“Effectiveness Of Cfg Pile-Slab Shape On Smooth Soil For Supporting Excessive-Pace Railway Embankment”

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Abstract-Reducing the settlements of smooth foundation efficiently is a crucial problem of excessive-pace railway creation in China. The new CFG pile-slab structure composite foundation is a floor remedy method that is carried out on CFG pile basis and pile-slab structure composite basis. Based on the revel in of constructing Beijing-Shanghai excessive-pace railway in China, the settlement-controlling effect, the settlement distribution legal guidelines and 3 key influence elements for structural shape of latest CFG pile-slab structural foundation are studied by the use of physical model exams and numerical simulations. The research results on this look at imply that the piles and soil bearing capacities of the new CFG pile-slab shape can be positioned into complete play due to the “load dispensing” function of slabs. The settlement decreasing effect of the new CFG pile-slab shape is first rate and can meet the requirements of high-pace railway creation. The affected location of engineering load has a depth over 18. Seventy five m and horizontal period of 7. Five m nearing the embankment slope toe. The parametric observe presents the optimizing structural form for high-quality agreement-controlling effect. The bodily version test results display precise concordance with the numerical simulation effects. The mixture of bodily version assessments and numerical simulations justifies the usage of this version in geotechnical engineering practices.

Keywords:- Soft Soils, CFG (Cement Fly Ash Gravel) Pile, Expansive soil; Lateral loading.

1. Introduction

With the speedy growing visitors needs, increasingly more high-pace railways are being constructed in China. The allowable maximum agreement of Chinese high-pace railway is the most crucial key production controlling thing in railway embankment creation.

[1]. When constructing high-speed railway in coastal tender soil foundation, not unusual basis remedy era can't meet the settlement controlling requirement of high-pace railway. Therefore, the floor development techniques together with composite basis are often followed and studied in latest years [2-10]. Jiang et al. [11] provided a numerical analysis to analyze the pile–slab supported embankment, and the end result shows the share of theload carried by the soil is small. Thus, it cainsignificantly reduce the settlement and the stress transfer from the soil to the piles. Messioud et al. [12]presented a comparison between rigid piles and pilefoundations. It has concluded the influence of theматress stiffness, the geometrical configuration, and head/tip fixity conditions on the dynamic response ofthe foundation system. Han and Bhandari [13] studied the stresses and deformations of geogrid-reinforcedembankments over piles. This study found the settlements of geogrid-reinforced embankments overgeosynthetic piles are 20-30% smaller than pile supported embankments. Okyay et al. [4] presented annumerical analysis to analyze the impedance functionsof slab foundations with rigid piles. The study hasformulated the stress change laws for rigid piles. Chenet al. [14] discussed the influences of pilingarrangement of the CFG pile composite foundation. Theresults show that the pile-soil stress ratio and the loadsharingratio can be adjusted through setting up cushionthickness. Shen et al. [9] set up a three-dimensionalsimulation model of CFG pile foundation to investigatethe influence of different cushion thicknesses on thedeformation of CFG pile foundation. Moayed et al. [10]studied the minimum settlement which has testedvarious pile arrangements under different vertical stresslevels. The results show that the arrangements of shortand long piles become more effective when verticalstress on the raft increases.

2. Literature review

A comprehensive search was conducted to review theexisting literature on pile structures and pile-slabstructure-supported embankments. The literature reviewincludes two parts. Detailed discussions on the two partssare presented below.

2.1. Pile structure-supported embankments

In the past few years, pile structure-supported embankments have been increasingly researched and adopted. Fornumerical simulations, Tan et al. (2008) presented a 2-Dnumerical model with pile walls and simulated the dissipation of excess pore water pressure in a stone column reinforced soft foundation under an embankment. Shenand Wang (2016) set up a three-dimensional
simulation model of a CFG pile composite foundation to investigate the influence of different cushion thicknesses on the deformation of the CFG pile composite foundation. Moayed et al. (2013) studied the settlement distributions of a composite piled raft with various pile arrangements under different vertical stress levels. The results of their studies showed that the arrangements of short and long piles become more effective when the vertical stress on the raft is increased. Huang et al. (2005) modelled a real existing reinforced pile-supported embankment in Berlin and compared their results with those of field measurements. The vertical and lateral displacements, the tension along the reinforcement, and the axial forces on the piles were presented. Smith and Filz (2007) illustrated drained axisymmetric numerical analyses using a mesh of linear elastic zones (to represent the reinforcement). Such analyses produce results in good agreement with instrumentation data and analytical solutions. Abusharar et al. (2009) investigated the consolidation behaviour of a road embankment constructed on a multi-column composite foundation using a finite element analysis. It was concluded from their study that a multi-column composite foundation allows for a fast rate of consolidation and significantly increases the embankment stability.

Chen et al. (2008a, 2008b) conducted model tests to investigate the soil arching mechanism in embankments with and without reinforcement. The tests indicated that the stress concentration ratio varied with the pile-soil relative displacement. A higher ratio of embankment height to cap beam clear spacing would result in a higher stress concentration ratio. Hironaka et al. (2008) investigated the soil arching modes in model tests using advanced computed tomography technology. Fagundes et al. (2017) performed a series of twenty-eight centrifuge tests on pile-reinforced embankments to assess the influence of pile spacing, embankment height, pile cap size, and pile stiffness on the load transfer mechanism and surface settlements. Szleno et al. (2000) proposed soil wedge model to simulate soil arching in embankments supported by piles. Jenck (2008) conducted 2-D physical experiments on a small-scale model simulating a granular platform over soft soil improved with vertical stiff piles. The experiments revealed the load transfer mechanisms and clarified the arching in the platform, settlement reduction, and homogenization.

2.2. Pile-slab structure-supported embankments

Pile-slab structures are mainly composed of concrete piles, cushions and a concrete slab. The slab is meant to distribute the relative horizontal loads between the soil and the piles. These structures can significantly reduce the settlements of soft foundations under high-speed railway embankments. Thus, they have been increasingly researched and adopted in recent years. Okyay et al. (2012) presented a numerical analysis to analyse the impedance functions of slab foundations with rigid piles. They founded stress-change laws for rigid piles. Yan Jiang et al. (2014) conducted a parametric study of well-monitored pile-slab-supported embankment for a high-speed railway to investigate the settlement, the load distribution between the soil and the piles, the structural design parameters, and the excess pore pressure. Messioud et al. (2016a, 2016b) presented a comparison between rigid piles and pile foundations.

They concluded that the mattress stiffness, the geometrical configuration, and the head/tip fixity conditions all had an important influence on the dynamic response of the foundation system. Han and Bhandari (2012) used the discrete element method to numerically simulate the stress and deformation of geogrid-reinforced embankments over piles. They found that the settlements of geogrid-reinforced embankments over piles were 20–30% smaller than conventional pile-supported embankments. Messioud et al. (2016a, 2016b) presented a 3D finite element model for the dynamic analysis of a soil–pile slab for identifying the influence of mattress stiffness and the pile–soil contact conditions on the dynamic response of the foundation system. Kim (2009) utilized SLOPILE software to design a piled bridge abutment reinforced by a piled slab at a real site. It was concluded that the piled slab could effectively prevent the lateral flow of the soft ground due to the placement of backfill and could satisfy not only the safety factor of a slope, but also the allowable bearing capacity of the piles. Zheng et al. (2013) established a 3-D FE model for an abutment pile foundation to investigate the behaviour of piled bridge abutments which were caused by the compression and 1460 D. Zhang et al. / Soils and Foundations 58 (2018) 1458–1475 horizontal displacement of the soft substratum due to the embankment load. Zhan et al. (2013) researched the dynamic deformation characteristics of pile-slab structures by carrying out indoor dynamic model tests. They concluded that the piles expanded the depth of the dynamic response of the foundation and improved the stress of the foundation soil.

According to the above reviews, it can be summarized that the studies on pile-slab structure-supported
embankments were mainly focused on the structure patterns, the mechanical characteristics, and the settlement distributions. However, there are no corresponding clear guidelines for pile-slab structures for high-speed railways. Theoretical research is seriously lagging behind engineering practice. The bearing capacities of concrete piles cannot be fully mobilized up to the failure of pile-slab structures. In order to improve pile-slab structures, limited engineering practice and studies have been conducted on CFG pile-slab structure-supported embankments. However, the mechanisms involving soil-pile-slab interactions are not clear for high-speed railways. The settlement-controlling effect, the settlement distribution, and the optimized structural form of CFG pile-slab structures should be investigated thoroughly with respect to their application to high-speed railways.

3. Research object

A map of the Beijing-Shanghai high-speed railway is shown in Fig. 3 (Baike, 2013). The part of this railway from Suzhou to Kunshan was selected for application of the proposed CFG pile-slab structure. This part of the railway was constructed on a large area of soft soil foundation, which has a low bearing capacity and is also prone to large settlements. Fig. 1(a) and (b) show the floor plan view and the cross-sectional view of this area, respectively, for use of the CFG pile-slab structure. The railway embankment is 6.25 m high with 1(V):1.5(H) side slopes. The depth of the investigated area is 25 m and the width is 50 m. The material of the embankment fill is well-graded sandy soil. A reinforced concrete slab, 0.8 m in thickness, is constructed under the embankment fill. Concrete piles are directly connected to the edge of the concrete slab, while CFG piles are covered with a cushion, 0.2 m in thickness. The piles are 15 m in length.

The main mechanism of the CFG pile-slab structure is the transfer of vehicle loads from the slab to the pile through a layer of sand cushion. The piles further help to spread the load to the soil between the piles and the soft foundation. The interaction among the pile groups, the slab, and the soil forms a system, which can help to reduce the settlements of the embankment. The strengthening mechanism of the CFG pile-slab structure-supported embankment can be summarized in the form of pile effects (replacement, compaction, and reinforcement) as well as slab effects (adjusting and homogenizing the upper loads).

With the increase in vehicle loads, more loads get transferred from the soil to the piles. While more loads transfer to the piles, smaller loads will be assigned to the soil. For the friction pile group, the sinking of the bearing slab could cause the soil to sink. This will then bring about the further transfer of loads from the bearing slab to the piles. The pile settlements will increase due to the increased load, which will further cause compressive force between the soil and the piles. Pile penetration, deformation, and compression of the soil between the piles are subjected to this cyclic process.

In real practice, CFG piles are installed at a depth of 15 m (i.e., deeper than soft soil layers). The other soil layers are extended to a depth of nearly 90 m. In the loading system, based on the scaling laws, the size of the simulated structure is 10 times smaller than the real structure. In order to decrease the boundary effect of the
studied area, the size of the area is kept much larger than the loading area. Therefore, the length, width, and height are set at 3.25 m, 1.25 m, and 2.5 m, respectively. These are four times larger than the loading area. The front and back sides of the box are embedded with tempered glass, 12 mm in thickness, and a smooth iron plate, 8 mm in thickness.

This dynamic loading system is composed of a reaction beam, a vertical reaction frame, a hydraulic jack, a force gauge, and a loading plate. The loading system helps to transfer the external loads to the top of the physical model.

The loads on the slab are composed of embankment weight and vehicle forces, which are considered to be uniformly distributed loads. The hydraulic jack exerts the simulated loads on the model through the loading plate. The value of the simulated loads varies between zero and the maximum test load. According to the scaling laws, these simulated loads are about two orders in magnitude smaller than the actual design loads of high-speed railways. Therefore, the loading system can simulate the varying stress exerted due to high-speed trains on the embankment foundation.

It can be observed from that the maximum settlements of the single CFG pile and the concrete pile are 6.2 mm and 5.2 mm, respectively. This corresponds to the case when the external load per unit is 350 kPa. The two types of piles are still in the elastic deformation stage. It can be concluded that the bearing capacities of the single CFG pile and the single reinforced concrete pile are both sufficient to resist the maximum load per unit area by high-speed trains. Under the same external loads, the settlements of CFG piles are larger than those of concrete piles because of the smaller deformation modulus. The bearing capacities of both piles are more than the maximum external pressure exerted by high-speed trains. However, after unloading, the resilience rate of both piles decreases. This is because of the compression of the cushion and the pile-bearing layer under external pressure.

A comparative analysis among the settlement of the natural foundation, the CFG pile composite foundation, and the CFG pile-slab structure-reinforced foundation. It can be observed that the maximum settlement of the natural foundation is much larger than that of either the CFG composite foundation or the CFG pile-slab structure. It can be noticed that when the external load per unit is 300 kPa, the CFG pile-slab structure is able to reduce the settlement of the natural foundation from 93.8 mm to 34.7 mm. Under this load, the settlement of the CFG composite foundation is 52.6 mm and when the stress is smaller than 175 kPa, the settlement of the CFG composite foundation is nearly the same as that of the CFG pile-slab structure. This is because of the distribution effect of the slab that causes the pile-soil stress ratio of the CFG composite foundation to be larger than that of the CFG pile-slab structure. Under this, more external loads are distributed on the piles. It can be concluded that the settlement-controlling effect of the CFG pile-slab structure on a soft soil foundation is remarkable.

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