

# Numerical Simulation Study on the Bearing Characteristics of Long Spiral Drilled Pressure Grouting Piles

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## Abstract

Long auger bored concrete pile is a kind of deep foundation, it has the advantage of pile foundation and other special advantages. Considering the particularity of the geological conditions in the loess area, study on the bearing characteristics of long spiral bored concrete pile with MIDAS/GTS software, through the numerical analysis of Long Auger Bored Cast with pressure concrete pile compared with other piles in the displacement, stress variation, and analysis of Long Auger Bored Cast with pressure concrete compared with other type of pile pile has the advantage. The results show that the GTS is a good simulation of the static loading test of pile, just a little bigger than the calculated value of experimental values, with the increase of pile top load, the influence of this error is more and more small; in the same pile diameter and geological conditions, long auger bored to many higher than the round bearing capacity of concrete pile.

## Keywords

Long Spiral Bored Pile; Pile Soil Interaction; Numerical Simulation; Baring Capacity.

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## 1. Introduction

Pile foundation, as a kind of deep foundation, has always been favoured by the engineering community because of its high bearing capacity and stability, its ability to pass through weak strata to transfer the superstructure load to the holding layer, and its good seismic performance. In recent years, with the vigorous rise of civil engineering construction, engineering construction has put forward better requirements for the construction quality of pile foundation. Some old construction techniques, which are easy to cause necking, hole collapse and pile breakage, are gradually eliminated by the engineering. A new construction technology, long spiral drilled and pressed concrete, comes into being.<sup>[1-4]</sup> Long spiral drilling and pressing concrete has many advantages, this construction technology adopts the method of long spiral drilling and then pumping concrete and inserting reinforcing cage through special equipment, which effectively avoids the occurrence of necking, pile breaking and hole collapsing phenomena mentioned above, and is favoured by the engineering community<sup>[5-8]</sup>.

## 2. Project Overview

### 2.1 Engineering Background

The construction project is located in Weifang City, north of Beigong West Street, west of Nanxu Road. Planning and construction of three automated cold storage and the corresponding outdoor supporting works, cold storage attached to the construction of supporting workshops, offices and equipment rooms. The planned net land area is 42296m<sup>2</sup>, and the total construction area is about

29163m<sup>2</sup>, of which the above ground construction area is 28516.56m<sup>2</sup> and the underground construction area is 646.44m<sup>2</sup>.

## 2.2 Geological Conditions of the Proposed Site

According to the drilling, there is no unfavourable buried material for the project, there is no liquefied soil layer and undesirable geological effect in the site, it is a stable site, suitable for construction, and it is a favourable lot for construction of anti-seismic.

During this survey, the stable groundwater level is 17.9-19.9m, the corresponding elevation is 22.7-23.0m, and the annual change is about 2.0m, according to the survey, the highest water level in the period of abundant water in the recent 3-5 years is about 5.0m below the natural ground level, and the corresponding elevation is about 27.0m, according to the 'Contour Map of Groundwater Buried Depth in the Period of Abundant Water in Changwei Area in 1975', the highest water level of the area in the past 50 years is about 0.0m, and the depth of water is about 0.0m, and the depth of water is about 0.0m. According to the 'Changwei Area 1975 Contour Map of Groundwater Depth in Abundant Water Period', the highest water level in this area in 50 years is about 0.0m, and the corresponding elevation is about 42.0m, and the anti-floating water level can be defended with reference to the highest water level in the past 50 years according to the elevation of 40.0m. The main sources of groundwater in the site are atmospheric precipitation and underground runoff, and the main discharge route is artificial extraction, and the groundwater in the site is pore diving. According to the investigation, the main aquifer layer of groundwater is the 4th layer of powder soil and the following soil layer. The site soil is slightly corrosive to concrete structure and steel reinforcement in concrete structure. The deformation modulus E of the medium-coarse sand layer was determined from the statistical results of the indoor geotechnical tests, in-situ test experiments and the geological characteristics of each soil layer.

## 3. Numerical Simulation

### 3.1 Selection of Calculation Parameters

Calculation data adopts the test pile of Lot 2 in the engineering area, and it is predicted that the test pile of Lot 2 adopts the long spiral drilling and compression filling column, with pile length of 35 m, pile diameter of 800 mm, and C40 concrete, and the 4th layer of medium sand as the holding layer of the pile end, and the vertical compressive static loading test of the monopile is adopted to determine its ultimate load bearing capacity. The geomorphological stratum lithology and layer stability of the area show that the base soil distribution is continuous, the layer is more stable, there is no weak interlayer, and the foundation bearing layer of each building is located in the same geomorphological unit, the specific distribution of the soil layer in the work area and the calculation parameters are shown in Table 1.

**Table 1.** Basic parameters of foundation soil

Soil layer name	Thickness	Deformation modulus	Poisson's ratio	Cohesion	Internal friction angle	Density
	m	kPa		kPa	°	Kg/m <sup>3</sup>
Miscellaneous fill	5.5	2340.0	0.38	8.5	15.8	1725.0
loess	10.2	1760.0	0.31	17.8	14.3	1960.0
silty clay	12.5	1520.0	0.37	38.2	17.8	1690.0
medium sand	20	4210.0	0.29	16.3	23.6	1740.0
weathered sandstone	23	70200.0	0.27	143.5	18.2	2210.0

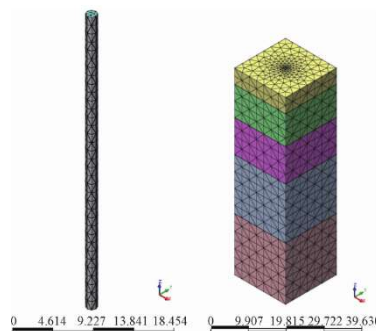
The Drucker-Prager principal model is selected, and the pile body is considered to deform plastically under the load. The main parameters of which are shown in Table 2.

**Table 2.** Calculation parameters of pile

Soil layer name	Deformation modulus	Poisson's ratio	Cohesion	Internal friction angle	Density
	kPa		kPa	°	Kg/m <sup>3</sup>
weathered sandstone	4000.0	0.22	2200.0	37.2	2510.0

### 3.2 Calculation Model Establishment

According to the test pile data in the project area, the length of the pile is 35 m, the diameter of the pile is 800 mm, and the range of 20 m around the pile is the calculation width, and two times the length of the pile is the calculation depth. At the same time, it is assumed that the structure and load are symmetrically distributed, and Goodman unit is used for the contact surface unit between the pile and soil, and the finite element model is established from the bottom to the top based on the distribution characteristics of the soil layer in the engineering area, as shown in Fig.1.



**Fig. 1** Solid model diagram

### 3.3 Loading and Solution Process

The Goodman unit without thickness and mass is used in GTS, which adopts the concept of spring stiffness and can simulate that the jointed rock body will produce misalignment, slip or cracking between the contact surfaces. The surface pressure is applied at the top of the pile with the mouth = 10600 kN/m<sup>2</sup>. a total of 10 levels are loaded step by step. In order to reflect the construction process of real foundation piles, the whole model analysis needs to be divided. In the first stage, the initial ground stresses are analysed under self-weight conditions, and in the calculated results, the stresses are retained and the gravity-induced displacements are eliminated; in the second stage, the construction of the foundation piles is carried out with the inclusion of the contact units; and in the third stage, the loads are added, which are divided into 10 stages.

## 4. Analysis of Calculation Results

### 4.1 Displacement Change Characteristics

In order to more intuitively observe the force changes within the pile and soil, 1/2 section of the model is taken for observation. Figure 2 can be intuitively seen, long spiral drilled and compacted concrete pile force mechanism is different from the circular pile, the circular pile is mainly rely on the pile side resistance and pile end bearing force to withstand the load, while the long spiral drilled and compacted concrete pile not only rely on the above two aspects of the prisoner to withstand the load also includes the end bearing force in the soil, this is the prisoner for the process of piling, the pumping of the concrete on the surrounding soil to produce a strong pressure, the surrounding soil is infiltrated and

compacted under the action of pressure, to a certain extent, increase the pile and soil internal displacement. Under the action of infiltration and densification, to a certain extent, increase the pile foundation and the combination of the surrounding soil, greatly improving the bearing capacity of the pile.

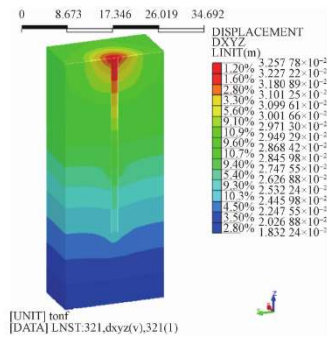


Fig. 2 Vertical displacement of soil

Table 3. pile body settlement

Pile length/m(bottom-up)	0-7	7-14	14-21	21-28	28-35
Settlement/mm	24.72	27.85	29.97	31.26	32.56
Soil displacement/mm	18.46	20.58	24.78	26.89	29.61

From Fig. 2 and Table 3, it can be seen that the combination and integrity of long spiral drilled and compacted concrete piles and the surrounding soil is very good, and this integrality is firstly shown in the long spiral drilled and compacted concrete piles, under the same loading condition, the settlement is much smaller than that of the circular piles; and secondly, the difference between the settlement of the piles and the displacement of the soil on the side of the piles is small compared with that of the circular piles, which shows that this kind of moulded piles can be fully utilized when bearing the upper load. play the role of close combination with the surrounding soil, and can withstand higher loads. In addition, according to the comparison between the measured data and the numerical simulation results, the actual settlement of the pile top under the ultimate load value of 10600 kN is 28.92 mm, while the simulation result is 32.57 mm, with a difference of 3.65 mm, which indicates to a certain extent that the results of using the MIDAS/GTS numerical simulation software are reliable.

#### 4.2 Characteristics of Stress Change

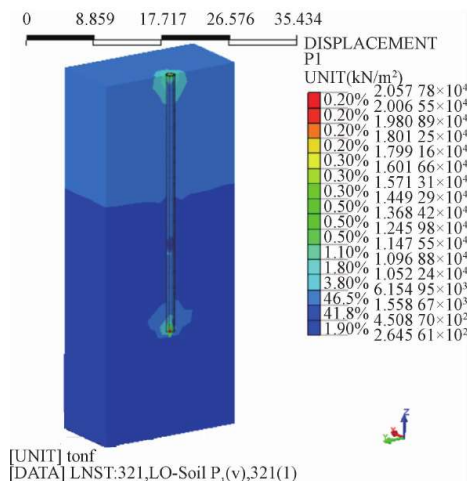
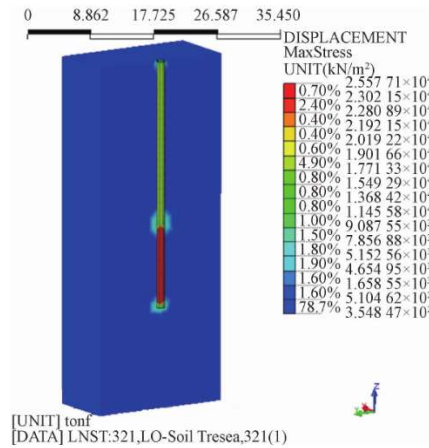


Fig. 3 Vertical stress

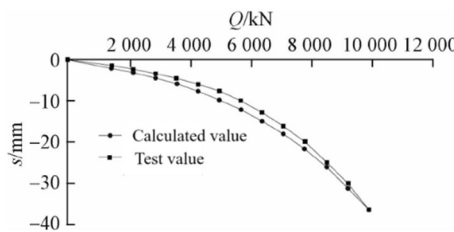


**Fig. 4** Maximum principal stress

It can be seen from Fig. 3-Fig. 4 that, like the circular pile, the stress change of the long spiral drilled compacted concrete pile gradually becomes smaller from the top of the pile to the bottom of the pile after the load is applied to the top of the pile, and the soil under the pile is obviously compressed, and the value of the compressive stress spreads out from the body of the pile to the two sides and the lower part of the pile, and the change of the stress field of the soil body in other regions is very small except for that in the vicinity of the tip of the pile.

### 4.3 Graded Loading Characteristics

For the vertical compressive static load test of foundation pile, graded loading up to two times of the design value is used, and the settlement and deformation of the top of the pile is recorded during the loading process. In this paper, GTS is used to simulate the vertical compressive static load test of foundation piles to record and analyse the displacement change of the top of the pile during the grading loading process, in which the  $Q$ - $s$  curve of the pile is shown in Fig. 5.



**Fig. 5** Test and calculation of  $Q$ - $s$  curve

As can be seen from Fig. 5, in the results of MIDAS/GTS simulation of vertical bearing capacity of foundation piles, the curves of the test values and the calculated values show a high degree of agreement, and the simulation effect is relatively good. The calculated value is slightly larger than the test value at the early stage of loading due to the relatively obvious deflection of the steel beam when the pile is overloaded, so the top of the pile is already deformed to a certain extent before the counting of the displacement meter starts, which results in the calculated value being slightly larger than the test value at the early stage of loading, but with the loading of the pile step by step, the deviation of the calculated value from the test value is getting smaller and smaller.

As shown in Fig. 6, under the final loading value (10600 kN) of the static load test, the test pile produces displacement in the vertical direction as well as obvious displacement in the horizontal direction. The load ratio reaches 80% and the side resistance contributes significantly to the ultimate bearing capacity.

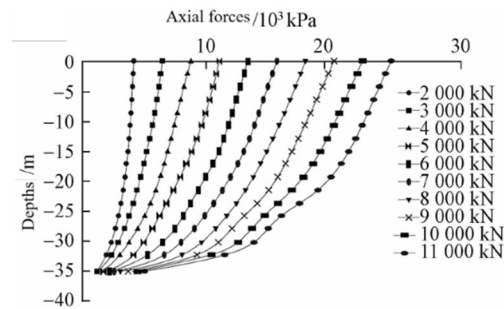


Fig. 6 Load transfer curve

## 5. Conclusion

Based on the results and discussions presented above, the conclusions are obtained as below:

- (1) Long spiral drilled and compacted concrete piles have strong pressure on the surrounding soil due to the pumped concrete in the process of pile formation, and the surrounding soil is infiltrated and compacted under the pressure, which increases the combination of the pile foundation and the surrounding soil to a certain extent, and greatly improves the bearing capacity of the piles.
- (2) The settlement of the long spiral bored pressed concrete pile under the same loading condition is much smaller than that of the circular pile; secondly, the difference between the settlement of the pile body and the displacement of the soil on the side of the pile is relatively small compared with that of the circular pile, which shows that this kind of pile can fully play the role of close combination with the surrounding soil body when it is subjected to the upper loading and can withstand higher loads.
- (3) According to the comparison between the measured data and the numerical simulation results, the actual settlement of the top of the pile under the ultimate load value of 10600kN is 28.92 mm, while the simulation result is 32.57 mm, with a difference of 3.65 mm, which indicates to a certain extent that the results of using the MIDAS/GTS numerical simulation software are reliable.
- (4) From the Q-s curve of the pile, the calculated value is slightly larger than the test value at the beginning of loading, but the deviation between the calculated value and the test value is getting smaller and smaller with the step-by-step loading.

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