.

***Saline soil*:** The saline soil on the 0~8.5m surface of the plant has a high salt content, which is medium-strong sulphate saline soil with chlorine saline soil distribution; the saline soil in the plant area is moderately-highly corrosive to concrete structures, and is highly corrosive to the steel bars in the reinforced concrete. The corrosiveness of the saline soil in the plant area to the concrete structure of the pile is shown as: the chloride ions and sulphate ions in the groundwater directly act on the concrete, they enter the solution in the pore of the concrete after diffusion and penetration, first the corrosive ions react with $Ca(OH)_2$ in the cement stone to form gypsum, then further react with hydrated calcium aluminate to form ettringite, which expands 2.5 times in volume, causing the structure to bulge and loose, and accelerate the immersion of the corrosive medium SO_4^{2-}. After the formation of ettringite, the pH value of the pore solution decreases, thereby destroying the alkalinity equilibrium condition of the hydrated calcium silicate and decomposing it. Moreover, the content of chloride and sulphate ions in groundwater in this area is tens to hundreds of times higher than other normal areas, which makes the corrosion damage more rapid. The residual strength of concrete after 8-20 years is only 5% to 10% of the original design strength, which will be a terrible consequence, meanwhile making it no longer possible to use concrete drilled cast-in-place piles for foundation treatment. Figs. 3 and 4 are examples of saline soil.

Fig. 3 (a): Example of saline soil.

Fig. 4 (b): Example of saline soil.

Fig. 5 (a): Construction example of dynamic compaction.

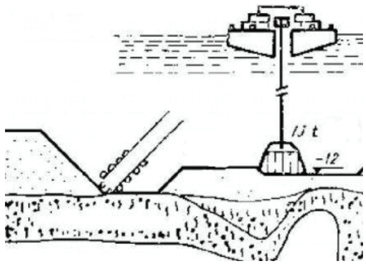

Fig. 6 (b): Construction example of dynamic compaction.

Analysis of alternative schemes: This paper mainly designed two schemes, as follows:

Scheme 1: Stick to the scheme of using reinforced concrete drilled cast-in-place piles for the treatment of foundation. Take measures to suppress the corrosion of the saline soil to the concrete structure and maintain the stability and durability of the concrete structure.

Scheme 2: Adopt other foundation treatment methods, such as: replacement method, dynamic compaction method.

Comparison and analysis of schemes: If the first scheme is taken, that is to control the chemical corrosion of saline soil and concrete structure, the following measures can be taken: (1) increase the design strength of concrete, use concrete of higher design strength as much as possible; (2) add anti-corrosion agents or corrosion inhibitors; (3) increase the thickness of the protective layer of concrete to minimize the corrosive effect of corrosive ions on the steel bars, because the corrosive effect of the corrosive ions on the steel bars is fatal.

If the second scheme is adopted, that is, the replacement method and the dynamic compaction method. For the replacement method, the southern part of the example area is a mountain area with good natural graded gravel soil, and the collapsible loess at the bottom of the foundation can be excavated and then backfilled. The foundation of most buildings in the plant area was designed to be about -4.0m, the earth excavation depth is about -8.0m, the thickness of the backfill is about 4m, perform layered rolling or dynamic compaction with a small amount of energy. The scheme can use local materials, and the construction process is simple; it can effectively improve the bearing capacity of the foundation, reduce settlement, and accelerate the drainage consolidation of the soft soil layer, but it is easy to disturb the soft underlying layer during the construction process, thereby large additional settlement would occur under the action of the structure; for the dynamic compaction method, as the loess layer and silt layer have characteristics of collapsibility and low foundation bearing capacity, the method of foundation dynamic compaction can be used to eliminate the collapsibility of foundation soil, so as to meet the requirement of plant area buildings and structures for the bearing capacity of the foundation. For the construction of dynamic compaction, it needs crawler crane, double support brackets and automatic disengaging device. The construction process of dynamic compaction includes compaction of 4-times: the main compaction, the second compaction, the full compaction and ramming compaction. The compaction strength of the main compaction and the second compaction is 5000k N·m, the compaction strength of the full compaction is 3000k N·m, and the compaction strength of the ramming compaction is 1400k N·m. The dynamic compaction method can improve the overall stability of the foundation, improve the strength of the foundation soil and reduce its compressibility, and it can improve its ability to resist vibratory liquefaction and eliminate soil collapsibility. However, if simply using the dynamic compaction method, the bearing capacity of the treated foundation soil may not meet the bearing capacity requirements of the above structures, especially important projects such as the main building, chimney and water tower. Figs. 5 and 6 are construction examples of dynamic compaction.

Combining the advantages and disadvantages of the above methods, we have adopted a foundation treatment scheme of dynamic compaction plus replacement method. The foundation treatment is first carried out by the dynamic compaction method, then the soil with a thickness of 2m under the foundation is excavated, and backfilled with crushed stones, layered rolling is conducted so as to ensure the compactness. With this method, the quality requirement for the bearing capacity of the foundation can be met, and the cost is economical and reasonable, the overall construction period is not too long, and the destructive effect of the saline soil is avoided, and there is no need to worry about the corrosion effect of chloride ions and sulphate ions.

RESULTS AND DISCUSSION

Part of the construction requirements are as follows: use crawler crane, double support brackets, automatic disengaging device, round compaction hammer with D=2.65m, the weight of the hammer is 27.8t. The lifting height of the main and second compaction point is 18.0m, the lifting height of the full compaction point is 10.8m. The construction process of dynamic compaction includes compaction of 4-times: the main compaction, the second compaction, the full compaction and ramming compaction. The second compaction points were arranged in 7.2×7.2m grid, the full compaction points were arranged in tangent circles, and the ramming compaction points were arranged in overlapped circles. Main compaction and second compaction were performed in order, the compaction was line-interlaced and dot-interlaced, and was completed twice; the ramming compaction includes reinforced compaction on the main and second compaction points, and alternative compaction between the main and second compaction points, the compaction was line-interlaced and finished twice. The ramming compaction was performed twice in order, for the first time, the ramming was performed one by one, the adjacent prints of the hammer should be tangent circles; the second time, the compaction points should overlap all gaps of the first-time compaction, and should be performed one by one, at the same time, the adjacent prints of the hammer should be tangent circles as well. According to the situation of test compaction, the compaction termination standard is controlled both by the compaction times and the compaction settlement. Compaction times: for the main compaction points, compact 17-18 times on each point; for the second compaction points, compact 14-15 times on each point; for the full compaction points, compact 10 times on each point; for the ramming compaction points, compact 2 times on each point. Compaction settlement: for the main and second compaction points, the average settlement between the last two strikes should not be larger than 100mm; for the full compaction points, the average settlement between the last two strikes should not be larger than 50mm, otherwise add compaction times, until the compaction settlement meets the requirement.

CONCLUSION

Through the research in this paper, we can know problems that may exist in the construction process of dynamic compaction and the methods to solve these problems, which also accumulated valuable experience for us to better carry out the foundation treatment in the future. Looking forward, because of the high level of modern technology and the variety of engineering, the dynamic compaction method studied in this paper is a kind of traditional method, and may not be applicable in modern engineering, so if you need to modify corresponding parameters this paper didn't mention any of it.

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