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Comparative Analysis and Research of Different Ways to Deal with the Soft Soil Foundation

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Abstract. Taking an engineering example as background, the deformation and settlement of CFG pile and artificial bored pile composite foundation under the same geological condition are analyzed by using finite difference method. The simulation results show: the same formation and pile material and compaction process, the large diameter and deep manual bored pile foundation can significantly restrain the foundation drop, the analysis results have certain reference value for similar projects.

1. Introduction

Affected by the May 12 wenchuan earthquake, people's awareness of the earthquake is getting higher and higher, at the same time, the earthquake intensity of the earthquake-stricken areas is increased, which leads to the foundation of the newly built buildings in the earthquake-stricken areas cannot meet the requirements of bearing capacity, which requires foundation treatment. Considering the principle of safety and economy, the commonly used foundation treatment methods include CFG pile, manual hole digging pile, replacement filling method and high-pressure rotary jet pile, etc, in this paper, two kinds of foundation treatment methods, CFG pile and manual bored pile under the same geological conditions, are selected to compare and analyze the settlement of foundation after construction, so as to choose a better treatment method.

CFG pile is made of gravel, debris, sand and fly ash mixed with appropriate amount of cement and water. A large number of engineering practices have proved that CFG pile composite foundation project has the characteristics of low cost, easy to draw materials and reliable technology, and is widely used to treat soft foundation [1]. Artificial bored pile is a kind of whole forming technology of cast-in-place pile formed by artificial excavation, which is suitable for dry land, less water and more dense soil or rock strata. It is widely used because of its advantages such as less occupied construction site, lower cost, simple technology, easy quality control and less pollution during construction. Both types of piles are common foundation treatment methods, and the existing settlement analysis mostly focuses on a single treatment method. This paper will combine numerical simulation to conduct comparative analysis and research on the settlement caused by the two methods.



2. Summary of foundation processing

2.1. Project summary

Two post-disaster reconstruction housing projects are located 500m apart in dujiangyan city, sichuan province. The building has 6 floors above ground and 0 floors underground. One is a brick-concrete structure and the other is a frame structure, all of which adopt strip foundation. The site is overlaid with quaternary artificial fill (Q_4^{ml}), which is composed of silty clay and pebbles formed by the upper pleistocene river alluvium (Q_3^{al+pl}) of the quaternary. The influence of groundwater is not considered in the foundation construction process

2.2. Foundation treatment requirements

According to the geological survey data of the site, the artificial fill soil layer, silty clay layer and loose pebble layer cannot meet the requirements of the bearing layer of the foundation of the building. Therefore, CFG pile foundation treatment is adopted for the brick-concrete structure and Manual hole digging pile foundation treatment is adopted for the frame structure.

2.3. Composite foundation design

CFG pile and Manual bored pile are adopted to treat composite foundation [2], main design parameters are shown in table 1.

Table 1. Major design parameters of composite foundation

Type	Diameter /m	Length /m	Pile spacing /m	Pile arrangement	The bearing capacity of a single pile/kN
CFG pile	0.35	3.5	1.09	square	150
Manually bored piles	1	14	2	square	150

3. The numerical simulation

3.1. Establishment of numerical model

3.1.1. Constitutive model. The foundation and soil layers are the ideal elastic-plastic constitutive model of the molar coulomb using the pull-shear composite failure yield criterion [3].

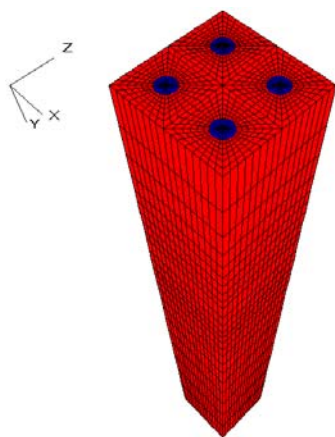
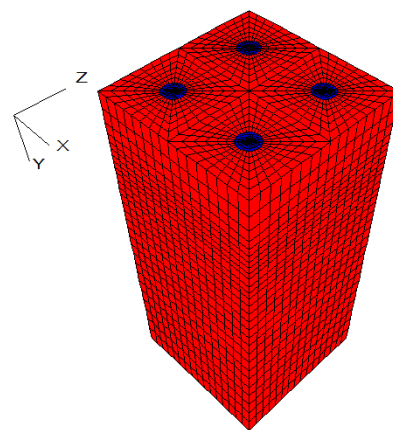
3.1.2. The physical mechanics parameters of the piles and the layers. Due to the numerical simulation can't truly represent the process of soil compaction, therefore, the parameters of each layer are mechanical parameters after compaction. The thickness of each soil layer and the physical and mechanical parameters of pile are shown in table 2.

Table 2. The physical mechanics parameters of the piles and the layers

name	thickness /m	Elastic modulus /MPa	Poisson's ratio	Cohesive force /kpa	Internal friction Angle /°	Tensile strength /kpa	Unit weight /kg·m ³
Filling soil	2.5	15.0	0.3	1.0	27	0.01	1800
Loose pebble	0.7	18.0	0.3	1.0	27	0.01	1800
dense pebble	0.7	24.0	0.3	5.0	33	0.05	2000
Loose pebble	0.3	18.0	0.3	1.0	27	0.01	1800
A dense pebble	0.5	24.0	0.3	5.0	33	0.05	2000
Micronesia pebble	0.8	33.1	0.3	10.0	35	0.1	2200
Dense pebble	12.0	47.0	0.3	50.0	30	1.0	2300
Concrete foundation	2.5	30000	0.2	6300	45	1250	2400
CFG pile	3.5	17500	0.2	3300	45	550	2200
Manually bored piles	14.0	17500	0.2	3300	45	550	2200

3.1.3. Establishment of numerical model. As the site where the residence is located belongs to a typical transverse view of the same medium, it is mainly subjected to vertical dead weight stress and vertical load of the building above, and numerical modeling has symmetry in geometry and stress. In addition, CFG pile and the Manual excavated pile are arranged vertically on the surface to the soil layer, and the arrangement points are also symmetrical, therefore, two kinds of pile foundation of the numerical modeling can only consider four piles, establish a symmetrical model, not only improve the calculation efficiency but also meet the general regularity.

According to the pile design parameters, the external dimensions of CFG pile model are 2.18m×2.18m×17.5m, four piles are arranged, grid partitioning is performed, The 3d numerical calculation model is generated as shown in Fig 1; The external dimension of the Manual excavated pile model is 8m×8m×17.5m, our piles are arranged too, grid partitioning is performed, The 3d numerical calculation model is generated as shown in Fig 2.

**Figure 1.** CFG pile grid numerical model**Figure 2.** Manually bored piles grid numerical model

The boundary conditions: the vertical Y of the model is the self-weight stress of the rock-soil layer, the horizontal XZ direction is the horizontal stress of poisson's ratio effect; the four vertical sides and bottom surfaces of the model are constrained by normal displacement to the boundary conditions to meet the requirement of symmetry.

Load conditions: the load transmitted on the foundation is simplified to a uniform load on the foundation, the distribution load shall be based on the self-weight and live load of the 6 storey building multiplied by the respective breakdown factor.

3.2. Numerical simulation brief

Firstly, the self-weight stress field of soil layer without pile foundation is calculated to obtain the stress field before engineering disturbance; Secondly, the pile is applied and the balance is calculated; thirdly, the foundation is applied and the balance is calculated; finally, the uniform load of the upper building is applied on the foundation surface and the balance is calculated.

4. Numerical simulation results

4.1. Vertical settlement displacement analysis

Fig 3 and Fig 4 show the vertical settlement of two types of pile foundations. It can be intuitively seen that under the load of the upper building, the vertical settlement caused by CFG pile foundation is 1.61cm. The vertical settlement caused by Manually excavated pile foundation is 0.835cm, if converted into the vertical settlement of unit area of a single pile, the vertical settlement of CFG pile is $1.61\text{cm}/(1.09\text{m}\times 1.09\text{m})=1.35\text{cm}/\text{m}^2$, and the vertical settlement of Manually excavated pile is $0.835\text{cm}/(4\text{m}\times 4\text{m})=0.0522\text{cm}/\text{m}^2$. respectively, it can be seen that under the same stratum and pile material and compaction technology, large diameter and deep manual hole digging pile foundation can significantly inhibit the settlement of foundation.

Center:
X: -1.521e+000
Y: 7.540e+000
Z: 2.611e+000
Dist: 1.478e+001

Rotation:
X: 330.000
Y: 45.000
Z: 0.000
Mag.: 0.328
Ang.: 22.500

Contour of Y-Displacement

Magfac = 0.000e+000

Live mech zones shown

0.0000e+000 to 2.0000e-003
2.0000e-003 to 4.0000e-003
4.0000e-003 to 6.0000e-003
6.0000e-003 to 8.0000e-003
8.0000e-003 to 1.0000e-002
1.0000e-002 to 1.2000e-002
1.2000e-002 to 1.4000e-002
1.4000e-002 to 1.6000e-002
1.6000e-002 to 1.6138e-002
Interval = 2.0e-003

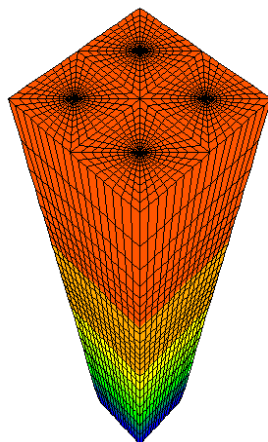


Figure 3. CFG pile foundation vertical settlement displacement cloud

Center:
X: 6.018e-001
Y: 7.608e+000
Z: 3.398e+000
Dist: 3.087e+001

Rotation:
X: 320.000
Y: 45.000
Z: 0.000
Mag.: 0.41
Ang.: 22.500

Contour of Y-Displacement

Magfac = 0.000e+000

Live mech zones shown

0.0000e+000 to 1.0000e-003
1.0000e-003 to 2.0000e-003
2.0000e-003 to 3.0000e-003
3.0000e-003 to 4.0000e-003
4.0000e-003 to 5.0000e-003
5.0000e-003 to 6.0000e-003
6.0000e-003 to 7.0000e-003
7.0000e-003 to 8.0000e-003
8.0000e-003 to 8.3535e-003
Interval = 1.0e-003

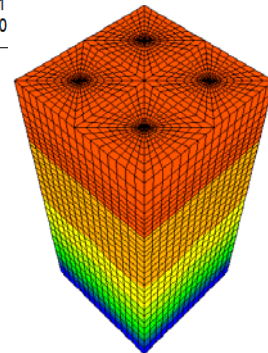


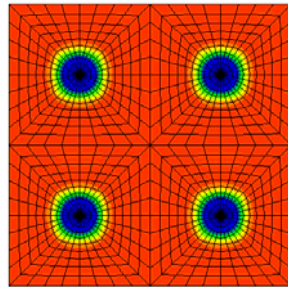
Figure 4. Manually excavated pile foundation vertical settlement displacement cloud

Center:
X: 5.450e-001
Y: 8.750e+000
Z: 5.450e-001
Dist: 1.478e+001
Rotation:
X: 0.000
Y: 0.000
Z: 0.000
Mag.: 0.8
Ang.: 22.500

Contour of SYY

Magfac = 0.000e+000
Live mech zones shown
Gradient Calculation

-1.1430e+006 to -1.1000e+006
-1.1000e+006 to -1.0000e+006
-1.0000e+006 to -9.0000e+005
-9.0000e+005 to -8.0000e+005
-8.0000e+005 to -7.0000e+005
-7.0000e+005 to -6.0000e+005
-6.0000e+005 to -5.0000e+005
-5.0000e+005 to -4.0000e+005
-4.0000e+005 to -3.0000e+005
-3.0000e+005 to -2.0000e+005
-2.0000e+005 to -1.0000e+005
-1.0000e+005 to -2.2861e+004
Interval = 1.0e+005



Center:
X: 2.000e+000
Y: 8.750e+000
Z: 2.000e+000
Dist: 3.087e+001
Rotation:
X: 0.000
Y: 0.000
Z: 0.000
Mag.: 0.8
Ang.: 22.500

Contour of SYY

Magfac = 0.000e+000
Live mech zones shown
Gradient Calculation

-2.4526e+006 to -2.2500e+006
-2.2500e+006 to -2.0000e+006
-2.0000e+006 to -1.7500e+006
-1.7500e+006 to -1.5000e+006
-1.5000e+006 to -1.2500e+006
-1.2500e+006 to -1.0000e+006
-1.0000e+006 to -7.5000e+005
-7.5000e+005 to -5.0000e+005
-5.0000e+005 to -2.5000e+005
-2.5000e+005 to -9.2934e+003
Interval = 2.5e+005

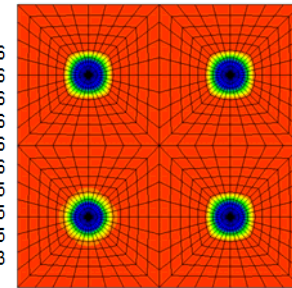


Figure 5. CFG pile base pressure cloud

Figure 6. Manually excavated pile base pressure cloud

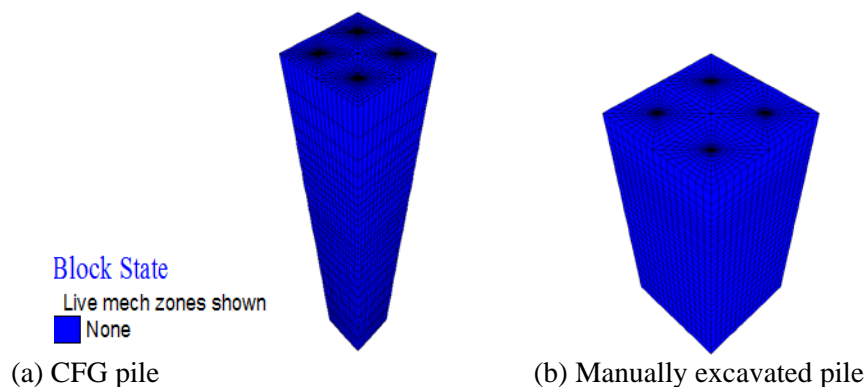


Figure 7. Plastic distribution of two pile foundation working conditions

4.2. Base stress analysis

Fig 5 and Fig 6 show the pressure cloud of the base. It can be clearly seen from the above that pile foundation bears a large foundation pressure and the foundation soil layer bears a small pressure, compared with the manually excavated pile, the foundation pressure of CFG pile itself and the soil around the pile is about twice as small as that of the Manually excavated pile. However, the plasticity of Fig 7 distinguishes the layout surface. The pile foundation and soil around the pile are in the elastic deformation stage, and no plastic zone is generated, which further indicates the stability of the pile foundation.

5. Conclusion

(1) After CFG pile composite foundation treatment, the soil between piles can be compacted, the bearing potential of pile and soil can be effectively exerted, the pile and soil can jointly bear the upper load in a way of coordinated deformation, and the settlement of foundation meets the requirements of the code.

(2) Composite foundation treated by artificial hollowing pile, the settlement of foundation meets the standard requirements due to the large pile diameter and long pile length

(3) Under the same condition of stratum and pile material and compaction technology, the settlement of foundation can be significantly inhibited by large diameter and deep artificial bored pile foundation.

Acknowledgments

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