Static Test and Result Analysis on Different Types of Pile Composite Foundation in the Same Field

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ABSTRACT: Combining with the situation of soil test site, the large scale experiment was studying about natural foundation, rammed soil-cement piles, CFG pile and gravel pil. A series of conclusions were given from p-s curve, the fitting curve, and the Angle of the stress ratio of pile-soil composite modulus. It has certain guiding significance for the design and construction of pile type, which is used in North China area.

Keywords: Compaction soil-cement pile; CFG pile ;Gravel pile ;Pile soil stress ratio ;Composite modulus

1 RESEARCH SITUATION AND PURPOSE

CFG pile is a representative of the rigid pile, which is made of cement, fly ash, gravel, sand stone chips and belongs to high bond strength pile. It is together with soil between the pile and mattress layer to form a composite foundation, and it was used for the tall buildings. Rammed soil-cement pile is a representative of the semi-rigid pile, which is medium bond strength pile. The uniform of cement-soil pile was made by using manual or mechanical pore forming, choosing relatively single soil materials, and mixing in a certain proportion to cement to hold backfill layer and strong ramming. Gravel pile is a representative of the flexible pile, which is a gravel (pebbles) or coarse sand as the main materials such as composite pile foundation reinforcement.

At present, it has been relatively mature on view of the single pile composite foundation theory and the study of the static problem [1-6], many studies about different pile types in the same site with finite element numerical simulation. It was few about large scale experiment. In order to further study the static characteristics of different types of pile composite foundation, combining with the situation of soil test site, the large scale experimental were studied about natural foundation, rammed soil-cement piles, CFG pile and gravel pil. A series of conclusions were given from p-s curve, the fitting curve, and the Angle of the stress ratio of pile-soil composite modulus. It has certain guiding significance for the design and construction of pile type, which is used in North China area.

2 COMPOSITE FOUNDATION BEARING CAPACITY CALCULATION

According to certain principle of superposition, single pile composite foundation bearing capacity includes pile bearing capacity and bearing capacity of soil between piles.

The formula is as follows:

$$f_{spk} = mf_{pk} + \beta(1-m)f_{sk} \tag{1}$$

f_{spk} : Characteristic value of bearing capacity of composite foundation (kPa);

m: Rate of replacement;

f_{pk} : Characteristic value of bearing capacity of pile (kPa)

f_{sk} : After processing of soil between piles bearing capacity characteristic value (kPa);

β: The bearing capacity between soil coefficient. Gravel pile composite foundation: β=1.0; Rammed soil-cement piles composite foundation: β=0.9-1.0; CFG pile composite foundation: β=0.75-0.95.

3 TEST

3.1 *Geology*

According to the geotechnical engineering investigation report, within the scope of the 20m depth reveal formation in addition to the surface of artificial soil, there existed the quaternary alluvial facies sedimentary formation. The soil total of five layers is planting soil, silty clay and fine sand and medium sand from up to down. The test did not involve the groundwater. And regardless of the liquefaction. the site formation distribution and mechanical parameters are shown in Table 1.

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Table 1. The site formation distribution and mechanical parameters

The soil	The thickness	The characteristic value of bearing capacity fak/kPa	The compression modulus Es/MPa	Extreme lateral resistance /kPa	Ultimate end resistance standard/kPa	The characteristics
Miscellaneous fill	0.2m	——	——	——	——	Brown, slightly thick, toughness is low;The surface of the original planting soil;
Silty clay	0.5m	130	6.17	60	——	Tan, plastic ~ RuanSu, tenacity is medium, clamp silt thin layer, mix powder soil mass;
Fine sand	1.5m	140	10	55	800	Gray, Micronesia, quartz feldspathic, sorting, sandy is pure;
Medium sand	8m	200	11.5	82	1500	Gray, Micronesia, sandy pure, sorting, quartz stone long
Silty clay	10m	270	5.84	65	1000	Tan, plastic ~ hard plastic, toughness of medium, including loess-doll and iron manganese rendering.

Table 2. The design parameters of composite foundation the model

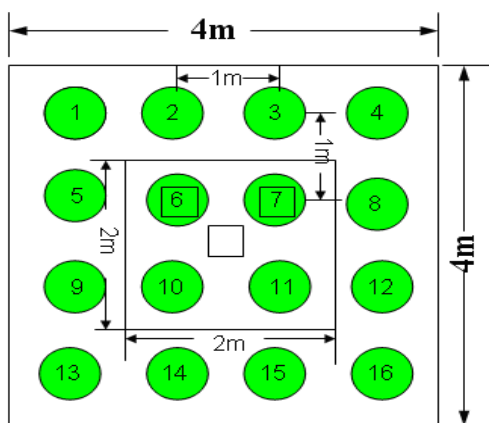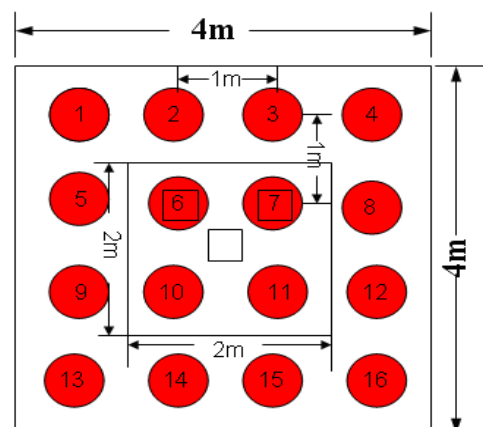| Type of composite foundation	symbol	The length /m	The diameter /mm	The pile spacing /mm	Rate of replacement
Rammed soil-cement pile	CSP	6.0	350	1000	0.096
CFG pile	CFGP	6.0	350	1000	0.096
Gravel pile	GP	6.0	350	1000	0.096

Figure 1. CSP layout

Figure 2. CFG layout

3.2 *Test model*

The experiment selects three typical rammed soil-cement piles, pile type (CSP) and CFG pile (CFGP) and gravel pile composite foundation (GP). The design parameters of composite foundation of the model were shown in Table 2. CFGP adopted C20 concrete. The proportion of cement and soil in CSP was 1:7, and the particle size of gravel for GP was 20 ~ 50 mm.

CSP, CFGP and GP composite foundation layout was shown in Figures 1 to 3. Test pile numbers were 6 #, 7 #, 10 #, and 11 #. The pressure box at the top of the test pile was used to measure the top of the pile stress. The pressure box on the surface of soil between piles was used to measure the top of the soil stress.
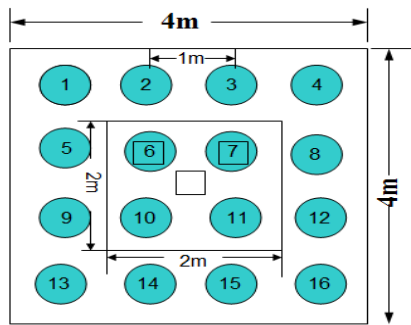

Figure 3. GP layout

4 TEST RESULTS ANALYSIS

4.1 *composite foundation curve of p-s*

The field experiment used three different composite foundations, and each set of test all used the same load level. The step was 45 kpa. The size of loading plate was 2*2 m, and the thickness was 20 mm. In order to prevent the load board corners tilted, increased steel beam on the load board. The levers were 45 kpa, 90 kpa, 135 kpa, 180 kpa, 225 kpa and 270 kpa.
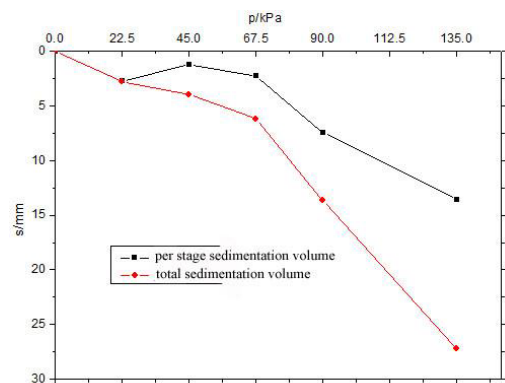

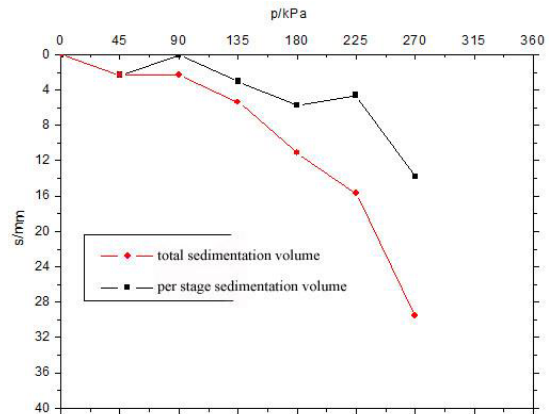
Figure 4. Natural foundation p - s curve
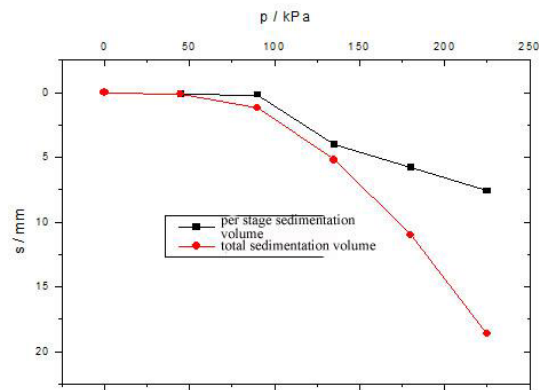

Figure 5. CSP p - s curve
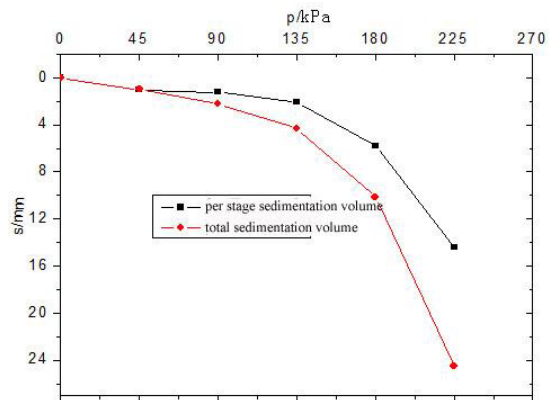

Figure 6. CFG p - s curve

Figure 7. GP p - s curve

The p-s curve of natural foundation, rammed soil-cement piles, CFG pile and gravel pile composite foundation were shown on Figures 4-7. The figures showed that after treatment bearing capacity of composite foundations were larger than the natural foundation.

To facilitate comparison of characteristic value of bearing capacity of composite foundation, we took the corresponding equal s/b= 0.008 in the same conditions of the pile diameter, the pile length and area replacement ratio. The CSP composite foundation bearing capacity characteristic value was the highest, which was 220 kpa. GP composite foundation bearing capacity characteristic value was the minimum, which was 203 kpa.

4.2 Composite foundation load test fitting curve

Natural foundation, CFGP, CSP and GP composite foundation p-s curve had obvious nonlinear relationship. The p-s curve used index form for nonlinear fitting, and the general form of the curve is as follows:

$$s = s_0 + A \exp(p/t) \qquad (3.1)$$

s_0 and $A \& t$ were the fitting coefficients.

Table 3 and Figures 8-11 show natural foundation, CSP, and the fitting coefficient of CFGP composite foundation. The autocorrelation coefficient of the fitted curve was greater than 0.99.
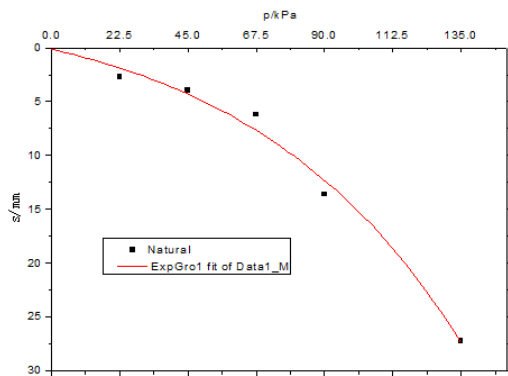

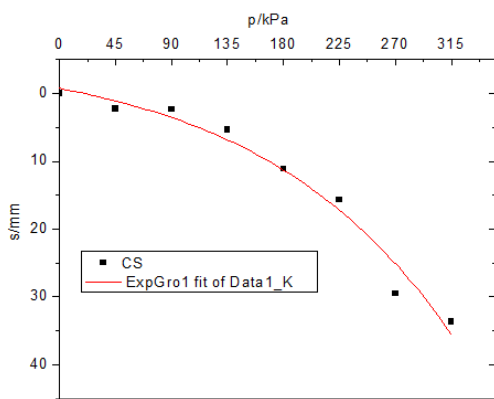Figure 8. The natural foundation fitting curve
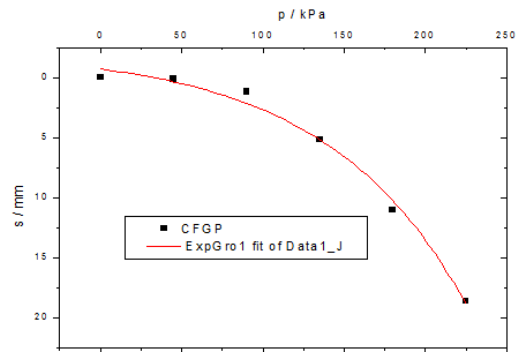

Figure 9. The CSP fitting curve
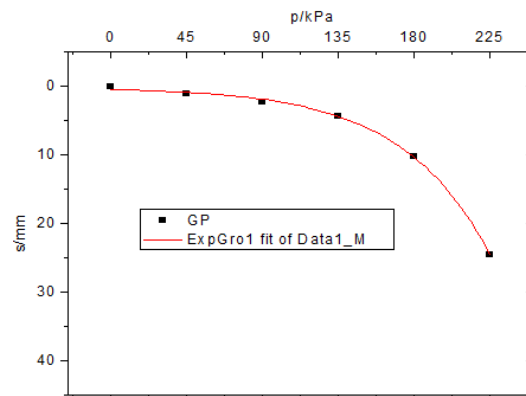

Figure 10. The CFG fitting curve
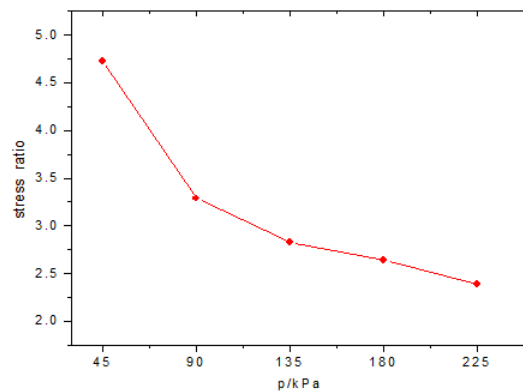

Figure 11. The GP fitting curve

Figure 12. GP of pile-soil stress ratio

4.3 Analysis of stress ratio of pile-soil

According to field test data, the analysis of the stress on pile top and soil between piles, pile-soil stress ratio under different ground treatment methods of mathe-

Table 3. Different composite foundation load test fitting curve function of various factor and bearing capacity

Type of composite foundation	$y = y_0 + Ae^{(p/t)}$			The correlation coefficient	The bearing capacity /kPa
	A	y_0	t		
natural foundation	4.72225	-4.60977	70.57301	0.995123	90
CSP	1.29126	-0.73233	85.89419	0.996138	220
CFGP	1.5446	-2.24319	85.98827	0.996263	212
GP	0.30712	0.09546	51.41749	0.99958	203

matical statistics was studied. The results were shown in Table 4. Pile-soil stress ratio of CFG pile was greater than the CSP composite foundations', and CSP's pile-soil stress ratio of composite foundation was greater than the GP composite foundations'. GP, CFG and CSP of pile-soil stress ratio were shown Figures 12-14.
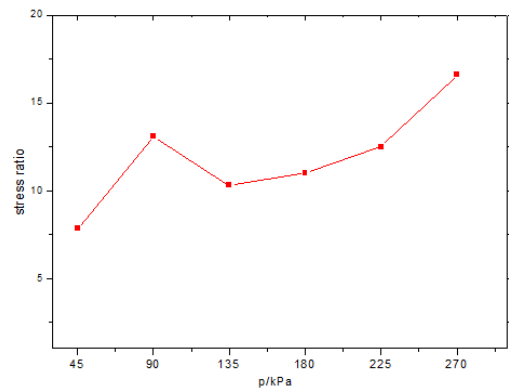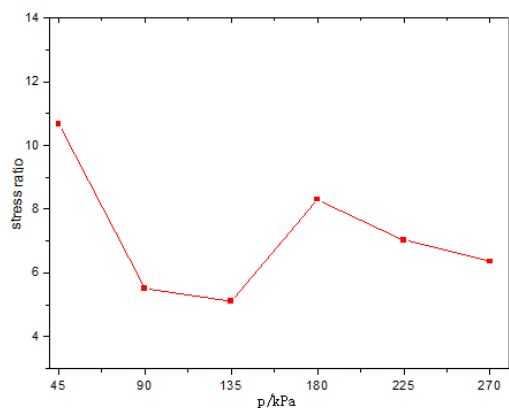

Figure 13. CFG of pile-soil stress ratio

Figure 14. CSP of pile-soil stress ratio

4.4 Deformation modulus of composite foundation

According to the p-s curve of composite foundation and composite foundation deformation modulus, the formula is as follows:

$$E_0 = \frac{pb(1 - \mu^2)}{s}\omega \qquad (3.2)$$

p: Curve fitting straight line segment of load intensity (kPa);

S: The corresponding coefficient to p which is the sink of the load board (mm);

b: The width of the loading plate (mm);

μ: The poisson's ratio of soil;

ω: The settlement influence coefficient.

The rigid loading plate takes $\omega = 0.88$ (square plate); $\omega = 0.79$ (round).

The poisson's ratio of composite foundation by the area weighted average calculation, single pile and the poisson's ratio of composite foundation press type calculation are as follows:

$$\mu_{sp} = m\mu_p + (1-m)\mu_s \qquad (3.3)$$

μ_{ps}: Poisson's ratio of composite foundation;

μ_s: Poisson's ratio of soil between piles;

μ_p: Pile material poisson's ratio;

m: The area of the pile soil replacement rate.

Two kinds of the poisson's ratio of pile type are combined with pile composite foundation press type calculation:

$$\mu_{sp} = m_1\mu_{p1} + m_2\mu_{p2} + (1-m_1-m_2)\mu_s \qquad (3.4)$$

μ_{p1}: The first pile material of poisson's ratio;

μ_{p2}: The second kind of pile material poisson's ratio;

m_1: The first kind of pile type of replacement rate;

m_2: The second kind of pile type of replacement rate.

The poisson's ratio of CFGP takes 0.23; Poisson's ratio of CSP takes 0.26; the soil between piles of poisson's ratio take 0.3. According to the p-s curve of the composite foundation, the deformation modulus was shown in Table 5. The CSP, CFGP, and GP deformation modulus of composite foundation were 31.51 Mpa, 60.49 Mpa and 71.57 Mpa.

Table 4. Pile soil stress ratio of composite foundation

Type of composite foundation	The maximum	The minimum value	The average	The standard deviation	Coefficient of variation
CSP	10.67	4.93	6.51	1.55	0.24
CFGP	16.59	7.83	11.88	2.7	0.23
GP	4.72	2.39	3.18	0.83	0.26

Table 5. Composite foundation deformation modulus

Type of composite foundation	CSP	CFGP	GP
Deformation modulus /MPa	31.51	60.49	71.57

5 CONCLUSIONS

Through the natural foundation, rammed soil-cement piles, CFG pile and gravel pile composite foundation for the large scale static load test, the following conclusions are drawn:

1) By p-s curve, when the load was 225 kpa, CSP composite foundation settlement was minimum. When the load of GP composite foundation was 135 kpa, settlement of GP was less than and CSP and CFGP composite foundation of composite foundation settlement. The p-s curves of Natural foundation, rammed soil-cement pile and CFG pile foundation, were obviously nonlinear characteristics.

2) Through the statistical analysis of the stress ratio of pile-soil load, pile soil stress ratio of CFG pile was greater than rammed soil-cement pile composite foundation, whereas the CSP pile-soil stress ratio of composite foundation was greater than the GP composite foundation.

3) Through the reflex composite foundation, the deformation modulus is ECSP<ECFG< EGP.

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