Model Test On The Settlement Controlling Effect Of New CFG Pile-board Structure Composite Foundation Based On Similar Theory

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Abstract. Based on the similar theory of physical model test, the similarity ratio of physical and mechanical parameters is derived for model test. The similarity ratio were used in model test of new CFG pile-board structure composite foundation to study the settlement controlling effect and settlement distribution character of Beijing-Shanghai high speed railway. The results show that new CFG pile-board structure composite foundation can effectively control the settlement of subgrade.

Introduction

Composite foundation technique has been widely used in civil engineering related fields such as water conservancy engineering, construction, transportation engineering and municipal engineering, especially building highway, railway, large-scale oil tanks and deep excavation in the deep soft soil foundation of coastal regions, the composite foundation technology has got rapid development. The new type of CFG pile-board structure is a special composite foundation technique dealing with soft soil foundation to controlling the settlement of high-speed railway. It is constituted by CFG pile, reinforced concrete pile and reinforced concrete board[1,2]. The edge of each reinforced concrete board is connected and supported by reinforced concrete pile into a line, and the middle of each reinforced concrete board is connected and supported by CFG pile into a square (Fig .1). In this paper, the similarity ratio of new CFG pile-board structure model test are derived according to the similarity ratio, the settlement controlling effect of new CFG pile-board structure composite foundation are studied for engineering reference.
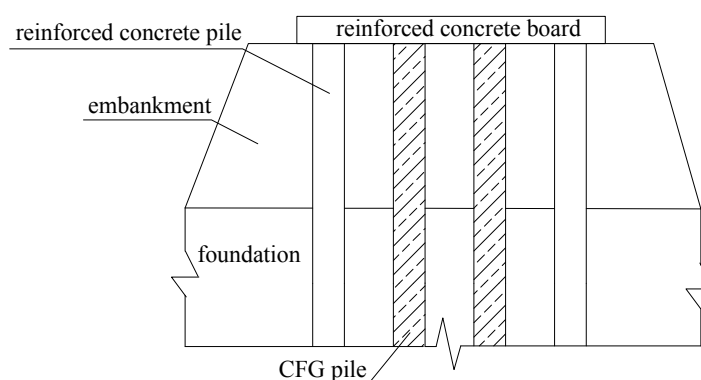

Fig.1 Schematic of CFG pile-board structure

Derivation of similarity ratio

The similar conditions consist of geometric conditions, physical condition, boundary conditions and initial conditions. All the conditions must meet the requirements of model test. The stress of CFG pile-board structure related to the geometry size, material density, elastic modulus, poisson's ratio, line load, surface load, displacement, strain and ultimate bearing capacity, so the structure stress, displacement and other variables can be expressed as the following formula:

$$f(\sigma, F, q, \gamma, l, E, \mu, p, S) = 0 \qquad (1)$$

At the formula, F is surface load, q is line load, γ is material density, L is geometry size, E is elastic modulus, μ is poisson's ratio, p is reinforcement ratio, σ is structure stress and S is displacement.

There are nine irrelevant variables in formula.1, the dimensionless analysis is used to choose two independent variables and get 7 dimensionless variables.

$$\Pi_1 = \frac{p}{F^{a_1} l^{b_1}}, \Pi_2 = \frac{\mu}{F^{a_2} l^{b_2}}, \ \Pi_3 = \frac{E}{F^{a_3} l^{b_3}}, \ \Pi_4 = \frac{\gamma}{F^{a_4} l^{b_4}},$$

$$\Pi_5 = \frac{q}{F^{a_5} l^{b_5}}, \ \Pi_5 = \frac{\sigma}{F^{a_6} l^{b_6}}, \ \Pi_6 = \frac{S}{F^{a_7} l^{b_7}}$$

Firstly , the first dimensionless variables is calculated for p is dimensionless factor.

$$[0] = \left[MLT^{-2} \right]^{a_1} [L]^{b_1}$$

$$\left. \begin{array}{ll} M & a_1 = 0 \\ L & a_1 + b_1 = 0 \\ T & -2a_1 = 0 \end{array} \right\}$$

Solution of formulas:

$$a_1 = 0, \quad b_1 = 0, \quad \Pi_1 = p$$

Other similarity criterion are calculated in the same way.

$$\Pi_2 = \mu, \ \Pi_3 = \frac{El^2}{F}, \ \Pi_4 = \frac{\gamma l^3}{F}, \ \Pi_5 = \frac{ql}{F}, \ \Pi_6 = \frac{\sigma l^2}{F}, \ \Pi_7 = \frac{Sl}{F}$$

Then the formula of all the similarity criterion is concluded.

$$f\left(F, l, p, \mu, \frac{El^2}{F}, \frac{\gamma l^3}{F}, \frac{ql}{F}, \frac{\sigma l^2}{F}, \frac{Sl}{F} \right) = 0$$

According to the " $a_E = a_\sigma = 1$ " , the following conclusions are made in Table.1

Table.1 Similar constant chart of model experiment

Physical quantity	Similar constant	Physical quantity	Similar constant
Geometry size	$a_l = 25$	stress	$a_\sigma = 1$
Material density	$a_\gamma = 1$	Surface load	$a_F = 625$
Elastic modulus	$a_E = 1$	Displacement	$a_s = 25$
Poisson's ratio	$a_\mu = 1$	Strain	$a_\varepsilon = 1$
Reinforcement ratio	$a_p = 1$	Ultimate bearing capacity	$a_R = 625$
Line load	$a_q = 25$	——	——

Model test

Figure 2 are typical survey area of the prototype of CFG pile-board structure model test. The survey area is half width of a typical section. CFG pile, reinforced concrete pile and reinforced concrete board are all on entity modeling, pile end are located in stability soil layer, the breadth of the board are consistent with the simulation subgrade.

According to prototype of CFG pile-board structure model test and similar ratio of the model test(1:25), so the size of model is 1300mm(length) ×500mm(width) ×1000mm (height), pile diameter is 2 cm, the pile length is 30cm and the size reinforced concrete board is 400mm×28mm×500mm.

Side and bottom of the model are constrained by the horizontal and vertical board. The maintenance and production of all the model parts are in standard way. The loading equipment of the

model test is oil jack. Five static load model tests of new type of CFG pile-board structure composite foundation are studied.

Subgrade plane of FEM model   Subgrade elevation of FEM model
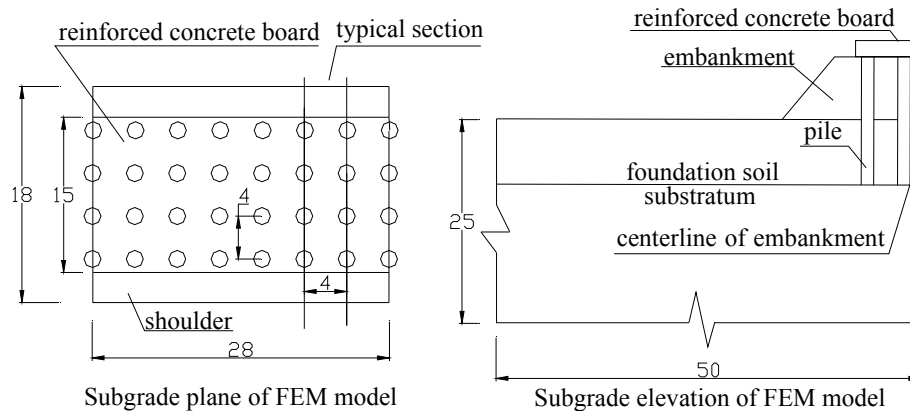
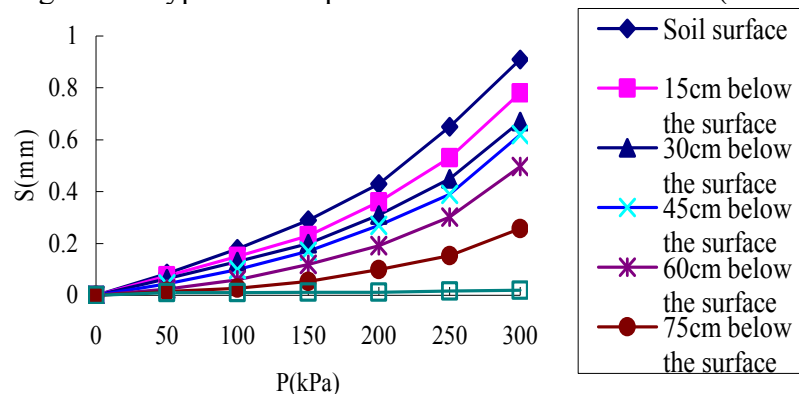Fig.2 Prototype of CFG pile-board structure model test(unit:m)

Fig.3 The p-s curve of pile-board composite foundation

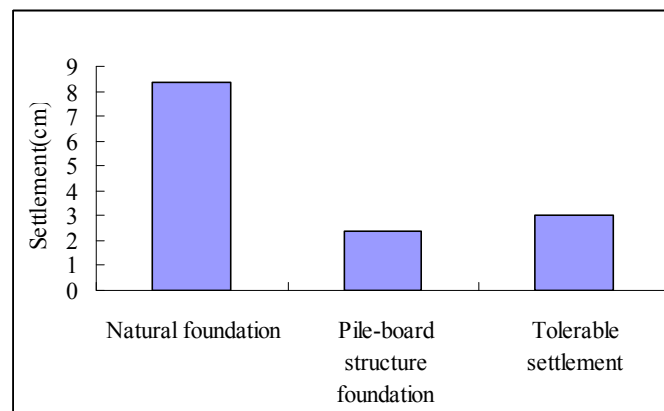Fig.4 The contrast picture of ground subsidence when p=300kPa

Result analysis

The p-s curve of pile-board composite foundation(Fig.3) show that the settlement in different depth of composite foundation increase linearly while the load is under 200kPa, the CFG pile-board structure is in elastic deformation stage. While the load exceed 200kPa, the settlement in different depth of composite foundation increase nonlinearity, the CFG pile-board structure is in a transition stage from elastic to plastic deformation and the critical load of test model is 200kPa.

In the whole test process, the settlement of CFG pile-board structure composite foundation is increasing with the the increasing load. At the beginning of loading, the external load is small , the reinforced effect of CFG pile-board structure in composite foundation isn't obviously, the foundation soil bear most of the external load. With the load increasing, the soil between the pile are compacting, Interaction between pile and soil also gradually strengthening, the CFG pile-board structure gradually

play a important role in reinforcing the foundation, the pile bear more and more external load, the settlement controlling effect are more and more obvious. From the settlement contrast of natural ground subsidence and CFG pile-board structure composite foundation (Fig.4), it shows that the maximum settlement of natural ground is 2.35cm (less than tolerable settlement of high speed railway) when p=300kPa. it concluded that adopting CFG pile-board structure to improve the working characters of soil and reduce embankment settlement has remarkable effect. By way of model based on similar theory, it shows that the new CFG pile-board structure theory can be generalized in engineering practice.

Conclusions

By means of adopting similar theory to build a model of new CFG pile-board structure composite foundation, the settlement controlling effect of the composite foundation is studied. The main conclusions are as follows:

The indoor model test of new type of CFG pile-board structure composite foundation is a effectively technique with advantages of small investment, short period, low cost and simple structure.

This model test based on similarity theory can effectively reflect the real state of experiment prototype, the research results are reliable.

From the research of model test, it concluded that adopting CFG pile-board structure to improve the working characters of soil and reduce embankment settlement has remarkable effect.

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