Hindawi
Wireless Communications and Mobile Computing
Volume 2022, Article ID 6340064, 10 pages
https://doi.org/10.1155/2022/6340064

Research Article

Foundation Reinforcement Method of Railway Logistics Center Station Based on Deformation Control and Thermodynamics

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Received 30 September 2021; Revised 3 December 2021; Accepted 14 December 2021; Published 17 January 2022

Academic Editor: Deepak Gupta

In view of the existing methods of foundation reinforcement considering the deformation of the site and the poor effect of the foundation reinforcement, a method of the foundation reinforcement of a railway logistics center station based on deformation control and thermodynamics is proposed. The basic principle of thermodynamics is introduced, and the influence of temperature on the soil properties of foundation is analyzed. Based on the analysis of the engineering geology and hydrogeological conditions of the site, the deformation of the site is calculated, the bearing capacity of the surrounding environment of the foundation pit to the additional deformation is analyzed, and the reinforcement mechanism of the yard foundation in the railway logistics center is proposed to realize the reinforcement of the yard foundation. The experimental results show that this method can use the least tamping pit filler under the same conditions, with a minimum of 7.34 m^3 to realize foundation reinforcement, the maximum ground settlement is only 5.98 mm, and the maximum lateral displacement of pile top is only 6 mm, which can meet the actual requirements and has high practical value.

1. Introduction

Deformation control is one of the core contents in the design of deformation control for the foundation reinforcement project of a railway logistics center. If the deformation of the retaining structure caused by deep foundation pit excavation and its influence on the surrounding environment can be predicted comprehensively and accurately, economic and reasonable retaining scheme and construction measures can be adopted, accidents of a deep foundation pit can be reduced, or resources can be avoided effectively [1–3]. However, due to the high complexity and regional characteristics of the city railway logistics center yard foundation strengthening project, although there are a lot of railway logistics center yard foundation strengthening project practices, there is no systematic understanding of its deformation characteristics of theoretical research, coupled with the foundation pit itself is a theory seriously lagging behind the practice of the subject, design, to be more accurate and reliable to predict its deformation is often more difficult. Through analyzing the factors affecting the construction of metro stations, the comprehensive evaluation index system of the construction risk of a metro station foundation pit is established [4, 5]. Based on the hierarchical structure of these factors, a three-stage fuzzy comprehensive evaluation model is proposed. The AHP method is used to determine the weights of the factors in each stage, and the fuzzy set method is used to determine the degree of membership and to sort the risks. Based on the practice of the railway logistics center yard, the deformation characteristics of the deep foundation pit of the railway logistics center yard are studied deeply and systematically, and the deformation control method is put forward. The research of the deep foundation pit design based on deformation control starts late [6–8]. As far as the research and engineering practice at home and abroad are concerned, there are four problems in this field: (1) The design of the deep foundation pit based on deformation control lacks reliable theoretical guidance, and it is difficult to achieve the scientific design. At present, the experience based engineering analogy method is widely used in deep foundation pit design in our country. Because of the characteristics of the deep foundation pit and the diversity of geological conditions, the guidance function of the system theory is less than that of other technical fields, so that the design of the deep foundation pit is too conservative under some conditions and causes waste, while in other cases, there are greater safety risks to the construction and safe use of the deep foundation pit [9–11]. (2) The understanding of the ground deformation law and mechanism caused by deep foundation pit excavation is not clear enough, and it is difficult to achieve refined design and construction. Previous studies on the deformation of the foundation pit mainly focus on the estimation of the maximum deformation, but the dynamic description of the deformation process is relatively deficient. Many of the formulas obtained are preliminary and not comprehensive. (3) Ignoring the space-time law of foundation pit deformation, a two-dimensional plane strain model to design and calculate is used, which causes the waste of stiffness design of the retaining structure near the pit angle; on the other hand, it increases the difference deformation between the middle of foundation pit and the pit angle and is unfavorable to the deformation control of the surrounding environment. (4) The deformation control index is single, and the standard is absolute, which is difficult for meeting the complex and sensitive environmental requirements around the deep foundation pit.

Because of the high complexity and regional characteristics of the foundation reinforcement project of the city railway logistics center, although there are a lot of practices of the foundation reinforcement project of the railway logistics center in various regions, there is no systematic theoretical research on its deformation characteristics, and the foundation pit project itself is a subject whose theory lags behind the practice seriously; it is often difficult to predict its deformation accurately and reliably in design. However, the design concept of deep excavation based on deformation control has not been put forward for a long time and is obviously different from the conventional strength control method. Lei et al., using laboratory model test and numerical simulation PFC2D, systematically analyze a new vacuum preloading method. Alternating vacuum preloading method is used to reinforce super-soft soil filled by dredging [12]. The study shows that the alternating movement of soil particles in the alternating vacuum preloading method can effectively restrain the formation of silted mud layer and the phenomenon of “soil column” and make the overall reinforcement effect more uniform and effective. Compared with the conventional vacuum preloading method, the displacement of the alternating vacuum preloading method increases 14.92%, the settlement increases 11.80%, the shear strength of the reinforced soil cross slab increases 21.65%, the water content decreases 26.74%, the density of the silt plugged layer decreases, the porosity of the area formed by the silt layer increases more than 30%, and the effect of breaking silt is obvious. But the foundation deformation is not statistically analyzed, and the reinforcement effect is not ideal. Based on the purpose of improving the construction level of geotechnical engineering, the application of the method of strengthening the foundation is simply discussed. From the point of view of ground control, the reinforcement effect is ensured. However, there is no detailed discussion on the foundation deformation [12–14].

Therefore, it is of great significance to study the deformation characteristics of deep foundation pit of railway logistics center, find out the corresponding deformation law, and apply it to the design of deep foundation pit based on deformation control and thermodynamics. In order to improve the effect of foundation reinforcement, a foundation reinforcement method of the railway logistics center station based on deformation control and thermodynamics is proposed in this paper. The basic principle of thermodynamics is introduced, and the influence of temperature on the properties of foundation soil is analyzed. Based on the analysis of the engineering geological and hydrogeological conditions of the site, the deformation of the site is calculated, the bearing capacity of the surrounding environment of the foundation pit to the additional deformation is analyzed, the reinforcement mechanism of the station foundation of the railway logistics center is put forward, the reinforcement of the station foundation is realized, and the effectiveness of the design method is verified by experiments.

2. Basic Theory of Thermodynamics

The process of heat conduction is a process of thermal motion in which objects with different temperatures contact or have different internal temperatures. Heat conduction can occur in solid, liquid, and gas, and heat convection often occurs in gas and liquid. Where the temperature of the object is higher, the microparticles have more energy. In the process of continuous collision between particles, the particles with higher energy will transfer energy to the particles with lower energy. From the macro point of view, when there is a temperature gradient, the heat will transfer from high temperature to low temperature.

3. Analysis of Foundation Reinforcement Conditions for Railway Logistics Center Yard

3.1. Influence of Temperature on the Properties of Foundation Soil. The influence of temperature on the properties of the soil mass is as follows: (1) The influence of temperature on the internal structure of foundation soil is the volume change of the upper particles and pore water caused by thermal expansion. (2) The influence of temperature on the physical and mechanical parameters of the foundation soil is mainly considered as shear strength, consolidation coefficient, and permeability coefficient. (3) The temperature has an effect on the thermal parameters of the soil, such as the resistance of the upper body.

3.2. Choice of Pavement Type. The selection of pavement types for the stacking yard of a road or railway logistics center shall be determined by comprehensively considering the characteristics of port loading and unloading operations, the requirements of the types of goods on the surface layer, and other conditions. Heavy container stacking area is located in the southeast of the logistics center, with wide terrain, large load, and large foundation settlement; construction conditions are not limited by objective factors; interlocking block pavement is selected. The dismantling and loading yard, empty container yard, road, gate area, sinking loading and unloading area, and auxiliary yard are located on the stacking yard and road of the existing railway logistics center, and the foundation settlement is relatively small, so the concrete pavement can be selected [15, 16].

3.3. Settlement Standard

3.3.1. Settlement Control Indicators. The settlement control indexes of the foundation of a storage yard mainly include differential settlement, overall settlement, and inclination (angle variable). The bearing capacity of additional deformation is closely related to the type of foundation, the type of foundation, the type of structure, the size of the building, the age of construction, the load, and the function of use. The bearing capacity of the whole settlement, differential settlement, and tilt (angle variable) is different even for the foundation of the same yard. Therefore, it is necessary to conduct a systematic study to determine the scientific and appropriate control standards, in order to avoid excessive damage to the surrounding yard foundation at the same time to prevent the blindly controlled waste of funds. Overall settlement, differential settlement, and inclination (angle variable) are the earliest parameters used as the foundation deformation control parameters of storage yard, and they are also the most widely used parameters so far. Therefore, they are introduced into the index system in this paper. Compared with the strain and the crack, the settlement value of the pile foundation is more easily obtained by monitoring and measuring. Numerous studies have shown that differential settlement is an important factor causing the pile site foundation inclination (angle variable), and differential settlement increases with the increase of overall settlement. When inquiring into the data of reinforced concrete frame structure and brick and concrete structure affected by excavation, the author found that, for the reinforced concrete frame structure, when the total settlement of the pile site foundation is greater than that of the pile site, the foundation of the pile site is damaged to some extent. The following can be found from the research on the influence data of foundation pit excavation on the pile foundation in the Middle East: (1) Old buildings with a construction time of more than one year are generally prone to damage, while recent buildings less than one year old have no major damage. (2) Compared with other foundation forms, the independent column foundation is more prone to differential settlement and is also more sensitive to stratum deformation. (3) The overall settlement of the clay soil layer pile foundation should be controlled within. When the overall settlement of the sand layer is greater than that, slight and moderate deformation may occur. (4) When the differential settlement is smaller, the slope is generally smaller, and the pile site foundation is not damaged; when the differential settlement is larger, a larger slope may occur. When it is tilted, the damage to the foundation of the general stacking site is slight, and if it is greater than that, moderate or severe damage occurs. Therefore, the inclination of general buildings should be controlled within, and its control index can be determined when considering the safety factor. And according to the damage investigation results of the pile site foundation, when the tilt is greater than that of the load-bearing wall and the partition wall of the frame-type stacking site base may crack, and if it is greater than that, structural damage may occur. It is recommended to use it as a control index for tilt.

3.3.2. Crack Control Index. The appearance and development of cracks are the precursors and intuitive manifestations of the destruction of the foundation structure of the pile site, for brittle materials such as concrete, gun body, stone, and brick wall. Because the compressive capacity is significantly greater than the tensile capacity, uneven settlement, horizontal deformation, and inclination will cause excessive tensile and shear stress in the wall to be the main reason for the formation of cracks. According to the monitoring results of various structural cracks on the railway logistics center site, the form, direction, and distribution of the cracking of the pile yard foundation caused by the excavation of the foundation pit are relatively complicated. In summary, there are two main types: (1) the pile yard foundation caused by uneven foundation settlement vertical cracks formed by tension of load-bearing walls; (2) oblique cracks formed by shearing corners of components such as doors and windows due to local stress concentration. The crack width is one of the important parameters for evaluating the damage of the pile site foundation. According to the width and distribution of the cracks, the extent of damage to the pile site foundation can be judged by the excavation of the foundation pit, and whether its bearing capacity and use function are greatly affected, and whether protective measures are required.

3.4. Site Conditions. A container railway logistics center station is built in the southwest corner of a railway logistics center station in a city in northern China, and some building materials are stacked in the south central station. In its northwest, there is a concrete pavement with a thickness of 0.15 m and coke accumulation. However, the concrete pavement is unevenly sinking, and the concrete pavement has been damaged and has been soaked in water for a long time. A large amount of construction and domestic waste are piled on the surface of the southeast, and the surface of the northeast is covered with a layer of white alkali residue, and the surface is low-lying water. In addition, the existing railway logistics center yards are in operation, and land acquisition and demolition need further coordination. There are 3 in-use alkali slag pipelines in the heavy tank site, running across the north and south. This alkali slag pipeline has been in use for 30 years. The pipe wall is rusty, and there are many small holes leaking alkali slag. Due to the tight schedule, the new alkali slag pipe cannot be built when the foundation is reinforced, and the old alkali slag pipe should continue to be used. If the design is not properly considered, deviations in the foundation settlement control during the construction process will cause the alkali slag pipe to distort and damage roads, a large amount of alkali slag leakage, and the shutdown of alkali plants and other immeasurable serious consequences.

(1) According to the engineering geological survey data, the soil layers of the railway logistics center area are distributed from top to bottom. Miscellaneous fill (mainly alkali slag, bricks, and furnace ash slag), silty clay, silt, silt, and silty clay. The surface miscellaneous fill soil is thin and cannot play the role of a holding layer; the silt or silty clay layer below about 20 m thick has high water content, large void ratio, and flow plasticity. It belongs to medium and high compressibility soil with low strength, and the settlement deformation is large. Therefore, the main purpose of foundation reinforcement is to improve the strength and bearing capacity of the soil, control the settlement of the foundation, and ensure the stability of the railway logistics center yard during construction and use. After investigation, a soda plant is located on the south side of the railway logistics center yard. About 1 km north of the railway logistics center yard is the alkali slag mountain, which is formed by the accumulation of alkali slag discharged from the alkali plant for 30 years. This is the reason for the existence of the alkali slag pipe. This area is formed by dredging and reclamation of the port [17]. In order to save investment and use waste, the alkali slag is turned over in the sun and filled with dredging soil. The plastic alkali slag on the surface is caused by the leakage of the alkali slag pipe. Before the foundation reinforcement is carried out, the alkali residue, construction waste, domestic garbage, and rot plants on the surface should generally be removed. In this project, nearly 200,000 m^2 is covered by alkali residue, and the thickness is 1.4~3.8 m. The removal cost will cost 20~30 million yuan. Because the alkali residue has good reinforcement characteristics, the alkali residue layer can be considered as a part of the foundation for reinforcement treatment, rather than for removal and disposal

4. Calculation Method of Yard Deformation

4.1. Calculation of Vertical Deformation of Stratum in Central Section

4.1.1. Calculation of Surface Settlement in Central Section. According to the actual measurement data collected by the author on the ground settlement of the deep foundation pit of the railway logistics center, the distribution function is used to estimate the distribution of the ground settlement outside the pit. Calculated as follows:

$$M = \alpha f_c A e_a + (\alpha - \alpha_t) f_y A_s N, \tag{1}$$

$$A_s = f_y r_s \frac{(\sin \pi\alpha + \sin \pi\alpha_t)}{\pi} + \frac{(r1 + r2)}{N}. \tag{2}$$

In the formula, α represents the proportion of the cross-sectional area of the foundation structure of the railway logistics center's stack yard affected by the slope of the foundation to the cross-sectional area of the entire model; α_t represents the cross-sectional area of the foundation structure of the railway logistics center's stack yard affected by the vertical tension of the foundation occupies the entire model. The ratio of the cross-sectional area of the model: f_c and f_y, respectively, represent the compression index and rebound index of the foundation structure of the railway logistics center yard under the influence of the slope of the foundation; A represents the circular cross-sectional area of the foundation structure of the railway logistics center yard; and A_s represents the model. The area of all longitudinal steel bars in the horizontal section: r_1 and r_2 represent the inner and outer radii of the circular planar section of the foundation structure of the railway logistics center storage yard, respectively; r_s represents the outer radius of all longitudinal bars in the model, generally $r_1/r_2 \geq 0.5$; and e_0 represents the foundation slope. The degree of eccentricity of the model ring section: e_a represents the additional eccentricity of the base structure of the railway logistics center stacking yard, and N represents the number of longitudinal steel bars in the plane section of the model ring structure, usually $N \geq 6$.

4.1.2. Calculation of Deep Soil Settlement in Central Section. It can be seen from the previous text that the formation deformation has certain stratification, but the overall deformation trend is obvious [18]. The settlement of deep soil above the bottom of the pit is caused by excavation and unloading, and the settlement is transmitted downward from the surface. Then, the expression of the settlement process of the deep soil in the central section is as follows:

$$B = \frac{M_k}{M_q(\theta - 1) + M_k} B_s, \tag{3}$$

$$B_s = \frac{\eta E_s A_s h_0^2}{1.15\psi + 0.2 + 6\alpha_E \rho / \left(1 + 3.5 r_f\right)}, \tag{4}$$

$$\psi = 1.1 - 0.65 \frac{f_{tk}}{\rho_{te}\sigma_s}. \tag{5}$$

Among them, ψ represents the uneven coefficient of tensile strain of the foundation structure of the railway logistics center yard under the influence of the foundation slope; α_E represents the ratio of the elastic modulus E_s of the steel bar in the model to the elastic modulus E_c of the tunnel concrete structure; ρ represents the railway logistics center yard reinforcement ratio of the steel in the foundation structure; r_f represents the ratio between the model's annular flat section and the effective section of the model web under the influence of the foundation slope; M_k represents the standard compression moment of the model; M_q represents the model under the influence of foundation slope compressive bending moment; θ represents the influence coefficient of the deflection of the model under the long-term influence of the foundation slope; f_{tk} represents the axial compressive strength of the tunnel concrete structure; ρ_{te} represents the reinforcement ratio of the tunnel structure's compressive effective steel bar affected by the foundation slope; σ_s represents the reinforcement stress of the tunnel structure affected by the slope of the foundation; and ρ' represents the reinforcement ratio of the compressed reinforcement of the model under the impact of the slope of the foundation.

4.1.3. Calculation of Horizontal Lateral Displacement of Central Section Retaining Wall. According to the statistics of the deformation characteristics of the deep foundation pit wall of the railway logistics center yard and the analysis of the basic law of deformation, it can be seen that for deep foundation pits with greater rigidity such as the internal support system of bored piles, the side of the retaining structure the axial deformation is usually convex. Therefore, a polynomial is used to fit the horizontal lateral displacement of the retaining wall, and the expression is

$$\omega_{\max} = \frac{\Psi l^4}{8EL}. \tag{6}$$

Among them, l represents the effective length of the longitudinal bolts in the tunnel structure model; $[\tau]$ represents the compressive strength of the longitudinal bolts in the model under the influence of the slope of the foundation; and EL represents the bending stiffness of the longitudinal bolts in the model.

4.1.4. Calculation of Deformation at Any Position of 3D Deep Foundation Pit. The deformation of the deep foundation pit has obvious spatial effect. The deformation of the pit corner is much smaller than that of the middle part, but the spatial effect only changes the magnitude of the deformation and does not change the shape of the deformation [19]. Therefore, the deformation at other positions can be estimated from the deformation of the main section according to the law of spatial deformation. The distribution function of the surface deformation parallel to the direction of the foundation pit wall is obtained.

$$b_i = \sum_{i=1}^{m} \omega_i \times s_{ij} = \min\left\{1, \sum_{i=1}^{m} \omega_i \times s_{ij}\right\}. \tag{7}$$

In the formula, $i = 1, 2, \cdots, m$, $j = 1, 2, \cdots, n$, b_i represents the deformation value of the interface type of the foundation pit in the j logistics center, s_{ij} represents the j structural factor of foundation structure factor of i yard, and ω_i represents the interface type of foundation pit in i logistics center;

4.2. The Tolerance of the Surrounding Environment of the Foundation Pit to Additional Deformation. The foundation structure of any pile site has a certain strength and can resist certain additional deformation. The allowable deformation of the pile yard foundation structure refers to the limit value of the deformation that can be used normally under the influence of the ground deformation [20]. The severity of the consequences of damage to the foundation of the stack is the main basis for the classification of the foundation protection. The "generalized" pile yard foundation damage level is divided according to the function damage of the pile yard foundation, which belongs to the definition of "qualitative" [21, 22]. It is generally divided into four levels: pile yard foundation, functional damage, structural damage, and collapse. The pile yard foundation affects the appearance of the pile yard foundation, resulting in visible appearance or "aesthetic" damage, generally manifested as slight deformation or cracking of the filling wall or decoration [22]. Wide cracks in gypsum walls and wide cracks in brick-concrete or plain walls are considered to be the upper limit of damage to the pile site foundation. Under normal circumstances, minor repairs may be required. Functional damage affects the use of the structure and the realization of its functions, resulting in usability or functional damage, manifested as follows: crack development, broken water pipes, and inclined walls and floors. Under normal circumstances, intermediate repairs may be required. All functions of the structure can be restored after repairs that are not related to the structure. Structural damage affects the stability and safety of the structure. It usually means that major load-bearing components such as beams, columns, and load-bearing walls have large cracks or deformations, resulting in structural or stability damage, and generally require major repairs. The load-bearing capacity of the pile yard's foundation has declined, and it has become a dilapidated building that needs to be reinforced, and some parts need to be overhauled. Part or all of the collapsed house collapsed and need to be rebuilt. The classification according to the degree of damage to the foundation of the heap site belongs to the definition of "quantity."

5. Reinforcement Mechanism of Pile Yard Foundation of Railway Logistics Center

After completing the calculation of the deformation index of the storage yard, the obtained data is counted. The main function of the deformation control method is replacement. The poor foundation soil is forced to be discharged by the pile forming machine and replaced with good performance gravel. The pile-earth railway logistics center pile yard foundation is formed as shown in Figure 1.

Since the stiffness of the gravel is greater than the stiffness of the cohesive soil around the pile, the stress in the foundation will be redistributed according to the material deformation modulus.

The ratio of the pile body stress to the cohesive soil stress between the piles, that is, the pile-soil stress ratio, is generally about one, and most of the load will be borne by the gravel pile [23]. Secondly, the replacement pile can also be used as a drainage sand well. When the selected pile material meets certain grading requirements, the gravel pile can form a good drainage channel in the clay foundation, greatly shorten the horizontal seepage path of pore water, and accelerate the drainage consolidation of soft soil and stabilize the foundation settlement. However, it should be noted that the grading requirements need to comprehensively consider many conditions such as gravel volume, pile material, loose bulk density, maximum particle size, and the actual situation of the pile yard. It is a dynamic standard, and the grading

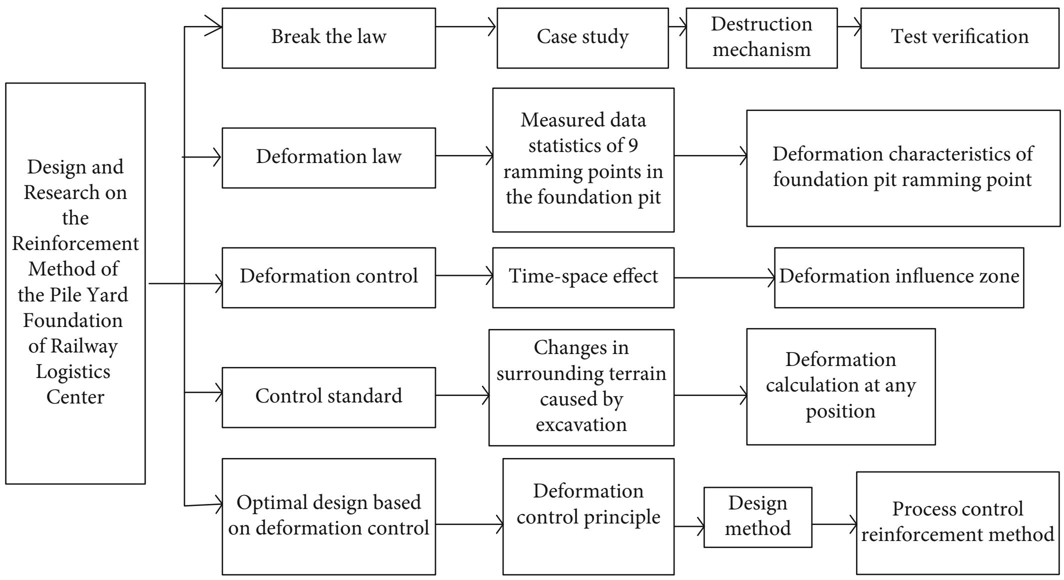

Figure 1: Reinforcement ideas of railway logistics center pile yard based on deformation control.

requirements need to be put forward after careful consideration of various conditions. At the same time, in this paper, in order to achieve the actual effect, the pile material required by grading needs to meet the requirements of strong structural strength and strong deformation resistance. Thirdly, the deformation control method also has the effect of dynamic consolidation. In the process of pile formation, due to vibration, squeezing, and other reasons, there will be a large additional pore water pressure in the soil between the piles, resulting in a decrease in the strength of the original foundation soil. After the pile is completed, on the one hand, the structural strength of the original foundation soil will gradually recover over time; on the other hand, the pore water pressure will transfer to the pile body and dissipate. As a result, the effective stress increases, and the strength increases and recovers and exceeds the original soil strength [24]. The main damage of the gravel pile is bulging damage. Because the gravel pile is composed of loose particles, it will not only produce vertical deformation but also radial deformation after bearing the load and cause the surrounding cohesive soil to produce passive resistance. If the strength of the cohesive soil is too low to allow the gravel pile to obtain the required radial support force, the pile body will be bulged and damaged, the gravel will be squeezed into the surrounding soft soil, and the foundation reinforcement effect will be poor. The replacement rate of several factors that affect the reinforcement effect of the deformation control method is determined by the distance between the ramming points and the diameter of the pile body, which directly affects the bearing capacity of the foundation of the railway logistics center. The depth of reinforcement is the length of the pile, which directly affects the sliding stability, settlement deformation, and allowable bearing capacity. The performance of crushed stone affects the internal friction angle and drainage effect of crushed stone [25]. Therefore, during construction, the construction procedures that affect the above three important factors should be strictly monitored to make the construction quality meet the requirements of the design. The schematic diagram of the shear characteristics of the pile site foundation is shown in Figure 2.

The intersection angle between the shear surface and the horizontal plane at a certain depth of the foundation of the railway logistics center of the logistics center is θ. If both the gravel pile and the soil between the piles are considered to exert the shear strength, the shear resistance of the foundation of the stack can be obtained. The intensity can be calculated as

$$Ts = \frac{F_m}{Wt} \cos \theta. \tag{8}$$

Among them, Ts represents the tensile strength, F_m represents the maximum tensile force recorded, W represents the width of the narrow part of the cutter, and t represents the thickness of the waterproof material. When the waterproof material is used in the foundation pit of the railway logistics center, the waterproof membrane will have a certain breaking elongation [26], and the breaking elongation can be expressed as

$$E_b = \frac{100(L_b - L_0)}{L_0}. \tag{9}$$

Among them, L_b represents the test length of the waterproof material when it breaks, and L_0 represents the length of the initial waterproof material. The components of the foundation pit of the railway logistics center are combined with each other, the waterproof material produces a certain amount of extrusion [27, 28], the waterproof material is uniformly loaded with a force of 2400 N, and the compressive

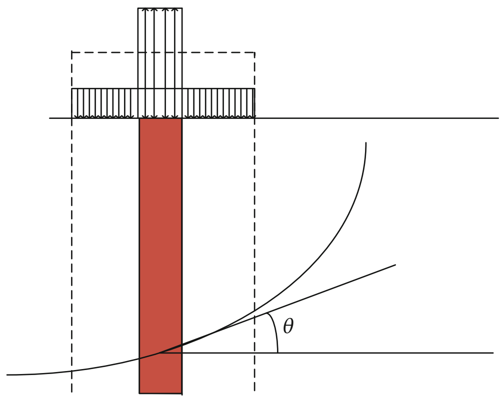

Figure 2: Schematic diagram of the shear characteristics of the pile site foundation.

strength of the waterproof material specimen is calculated, which can be expressed as

$$R_c = \frac{F_c}{A}. \quad (10)$$

Among them, F_c represents the load value when the waterproof material is destroyed, and A represents the compression area of the waterproof specimen. After the physical performance testing indicators are determined, according to the physical performance testing platform built, the water seepage calculation formula is constructed, which can be expressed as

$$\frac{Q}{S} = -\frac{k}{\mu}\frac{\Delta P}{L}. \quad (11)$$

Among them, Q represents the total flow through the waterproof material per unit time, S represents the cross-sectional area of the solution through the waterproof material, k represents the absolute permeability, μ represents the dynamic viscosity coefficient of the solution, ΔP represents the pressure difference on both sides of the waterproof material, and L represents the solution on the waterproof material that occupies the length of the waterproof material [29].

6. Experimental Analysis

In order to be able to deal with the foundation reinforcement treatment of the large railway logistics center yard, we select a certain area as a test base for comparison of foundation reinforcement methods. The foundation reinforcement methods suitable for a certain area are compared in terms of applicable conditions, reinforcement bearing capacity, maximum reinforcement depth, reinforcement construction period, and cost, so as to obtain large-area foundation treatment effective experience.

This foundation pit protection system adopts fully enclosed deep-house stirring piles as the water-proof scheme of the foundation pit, which extends into the relative waterproof layer of the soil layer. Except for the section (excavation location) which is supported by soil nails, the section uniformly uses cast-in-place piles and prestressed anchor cables to form a foundation pit support system. The reinforcement layout of the supporting plane soil is shown in Figure 3.

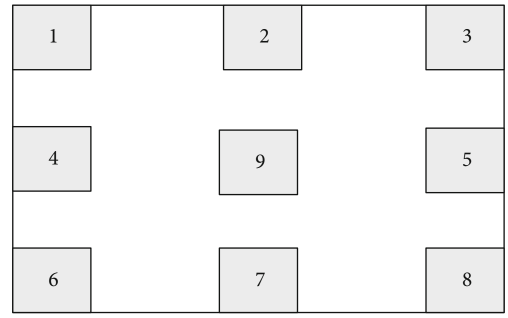

Figure 3: Reinforcement layout of supporting plane soil.

Table 1: Filling amount of ram pit at the first ramming point.

Tamping point number	Filling amount of ramming pit (m^3) The proposed method	Literature [12] method	Literature [14] method
1	10.89	12.63	13.54
2	10.56	12.96	13.98
3	10.58	12.65	13.45
4	10.34	12.87	13.67
5	9.98	12.54	13.58
6	9.56	12.67	13.69
7	10.24	12.58	13.57
8	10.32	11.63	13.56
9	10.69	11.97	13.94

6.1. Comparison of Ramming Pit Filler. In order to determine the effective replacement depth of the deformation control method and the dynamic consolidation effect of the soil between piles, the test area is specially arranged in the early stage of the project. Tamping pit filling amount statistics the first ramming point, the second ramming point tamping pit filling amount construction statistics as shown in Tables 1 and 2.

As shown in Tables 1 and 2, the proposed method uses the least amount of ramming pit filler under the same conditions, which can minimize the cost and has high practical applicability.

6.2. Analysis of Surface Settlement. The surface deformation rate decreases with the increase of time. During the excavation of the foundation pit, the settlement speed is greater; the ground settlement continues to increase during the dismantling process; the surface deformation rate is slow during the construction of the internal structure; and with the internal structure strength gradually increasing, the settlement decreases slightly, the surface deformation tends to be stable, and the deformation is mainly caused by the creep of the

Table 2: Filling amount of ramming pit at the second ramming point.

Tamping point number	Filling amount of ramming pit (m^3) The proposed method	Literature [12] method	Literature [14] method
1	8.65	10.21	11.31
2	8.34	10.56	11.54
3	8.69	10.45	11.47
4	8.57	10.57	11.59
5	7.56	10.57	11.54
6	7.58	10.58	11.67
7	7.34	10.34	11.57
8	8.12	10.24	11.52
9	8.01	10.54	11.57

Table 3: Statistics of surface settlement of the proposed reinforcement methods.

Tamping point number	Standard settlement (mm)	Depth of surface settlement (mm) 24 hours later	48 hours later
Northeast corner	30	10.34	5.34
Northwest corner	30	10.36	5.28
Southeast corner	30	10.87	5.12
Southwest corner	30	10.98	5.98
East	30	12.54	5.64
West	30	10.35	5.37
South	30	10.46	5.84
North	30	10.34	5.64
Intermediate	30	10.54	5.12

soil. Statistics on the settlement of the proposed method is shown in Table 3.

As shown in Table 3, in different areas of the deep foundation pit pile foundation, the settlement of the proposed reinforcement method is within the standard settlement range, which meets the actual demand. The surface settlement gradually shrinks with the development of time, and the settlement gradually stabilizes during the excavation of the foundation pit.

6.3. Analysis of Pile Top Lateral Displacement. The horizontal displacement of the pile top of the cross-section develops with time. Like ground settlement, the horizontal displacement of the pile top decreases with the development of time. The amount of lateral displacement of the pile top is shown in Figure 4.

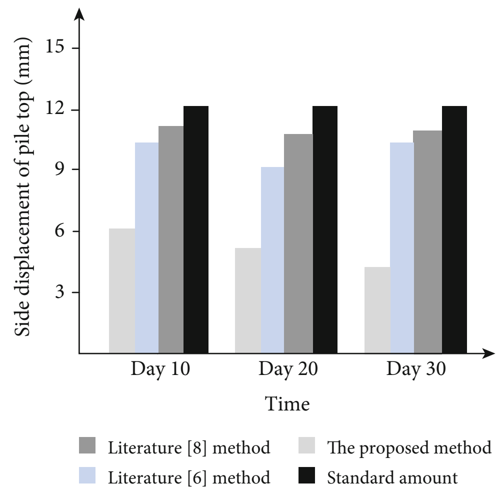

Figure 4: Offset of pile top.

As shown in Figure 4, within one month, the pile top offset of the proposed reinforcement method is within the standard range, the maximum is only 6 mm, and the pile top offset shrinks with the increase of time. During and after the construction, the ground pile top offset is controlled within the allowable range, the pile foundation settlement is well controlled, the deformation control effect is good, and the reinforcement effect is stable. The pile top offset of the other two methods far exceeds that of the design method in this paper, with the maximum of 10 and 11 mm, and does not show the trend of shrinkage. Therefore, it can be seen that the design method in this paper has good effect and certain application value.

7. Conclusion

The railway logistics center stack yard foundation reinforcement project is an important part of the construction project. When the railway logistics center stack yard foundation reinforcement plan, if it can comprehensively and accurately predict the deformation of the enclosure structure caused by the deep foundation pit excavation and the impact on the surrounding environment, and then adopting economical and reasonable support plans and construction measures can effectively reduce deep foundation pit accidents or avoid waste of resources. Therefore, in this paper, a method based on deformation control and thermodynamics is proposed to reinforce the pile field of the railway logistics center. Through the analysis of the engineering geology and hydrogeological conditions of the site, the deformation of the station is calculated, and the bearing capacity of the surrounding environment of the foundation pit for additional deformation is analyzed. The mechanism of the reinforcement of the railway logistics center yard foundation has realized the reinforcement of the yard foundation. The experimental results show that this method can use the least tamping pit filler, at least 7.34 m^3, to realize foundation reinforcement under the same conditions; the maximum ground settlement is only 5.98 mm; and the maximum lateral displacement of the pile top is only 6 mm, which can improve the stability of the basic structure and maximize the project quality on the premise of ensuring the stability of the foundation construction, and has a certain application prospect. However, because more pile foundation differences of the railway logistics center are not considered in the design process of this paper, the reinforcement effect may be affected. Therefore, this will be used as the starting point for in-depth research in the next research, so as to better improve the stability of pile foundation.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

It is declared by the authors that this article is free of conflict of interest.

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