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The Application of CFG Pile Composite Foundation in the Reconstruction of the Dujiangyan

Jia Chen^a, Wei Chen^b, Ke Zhang^{*}, Lin Li^c

College of Civil Engineering, Sichuan Agricultural University, Dujiangyan 611830, China

*Corresponding author e-mail: zhangke@sicau.edu.cn, ^achenjia@sicau.edu.cn, ^bchenwei@sicau.edu.cn, ^c27217493@qq.com

Abstract. There are many shallow treatment methods for soft foundation, CFG pile composite foundation is one of the common treatment methods. In this paper, the application of CFG pile in multi-storey residential building is introduced, it is pointed out that CFG pile composite foundation is a simple, rapid, economical and effective foundation treatment method.

1. The introduction

Composite foundation is a kind of artificial foundation in which a certain proportion of the reinforcing body is set in the natural foundation and the soil body and the reinforcing body bear the upper load together, it is an effective method to treat soft foundation soil, it has been widely used in soft soil area [1]. CFG pile composite foundation is also called cement fly ash gravel pile composite foundation, it was successfully developed by the foundation research institute of China academy of building science, generally composed of stone debris, gravel and fly ash, etc, CFG pile, soil between piles and cushion layer on the base together constitute composite foundation. A large number of engineering practice, CFG pile composite foundation project has the characteristics of low cost, easy to draw materials and reliable technology. It is widely used to treat all kinds of soft foundation such as cohesive soil, silty soil and sandy soil.

2. The engineering application

2.1. Project summary

The proposed building is a 6F high brick and concrete structure residential building, located in dujiangyan city, Sichuan province, it is a residential building reconstruction project on the original site after the disaster. According to geological prospecting data, the soil layer below the designed elevation of the ground base of the site is mainly composed of plain fill layer, silty clay layer and pebble layer from top to bottom, due to the improvement of seismic intensity, plain fill layer, silty clay layer and loose pebble layer cannot meet the requirements of the foundation bearing layer of the building, so CFG pile should be used for foundation treatment.



2.2. The engineering geological conditions

Proposed the diluvia plain field geomorphic units belong to Chengdu minjiang river drainage II level terrace. The regional geological structure of the site is stable and there is no adverse geological effect. Liquefaction of foundation soil is also not considered. The site is covered with quaternary artificial fill (Q_4^{ml}), which is composed of silty clay and pebbles formed by the upper quaternary Pleistocene fluvial alluvium (Q_3^{al+pl}). The groundwater of the site belongs to the quaternary pore diving type and is slightly confined. The sand and pebble layer is the main aquifer.

3. CFG pile design calculation

3.1. Preliminary design

The load-bearing eigenvalue of the post-composite foundation $f_{spk} \geq 270\text{kPa}$, $E_{sp} \geq 15.0\text{MPa}$, Pile strength is greater than or equal to 10MPa . According to the site geotechnical engineering geological conditions, slightly dense pebble layer is selected as pile end bearing layer, the pile is required to enter the bearing layer no less than 500mm , and consider a 300mm protection stake for the stake, net pile length after pile cutting shall not be less than 1.50m .

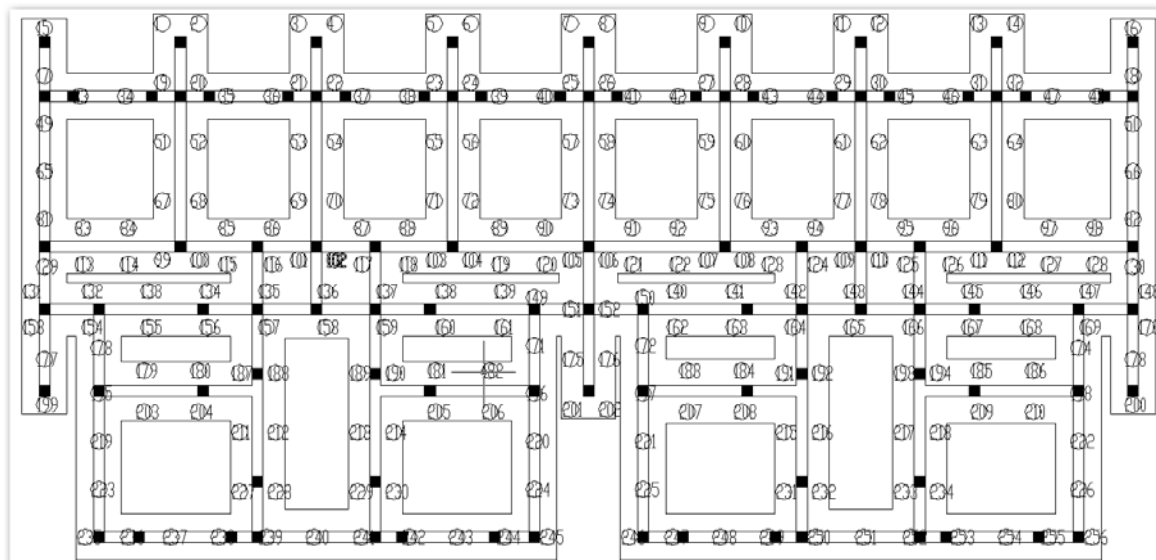


Figure 1. The pile layout diagram of CFG pile

3.2. Evaluation of characteristic value of composite subgrade capacity

(1) Determine the characteristic value of soil bearing capacity between CFG piles

According to the stratigraphic conditions and physical and mechanical parameters of the soil in the geotechnical engineering survey report of the site, see Table 1, we also consider the actual effect of the top layer of layers below the base, weighted by thickness. Because of the soil between piles for the silty clay, after compaction, the bearing capacity characteristic value of 160.0kPa .

Table 1. The table of physical and mechanical parameters of soil

Soil	Thickness $H(m)$	Severe $\gamma(kN/m^3)$	Characteristic value of bearing capacity $f_{ak}(kPa)$	Compression modulus $E_s(MPa)$	CFG pile	
					Characteristic value of pile tip resistance $q_p(kPa)$	Characteristic value of pile lateral resistance $q_{si}(kPa)$
Grain filling	0	19.0	80	3.0		10
Silty clay	1.5	19.5	160	6.0		30
Loose gravel	0	20.5	180	20.0		40
A dense pebble	0.5	21.0	350	24.0	1200	60

Note: design parameters of CFG pile are determined according to geological survey report.

(2) Calculate the bearing capacity of the CFG stake R_a

The exploration point No.31 was selected as the most unfavorable calculation point, after pile cutting, the actual pile length is 2.00m and the pile diameter is 0.35m. according to the requirements of the code [2], the characteristic value of single pile bearing capacity is:

$$R_a = U_p \sum_{i=1}^n q_{si} l_i + q_p A_p \approx 197.82 kN \quad (1)$$

Consider at 190Kn.

(3) Calculate the minimum area replacement rate of CFG pile

According to the code of composite foundation bearing capacity formula $f_{spk} = m(R_a/A_p) + \beta(1-m)f_{sk}$ [2], take the soil between piles bearing capacity reduction factor $\beta = 0.75$, the replacement rate is:

$$m = \frac{f_{spk} - \beta f_{sk}}{\frac{R_a}{A_p} - \beta f_{sk}} \approx 8.7\% \quad (2)$$

(4) Determine the distance of CFG pile

According to the specification of replacement rate formula $m = d^2/d_e^2$ [2] get:

$$d_e = \sqrt{\frac{d^2}{m}} \approx 1.2311 \quad (3)$$

(5) The characteristic value of bearing capacity of CFG pile composite foundation is estimated

According to the specification of composite foundation bearing capacity characteristic value calculation f_{spk} get:

$$f_{spk} = m(R_a/A_p) + \beta(1 - m)f_{sk} \approx 281.49kPa \geq 270.0kPa \quad (4)$$

Meet the requirements of bearing capacity of composite foundation design.

3.3. The calculation of the compressive modulus of the CFG composite foundation

According to the compression modulus formula in the specification:

$$E_{sp} = \zeta E_{sa} = 1.687 \times 9.0 = 15.183 MPa > 15.0 MPa \quad (5)$$

(Where $\zeta = f_{spk}/f_{sk} = 270/160 = 1.687$)

Where: E_{sp} is the compression modulus of composite foundation soil (MPa); E_{sa} is the compression modulus weighted value of foundation soil layer between piles (MPa), which is 9.0 MPa; ζ is the modulus increasing coefficient.

3.4. Determination of strength and proportion of CFG pile piles

(1) Pile strength

The current compressive strength f_{cu} shall be determined by curing the average of 28d compressive strength by the test block ($100 \times 100 \times 100 mm$) of the pile mixture test blocks, therefore, the value is determined according to C10. According to the standard formula,

$$f_{cu} \geq 3 \frac{R_a}{A_p} \approx 5.93 MPa < f_{cu,k} = 10.0 MPa \quad (6)$$

Meet the design requirements.

(2) Mix design

The pile material is mainly gravel. (gravel particle diameter is 2 to 5cm, and the aggregate is less than 3% of the material), with a certain amount of mechanism of coarse sand, cement, etc. The construction mix ratio refers to the design code for the mix ratio of ordinary concrete (JGJ55-2011), The slump is not greater than 3cm, using the field machine. The specific C10 mixture ratio was determined according to the mixture ratio design experiment.

4. Mattress layer

Because of the mattress, CFG pile can ensure that the external load is borne by soil and piles between piles, and it can be adjusted to the vertical load ratio, to ensure that the foundation bearing capacity and design requirements, therefore, after the pile construction is completed, manually excavate the earth to the designed bottom elevation of the mattress layer, cut the pile, and lay the mattress layer on the top of the composite foundation in the foundation area (foundation boundary line outward expansion of 300mm), so as to ensure that the pile and soil can bear the load together. The mattress is made of graded medium coarse sand and about 70% gravel, and the gravel particle size should not be larger than 30mm. The thickness of the mattress layer is reasonable, and it has a larger impact on the bearing and settling of the CFG's composite foundation [3], therefore, the design of the false floor mat is at the top of the pile, which is at the top of the pile, and it will be built at the top of the pile, and it will build up to 300mm, so that the pressure of the base will be reduced, and it will be reduced to 0.87 to 0.90.

5. The quality assurance of the composite foundation

5.1. Material quality control

Pile material is mainly composed of egg (broken) stone, coarse sand, cement and water. Therefore, 2~5cm egg (crushed) stone was used in CFG pile, and the mud content was less than 3%, the cement adopts composite Portland cement P.C32.5, to ensure the reinforcement effect, the pile tip was rammed

and compacted into the pebble layer with 15~20cm heavy hammer, the slump is controlled in 10~30mm when the mixture ratio is satisfied.

5.2. *Quality control of CFG pile*

For independent basis, the deviation of pile position shall not exceed 0.40 times of pile diameter, i.e. 160mm, the vertical deviation shall not exceed 1%, the allowable deviation of pile diameter is 20mm, pile tip into the bearing layer is not less than 800mm, after taking soil into holes, the thickness of the residual empty soil at the bottom of the hole shall not be more than 10cm. After the pile hole is formed, empty pile should be flushed naked for 3~5 times before packing, using $\Phi 15\text{cm}\sim 20\text{cm}$ pebble hit bottom, it will be filled in with all of the holes in the bottom of the hole, and then the CFG packing. In order to prevent the generation of broken pile, if the formation collapse in the construction of filler, should be re-hole to ensure that no broken piles will occur during the construction, the hammer drop distance is 2.0~3.0m after each of the feeding 1 bucket truck (about 0.08m^3) is tamper-five times. Meanwhile, this project adopts CK-15A (B) pile machine, the soil sampler is an improved large-diameter soil sampler (the outer diameter of the tube is 275mm, the outer diameter of the cutting edge is 295mm, and the pore diameter can reach 325mm after drilling).after pouring in C10 concrete, it is compacted and rammed with 800kg heavy hammer from bottom to top, and the pile diameter can exceed 350mm.

5.3. *Quality inspection of composite foundation*

In order to guarantee the engineering quality, the single pile composite foundation load test should be adopted for CFG pile, and the quality inspection should be carried out 15 days after the completion of CFG pile construction and the pile body meets the design requirements. The detection points shall be 1% of the total pile number and no less than 3 points for each building. The detection points shall be representative and the pile position shall be at the center of the detection points. The detection method and the number of measurement points shall be executed according to the relevant specifications. The specific process is to clear the bottom to the mattress bottom elevation, cut the pile to the bottom elevation of mattress, the coarse sand layer of virtual paving is 5cm~15cm, then the static load test is carried out on it, see Figure 2. According to the test results, the characteristic value of bearing capacity of the composite foundation meets the design requirements.



Figure 2. Static load test of CFG pile

6. Conclusion

As an effective foundation treatment method, CFG pile composite foundation is widely used in various fields of engineering. In this paper, the design and quality control of CFG pile composite foundation are introduced. From the point of view of this project, CFG pile composite foundation, simple design, easy to draw materials, under the premise of ensuring construction quality, the strength potential of foundation soil can be brought into full play, improve the bearing capacity of composite foundation, belongs to a kind of more effective foundation treatment method.

Acknowledgments

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