Application Of Fender Piles In The CFG Pile Composite Foundation In Strongly Weathered Soft Rock

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***Abstract*- Analysis of the performance of CFG pile composite foundation found that a plastic deformation zone surrounding the CFG pile composite foundation with an area of about one time piles' distance was formed, and it is the main cause of instability of the whole composite foundation. Comparative analysis of characteristics as stress change, foundation settlement of the composite foundation before and after adding a row of fender piles in the plastic deformation zone, found that foundation performance got obvious change after pile enforcement. In the same conditions, the foundation settlement reduced significantly and the stability improved obviously.**

Keywords- CFG Pile Composite Foundation, Fender Pile, Strongly Weathered Soft Rock, Foundation Settlement, Foundation Stability

I. THE CONCEPTS OF FENDER PILE

Fender pile refers to the piles located outside a foundation and its sphere of influence area with the function of reducing foundation settlement and improving the stability of the foundation. Simulation analysis of the CFG (Cement Fly - ash Gravel) pile composite foundation found that a plastic deformation zone was formed outside pile lateral about one times pile distance area of the CFG pile composite foundation, and it is the main cause of the instability of the whole composite foundation [1]. So, setting fender pile in the CFG pile composite foundation laterally to prevent this kind of plastic deformation zone can increase the CFG pile composite foundation stability and reduce ground settlement.

"Technical code for ground treatment of building"（JGJ79-2002）clearly requires that gravel pile processing range should be greater than basal range, processing width should be expanded 1 ~ 3 row pile outer than the base. For cement-flyash-gravel (CFG) piles, whether they should be in the basic lateral arrangement, there is no specific provision, nor theoretical related research [2]. As a case study, this paper researches the characteristics of the CFG composite foundation after adding the fender pile outside the foundation lateral.

II. INFLUENCES OF FENDER PILE ON THE CHARACTER OF CFG PILE COMPOSITE FOUNDATION

A. Model Establishing

A study on a CFG pile showed that [3], the shear zone of CFG pile foundation occurred mainly in the lateral of side piles of about 2m. For ease of study, two piles were added outside the raft and contrasting analysis simulation was conducted. According to the actual situation of the project, the length of fender piles is set to 12 meters. Respectively, spacing of the raft side pile is 1m and 2m, as shown in the Figure1.

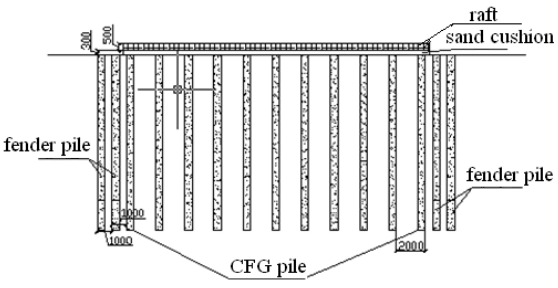

Fig.1 Sketch of fender-pile

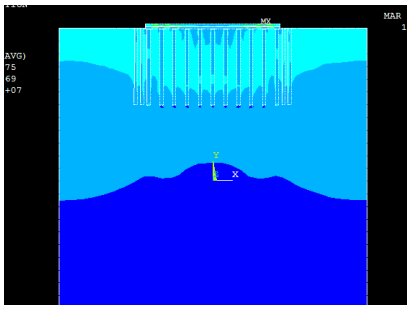

Fig.2 The first main stress

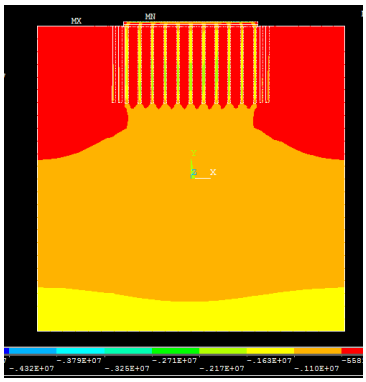

Fig.3 Third principal stress

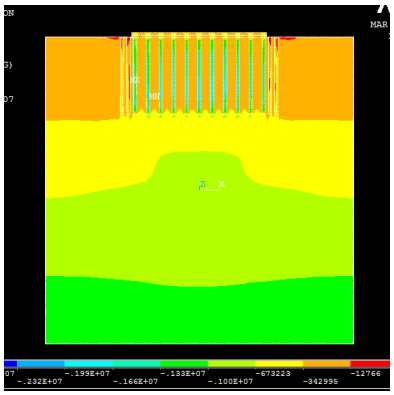

Fig.4 The principal stress of Y direction

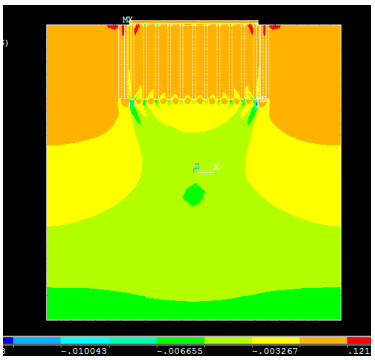

Fig.5 Principal strain of Y direction

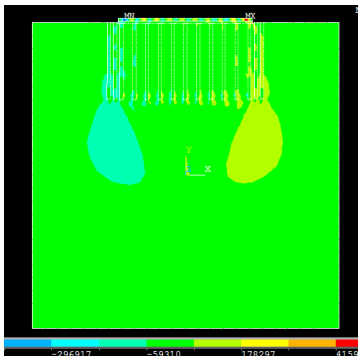

Fig.6 Shearing stress of XY direction

B. Influence of Fender Pile on Stress of CFG Pile Composite Foundation

According to finite element simulation based on the model established above, the result is presented in Figs. 2-6. As the Figs. 2-6 show, after fender pile enforcement, the stress of CFG pile composite foundation has following changes: the maximum value of the first principal stress is -834.469kPa, 34.93 kPa less than that without fender pile. Upward normal stress in the cushion between CFG pile and the raft plate appears, and its value is 269kPa. The maximum stress is in the end of pile. The maximum value of the third principal stress is -236kPa. The third principal stress of piles gradually decreases from the top of the pile to pile bottom. At the base of pile, the third principal stress value is up to -836.883kPa, and the third principal stress of the soil between piles is more than that in the pile body. After adding of fender pile, XY direction shear stress main distribution in the fender pile lateral, and pile body shear stress value become smaller. It is shown that after adding of the fender piles, the foundation reinforcement area outside the soil mass strength is largely improved, and the edge pile in CFG pile-raft composite foundation has better side constraint role, improving edge pile and the soil around the pile of common role [4]. Soil between group piles will produce larger normal stress under the action of vertical load because of the blocking effect of pile. But the normal stress for the center piles, side piles and corner piles of soil around pile are not the same because of different constraint effect of piles. Due to constraint of edge pile and corner pile, stress can easily pass on the soil around pile. As for the pile top stress, before adding fender pile, the load can be easily transferred in the soil around the piles because constraint of the side piles and corner piles is relatively smaller. And the stress is easy to diffuse. The pile top stress for the edge pile, and corner pile is smaller than the center pile tops, thus the side pile has good protecting effect.

Comparative analysis of the stresses before and after adding fender pile found that, the shear stress of the CFG pile's body under the raft has correspondingly decreased, and around the CFG pile does not appear obvious shear zone and the stability of the whole foundation is improved after the fender pile is added outside the CFG pile-raft composite foundation.

C. Influence of Fender Pile on Displacement of CFG Pile Composite Foundation

Based on the model established above, finite element simulation is conducted and the result is presented in Figs7-8. Figures 7-8 show that the maximum displacement in X direction is 9.72 mm, 0.92 mm more than that without fender pile. The maximum displacement in X direction is 5.48 mm in the unreinforced area on both sides of the raft, 3.32 mm less than that without fender pile. The total vertical displacement occurs mainly in the foundation and its bottom, and its area decreases significantly. The displacement in Y direction in the reinforcement area is 65.20mm, 9.11mm less than that without fender pile. Settlement in both sides of the raft reinforcement area is 25.97mm less than that without fender pile. Plastic deformation in Y direction mainly occurred in the substratum under the pile tip, which was 1.98 mm less than that without fender pile. There was no obvious plastic strain in the reinforcement area. And no connected plastic deformation zone appeared outside pile lateral. Therefore, the entire foundation's ability to withstand overall shear failure is increased.

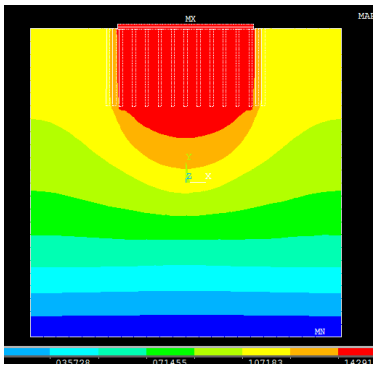

Fig.7 The total displacement

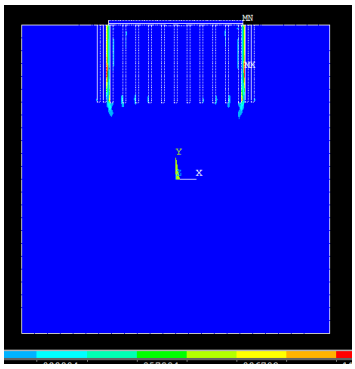

Fig.8 The total strain

Analysis of displacement in x and y direction finds that, it not only effectively reduces buildings settlement, but also better controls the un-uniform settlement of the foundation and the soil mass settlement around the foundation after adding fender pile at the outer side of CFG pile-raft composite foundation. Setting fender pile at the outer side of CFG pile-raft composite foundation can reduces plastic deformation of foundation, and can makes it difficult to appear the plastic deformation zone at the unreinforced area both sides of the foundation, thus improving the stability of foundation.

III. FENDER PILE INFLUENCE OF CFG PILE COMPOSITE FOUNDATION SETTLEMENT

A. The fender Pile Distance Effects on Bearing Behavior of CFG Composite Foundation

Impact of the distance change between fender pile and side pile on CFG composite foundation settlement was obtained by comparing different pile distances(2d, 3d, 4d, 5d, 6d, 7d, 8d, where d is the diameter of CFG piles), the result is shown as Fig 9.

The fender pile, setting outside the raft with a distance of less than 3m, has a certain impact on the settlement of composite foundation. But its influence is limited, showing a negative correlation. Fender piles with pile distance greater than 3m almost have no effect on the foundation settlement. Overall, adding a row of fender pile outside the foundation lateral has little impact on the settlement of the foundation. When the pile distance between the fender pile and side pile is 6 times greater than pile diameter, the fender pile has no effects on the bearing behavior of composite foundation. The main reason is that the bearing capacity of composite foundation relies on pile-soil interaction of the natural foundation. According to the design principle of CFG pile, single pile's sphere of influence is limited. The replacement rate of this composite foundation model is 0.05, and pile distance is 2m, thus its sphere of influence is considered to be 2m.

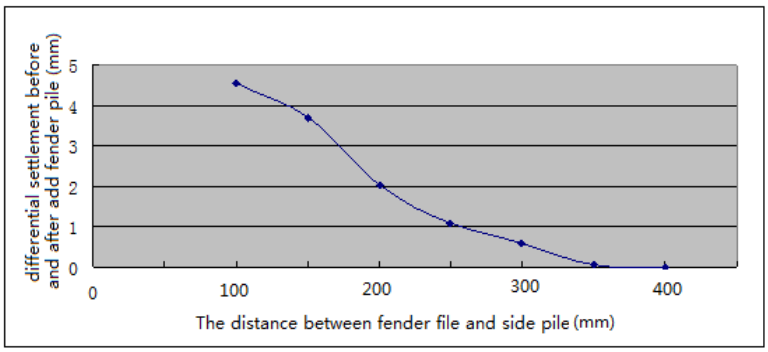

Fig.9 Differential settlement values of the reinforcement area under the raft before and after add different position fender pile

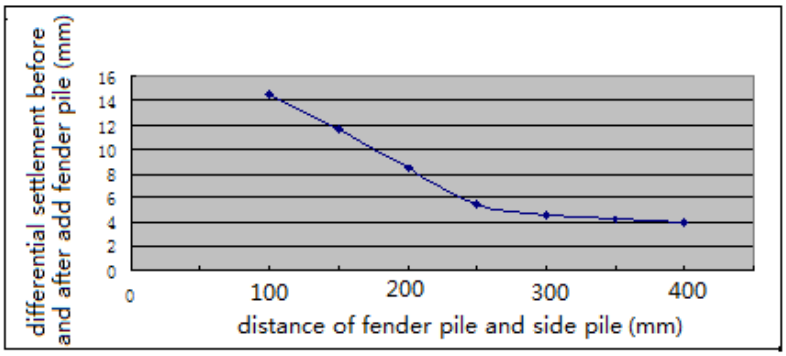

Fig.10 Differential settlement values of the unreinforced area outside the raft before and after add different position fender pile

Analysis of Figure 10 found that, on the whole, setting the fender pile outside the raft can reduce settlement of the unreinforced area on both sides of raft. As the distance between fender pile and side pile increases, the differential settlements value of unreinforced region on both sides of the foundation both decreases before and after adding fender pile. When the pile distance is greater than 3m(6d), the fender pile has very little impact on the settlement of un-reinforced area.

Combining these simulation results, the distance between fender pile and side pile distance should not be more than 6d when adding fender pile on both sides of the foundation. When the distance between fender pile and side pile is very large, the pile cannot play their effectiveness, and large range of foundation pit excavation increases cost of the whole project.

B. Influence of Fender pile rows on the bearing behavior of CFG composite Foundation

By respectively adding on both sides of raft one to six rows of fender pile (the distances between fender pile and fender pile, and that between fender pile and side pile are1m), the simulation result is showed as Figure 11.

Fig.11 shows that the settlement of composite foundation decreases as the number of fender pile increase. When the rows number of fender piles is 1 to 3, the reinforcement regional settlement of the composite foundation has large reduction and good effect. When the fender pile rows are more than 3, they have little influence on the settlement of reinforcing region, and less effect.

Figure 11 also shows that, the more fender piles on both sides of the foundation, the smaller influence they have on the foundation settlement of surrounding buildings. When the number of fender piles increases to a certain value, the settlement reduction tendency slows down. Therefore, the fender piles in both sides of foundation can effectively control the foundation settlement around caused by building.

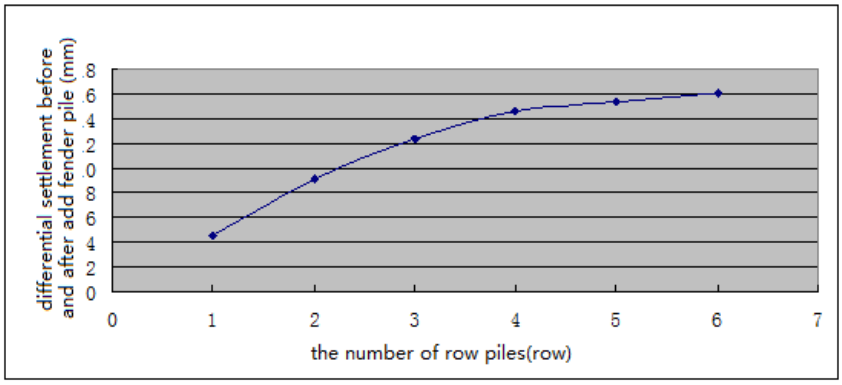

Fig.11 Differential settlement values of the raft before and after add one to many row fender piles.

IV. SUMMARY

The above research reaches the following conclusions. Fender pile can not only effectively prevent formation of plastic deformation zone on both sides of edge pile and improvement of the overall stability of CFG pile composite foundation, but also effectively reduce CFG pile composite foundation settlement. Particularly, it has obvious controlling effect on foundation settlement around the buildings. In addition, fender pile changes stress distribution in reinforced and non-reinforced area, and the foundation settlement in reinforced and non-reinforced area. It also adjusts the pressure distribution on the raft and the uneven settlement of the foundation.

It should be noted that the distance between fender pile and side pile should not be too large. When the distance between fender pile and side pile is over 6D, it has little effect. 2~3 rows of fender piles on both sides of foundation are generally believed to be the best in controlling settlement effectively. When fender pile rows number continues to increase, its effect becomes less obvious. Reasonable length of fender pile can not only controls the foundation settlement, but also reduces the cost of the project greatly.

ACKNOWLEDGMENT

The paper is provided by National Natural Science Foundation of China (project No.: 51368015).

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