Study on the Impact of Foundation Pit Precipitation on Neighboring CFG Pile Composite Foundation

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ABSTRACT: The numerical simulation was used to examine the impacts of pit precipitation and the presence or absence of waterproof curtain on the CFG pile composite foundation near to the under-construction pit, and the following primary results were reached. For starters, the precipitation will force the CFG pile composite foundation to slope towards the entire under-construction pit. Second, the waterproof curtain can help to mitigate the negative impact of pit precipitation on the nearby CFG pile composite foundation.

1. INSTRUCTION

1.1. CFG pile composite foundation

When the natural foundation does not meet the bearing requirements of the higher structure, a reinforcement can be installed in the natural foundation to produce a composite foundation, such as a CFG pile composite foundation, to increase its bearing capacity. Between flexible and rigid piles is a third type of high-strength pile known as CFG pile. It is made up of CFG piles and the soil in between the piles, and these two elements work together to form a reinforcement zone. The bearing force of its foundation is passed from the mattress layer to the CFG pile, and the mattress layer is able to adjust the stress distribution between the pile and soil in order to create an effective bearing effect [1][3][8-10]. The decrease in groundwater level will undoubtedly lead the soil to become more compact and settle, which could possibly damage the structures that are already there as well as the subterranean pipelines [2][4-6]. Therefore, this paper is based on the numerical simulation method to analyze the influence of pit precipitation on the adjacent CFG pile composite foundation in the context of a project.

1.2. Project overview

The excavation plane size of a foundation pit is about 470m×350m, the excavation depth is about 13m, the static water table burial depth is about 3m, the average permeability coefficient is 2.32×10^{-5}m/d, the relative impermeable layer is located 30m below the surface, and the groundwater level is required to be controlled at 2m below the pit bottom. Due to the problem of construction progress, the east side of the pit already existed in the plane size of about 16m×21m CFG composite foundation surrounded before the precipitation excavation. Moreover, the nearest distance of the composite foundation from the pit is only about 5m, and the precipitation and excavation of the pit to be excavated will inevitably have certain influence on the foundation. The diameter of the CFG pile is 400mm, the effective pile length is 14m, and the spacing is 1.6m. The research objects are pits without waterproof curtain and pits with waterproof curtain which is 24m deep and 1m thick. Under the premise of ensuring the effect of precipitation, the various effects of precipitation on the neighboring CFG composite foundation are evaluated.

2. CFG PILE COMPOSITE FOUNDATION FORCE CHARACTERISTICS

The most important characteristic of a CFG pile composite foundation is the presence of a zone of negative friction resistance during the initial loading phase. Due to the role of the mattress layer, under the action of the upper load, the top of the pile can be pierced into the mattress layer, causing the settlement of the soil within a certain range of the pile perimeter to be greater than the settlement of the pile, thereby creating negative friction resistance on the pile side. Simultaneously, the pile end will penetrate downward into the lower lying soil layer, meaning that the soil settlement will be less than the pile settlement, resulting in a positive frictional resistance on the pile side. When there is no difference in the amount of soil that has settled between the pile and the pile, the pile's side frictional resistance is equal to zero. As can be seen in Figures 1 and 2, this location represents the neutral point of the pile, which also happens to be the place where the force on the pile shaft is at its greatest. Because the elastic model of the pile is significantly larger than the elastic modulus of the soil, the pile settlement will increase proportionally whenever the groundwater level declines. This is due to the fact that the settlement consolidation of the soil causes the pile settlement to increase. As a result,

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the upper weight will be shifted partially or possibly completely to the pile body [7], which will accelerate the sinking of the pile.

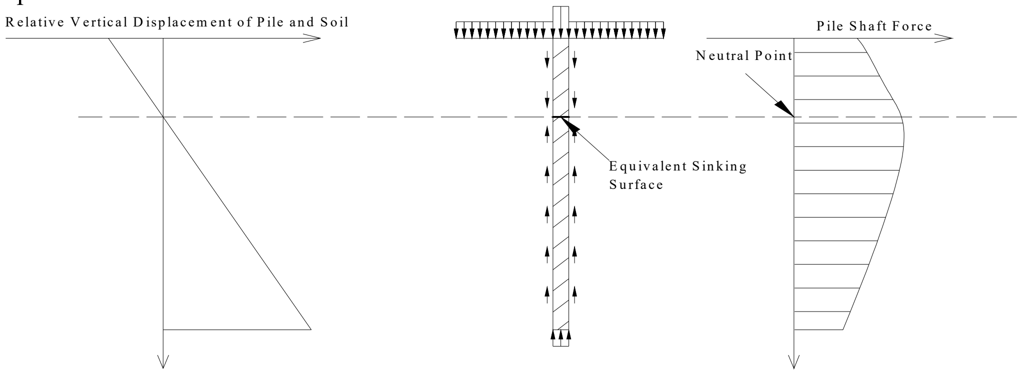


Figure 1. Relative vertical displacement of Pile and soil Figure 2. Pile shaft force

3. LNUMERICAL SIMULATION ANALYSIS

3.1. Model building

Since it is necessary for the simulation process to take into account the pile-soil contact, if the calculation is performed in accordance with the actual project, the number of piles is excessive, which will cause the calculation to take a long time, and the results will be difficult to converge on. As a result, when constructing the 3D model, just one row of piles that runs perpendicular to the direction in which the pit extends is taken into account, provided that the boundary conditions are accurate representations of the real-world circumstance. In addition, under the condition of constraint to calculate the displacement in each direction of the model, it is known through numerical simulation that the influence distance of precipitation outside the pit without waterproof curtain is 300 meters, after ensuring that the water level is lowered to 2 meters below the bottom of the pit, whereas the influence distance of precipitation outside the pit with a 24 meter deep curtain is 158 meters. Furthermore, the water level at the curtain position is 8.58 meters below the surface of the land at the present time. Therefore, the final model solution was taken in X-axis to the farthest non-influential boundary, i.e. 300m outside the pit and 30m inside the pit, and only one pile spacing width was taken in Y-axis direction. 30 m was taken in Z-direction. model plan, i.e. section, is shown in Figures 3 and 4. The calculation parameters of soil, waterproof curtain, CFG pile and mattress bedding in the calculation model are shown in Table 1.

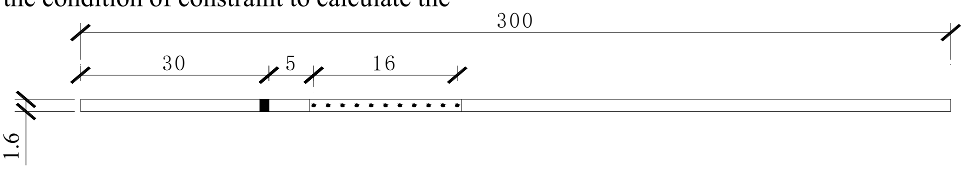


Figure 3. Plan figure

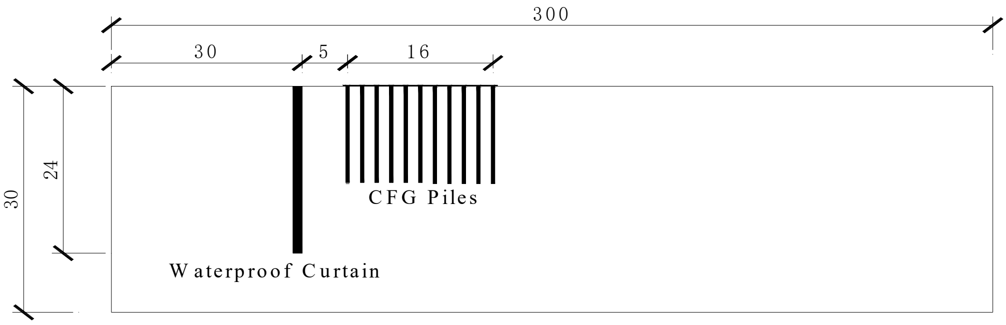


Figure 4. Cross-sectional figure

Table1. Calculated parameters for each component of the model

Name	Ontological model	Dry Density (kg/m^3)	Modulus of deformation (MPa)	Poisson's ratio	Cohesion (KPa)	Angle of internal friction (°)	Permeability coefficient (m/s)
Soil	Moore Cullen	1700	86	0.28	19.9	35	1.3×10-4
Waterproof Curtain	Moore Cullen	2000	300	0.28	35	18	1×10-9

Matting layer	Moore-Cullen	2000	120	0.2	1	35	-
CFG Pile	Line Elasticity	2000	1×104	0.2	-	-	-

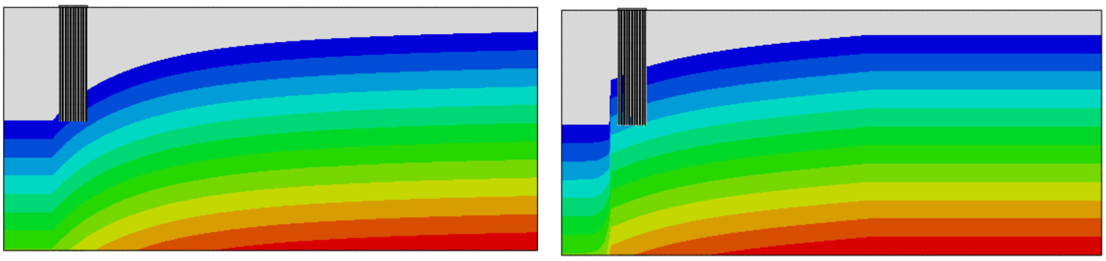
3.2. Simulation process

The following steps make up the calculating procedure for the model: First, a gravity load of 10×10^{-3}kN/Kg is applied. Second, the first seepage field is created, and then the entire model is calculated while the water level is three meters below the initial surface. In the third step of the process, the CFG pile composite foundation will have a uniform top load of 200 kPa applied to it in order to perform consolidation settlement analysis, also known as pre-precipitation calculations. In the fourth step, each fixed head boundary should be activated, and a consolidation settlement analysis should be performed, also known as a post-precipitation calculation.

3.3. Analysis of simulation results

3.3.1. Groundwater Level Curve

Figure 5 depicts the groundwater level clouds before and after the application of waterproof curtain following the accumulation of precipitation. According to the findings of the extracted calculation for the water table depth, it is possible to deduce that there is a difference of approximately 1.88 meters in the water table depth on both sides of the composite foundation that does not have a curtain. The composite foundation with curtain creates a variation in water table depth of approximately 1.17 meters on both sides of the foundation. It suggests that the alteration in the groundwater around the foundation pit brought on by the usage of an open style of precipitation is more noticeable.



(a)With waterproof curtain (b)Without waterproof curtain

Figure 5. Groundwater level after Precipitation

3.3.2. Foundation deformation analysis

Figure 6 depicts the changes that occurred on the ground surface outside the hole as a result of the settlement. Prior to the onset of precipitation, the settlement pattern outside the pit with and without the curtain was almost identical. The maximum settlement position was located at the center of the composite foundation position, and the settlement influence range was approximately twice as long as the CFG pile length. When there isn't a curtain across the drain, the amount of precipitation that causes the water level to decrease is more than when there is. As a result, the total surface settlement with no curtain is significantly higher than the surface settlement with curtain. Even though the highest settlement in both scenarios is still centered on the middle of the composite foundation, the settlement impact range is expanded to include the same area as the precipitation influence range.

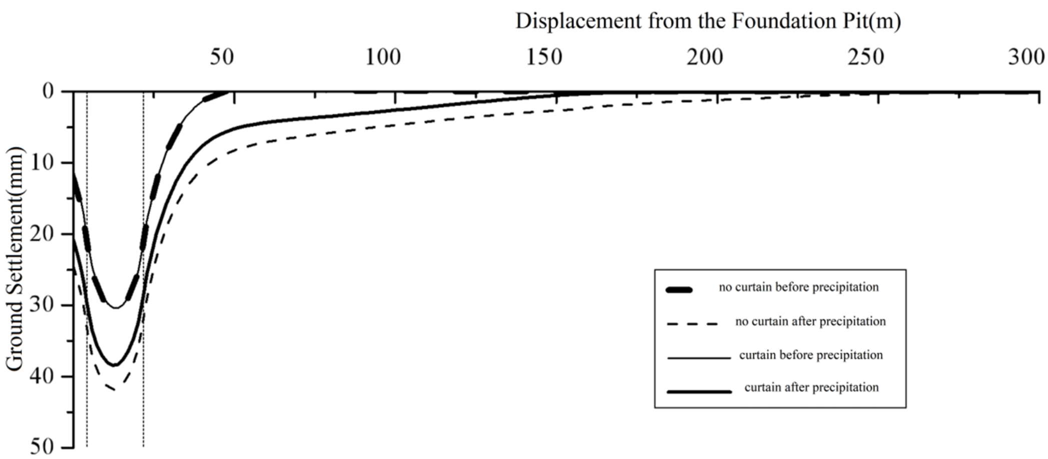
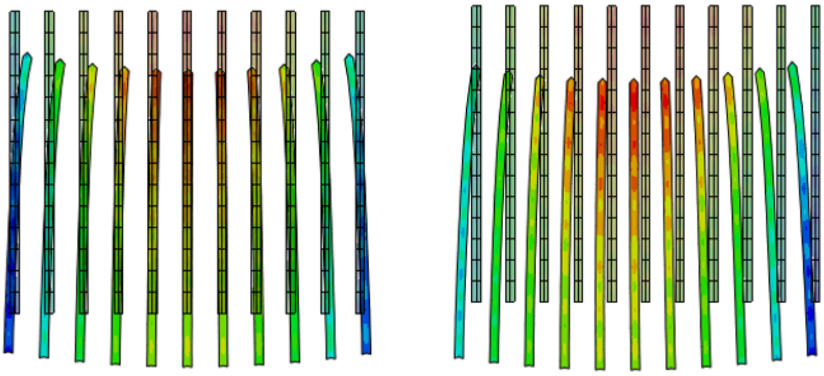


Figure 6. Ground settlement curve outside the pit

3.3.3. CFG group pile deformation analysis



(a)Before precipitation (b)After precipitation

Figure 7. CFG group pile before and after deformation comparison

When the deformation results of all CFG piles are extracted, it is clear that the deformation rule for group piles with and without a curtain is very similar. As a result, the influence that precipitation has on the shape change that occurs in group piles that do not contain a curtain is investigated, as can be seen in Figure 7. The top of the group pile was skewed toward the center of the composite foundation before to the onset of precipitation; but, following the onset of precipitation, the group pile was inclined toward the pit as a whole.

3.3.4. CFG monopile force analysis

According to the findings of the extraction, it was discovered that there is some continuity in the progression of the change in the internal force exerted by each individual pile as it moves further away from the foundation pit. For the purpose of conducting a force analysis both prior to and following the onset of precipitation, three representative piles were removed from the pit. These piles were located as follows: the nearest side pile, also known as the nearest pile; the middle pile; and the farthest side pile, also known as the farthest pile.

Figure 8 depicts the distribution of axial force across each pile both prior to and following the precipitation that occurred without waterproof curtain. It can be observed from the axial force diagram that after precipitation, the axial force of each pile at each position of the pile body increased. This suggests that the pile-soil stress sharing ratio increased as a result of the influence of precipitation. Comparing the maximum values of the axial force of each single pile shows that: the middle pile > the nearest pile ≈ the farthest pile before the precipitation. After precipitation, the nearest pile > middle pile > farthest pile. The largest increase was in the nearest pile. Before precipitation, the neutral point of the group piles was located approximately 0.2 times of the pile length below the surface, and after precipitation, it was located approximately 0.5 times of the pile position and was located in the middle of the pile.

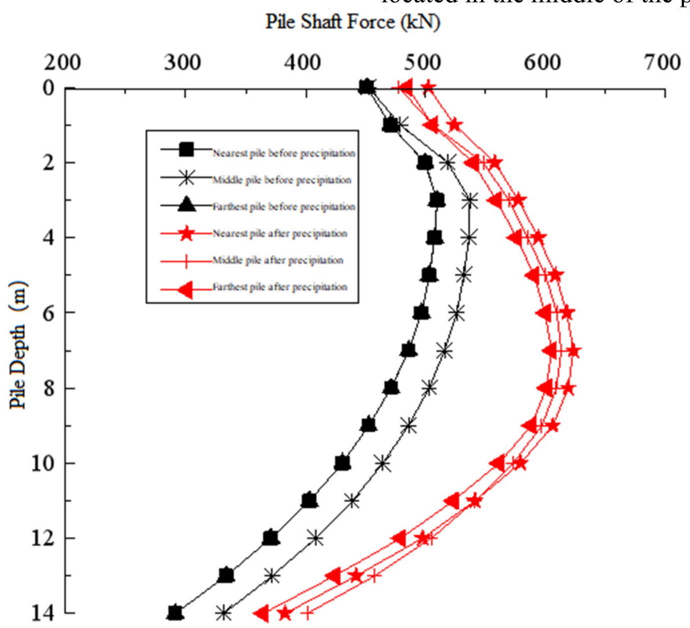


Figure 8. Pile shaft force without waterproof curtain

Figure 9 depicts the distribution of the pile axial force for each single pile both before and after precipitation with waterproof curtain. Comparing Figure 8, it can be seen that the variation pattern of axial force is basically the same as that of the curtain-free condition. When we compare the maximum axial force values of each individual pile, we can observe that, prior to precipitation, the middle pile > the farthest pile > the nearest pile. Following precipitation, the nearest pile > middle pile > farthest pile. The nearest pile still has the greatest growth, and its axial force is somewhat more than that of the furthest pile before precipitation. Check the Water Curtain has a high strength, therefore it is resistant to the deformation of its surrounding soil layer. It will, as a result, improve the bearing capacity of the soil in a particular radius around it. Because the nearest pile is close to Check the Water Curtain, its surrounding soil has a somewhat higher bearing capability than the furthest pile. As a result, the load shared by the nearest pile will be somewhat less than the weight shared by the farthest pile. Furthermore, following precipitation, the location of the cluster pile neutral point decreases to 0.43 times the location of the pile length.

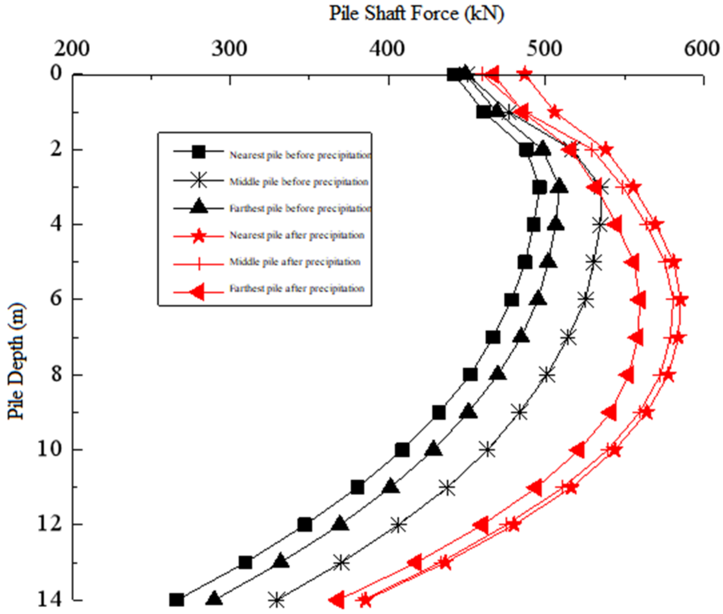


Figure 9. Pile shaft force with waterproof curtain

4. CONCLUSION

(1) When the waterproof is set, the change in groundwater level and surface settlement induced by the open pit precipitation technique surrounding the pit is more visible. As a result, it will have a greater negative influence on the structures around the foundation pit.

(2) The deformation and force law of CFG group piles in composite foundation with and without waterproof curtain are, for the most part, the same thing. After precipitation, the tops of the group piles as a whole leaned in the direction of the pit, which was not the case before the precipitation. Prior to the precipitation, the tops of the group piles were relatively near to the center of the composite foundation. Because of the precipitation that occurred in the foundation pit, the pile axial force of each pile rose to some degree; however, the pile that had the greatest increase in force was the pile that was located in the most immediate proximity to the foundation pit. Additionally, the increase in the axial force of the pile both before and after the precipitation is greater when the curtain is there than when it is not. This is the case regardless of whether or not the curtain is present. As a result, activating waterproof curtain has the potential to effectively lower the pile-soil stress sharing ratio of CFG pile composite foundation.

(3) When there is no waterproof, and the neutral point of the pile is lower than when there is a curtain, setting Check the Water Curtain can reduce the negative frictional resistance zone of the pile and reduce the adverse effect of the pit precipitation on the force condition of the adjacent CFG composite foundation.

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