Study on the Influence Factors of Cast-in-situ Bored Pile Bearing Capacity under Karst Geology Condition

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Abstract. Influence factors of the bearing capacity of cast-in-situ bored piles under the karst geology condition are studied. Taking the large diameter cast-in-situ bored piles of Yuanshui bride piers in karst region as an engineering example, effects of three influence factors on the bearing capacity of bored piles are analyzed using FEM, which are the buried depth of the karst cave, the rocked-socketed depth of the pile tip, the distance from the cave to the pile. The results show that the deeper the cave, the higher the bearing capacity of the pile and the more embedded in the rock the pile tip , the higher the bearing capacity of the pile, that is, the deepening of the pile tip embedded in the rock can improve the bearing capacity of single pile. The karst cave different distances far away from the pile, the effect of pile friction is basically the same.

Introduction

Bearing capacity of a pile is the result of the interaction producing between pile and soil or rock. It is closely linked to the factors including the size, distribution, number of karst caves around the situation of the bearing stratum at the end of pile under the karst geology condition [1]. In recent years, study of pile stress mainly concentrates on the stability of the roof of the cave below the pile tip. However, there is no more study fixed on the bearing characteristics of large-diameter pile, when the cave around the pile.

It is vital for saving the expense and speeding up the construction period to correctly analyze effects of various factors on the bearing capacity of a pile in karst region [2]. For pile foundation engineering in karst region, the related theories are still not mature at present stage, whose research mainly use model experiments or field tests [3, 4]. However, a model experiment is based on the study of a particular project and in a particular condition, which is not systematic and lack of universality. It seems the only way that using simulation analysis do some related research to comprehensively reflect what effect the influence factors have on the stress characteristics of pile foundation in karst region.

Combined with large-diameter cast-in-situ bored piles used in Yuanshui bridge, the factors influencing the bearing capacity of pile are systematic analyzed using ABAQUS, in order to provide some reference for the design and construction of pile foundation in karst region. And, the factors analyzed include the buried depth of the karst cave, the rocked-socketed depth of the pile tip, and the distance from the cave to the pile.

Project Profile

Yuanshui bridge over Yuanjiang, a part of Xupu-Huaihua Highway, has 798.12 meters long. The bridge is located where the river is wide, the water is deep, the riverbed covering layer changes a lot and part of the riverbed appears almost bare rock. The bridge in karst development region, its pile foundation mostly uses cast-in-situ bored piles with a diameter of 2.5 m. Because of the caves, the length of pile varies greatly, ranging from 13.5 m to 49.5 m. The main forms of karst development are karren, fissure and cave, filled with flow plastic clay commonly and part of which are empty.

Finite Element Model

Model parameters. Pile body uses linear elastic model without considering its destruction. The soil layers around the pile and at the end of the pile use Mohr-Coulomb model. Specific parameters are shown in Tab.1 below.

Tab.1 Parameter list of finite element analysis

Material	Internal friction angle (°)	Severe (kN/m^3)	Elasticity modulus (Pa)	Cohesive force (Pa)	Poisson's ration
Pile	/	24	2e10	/	0.2
Lithosphere around pile	20	17	3e8	0.6e6	0.23
Lithosphere at the end of pile	25	23	8e9	1.2e6	0.22

Boundary condition. The model uses axisymmetric model with geometric symmetry, symmetrical load and a round cave. Horizontal displacement in central of model is limited. Vertical and horizontal displacements at the bottom and the side of the model are limited.

Finite element model. According to the actual situation of the engineering, the pile diameter is 2.5m and the length is 40m. The boundary of horizontal direction is one time the pile diameter of 40m and the bottom boundary is one time the pile length, that is, 40m. Fig.1 shows the pile 1d (2.5m) embedded into the supporting layer, with a cave having a radius of 6.25m and a height of 5m. And, the cave is 5m below the covering layer.

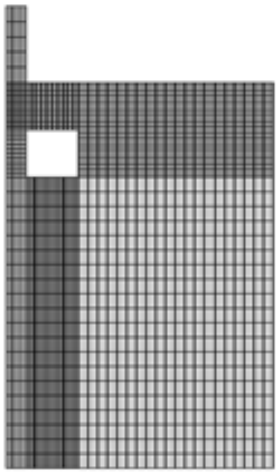

Fig.1 Finite element model

Calculation Results and Analysis

Influence of cave's buried depth. There is a cave with a radius of 6.25m and a height of 5m in karst geology. The pile body goes through the cave center and the rocked-socketed depth of pile tip is 2.5m. Three cases, supposing karst cave top 5m, 10m or 15m below the covering layer, are analyzed.

It can be seen from Fig.2 that when the cave is located 5m and 10m below covering layer, the P-S curve below the cave changes greatly, the P-S curve up the cave changes gently, then there is a steep drop section later. And, the ultimate bearing capacity of the pile is 7000KN. When the cave is located 15m under the covering layer, the pile top settlement curve changes smoothly and the ultimate bearing capacity of pile also accordingly increases to 8000kN. It shows that pile friction of the upper part of the pile plays a full part and the cave locates around the upper part of the pile has great influence on the ultimate bearing capacity of the pile.

Fig. 3 shows the changes of pile friction along with the length of pile varying in three cases when the pile top load is 7000kN. It can be seen from Fig.3 that the pile friction reduces to zero where locates the cave. With the same soil layers, the two cases are the cave 10m or 15m below the covering layer. The conclusion is the pile friction value of the latter is far greater than the former along the pile segment

between 15m-20m. And for the two cases of the cave 5m and 15m below the covering layer, effect of pile friction of the later is much greater than the former along the pile segment between 20m-25m. This is the main reason for the difference of the pile's bearing capacity.

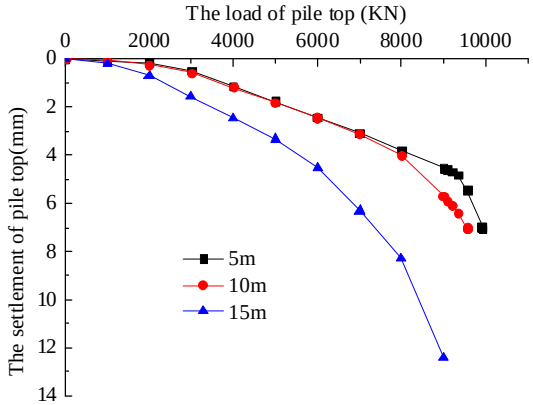

Fig. 2 Comparison of load-settlement curve of pile top

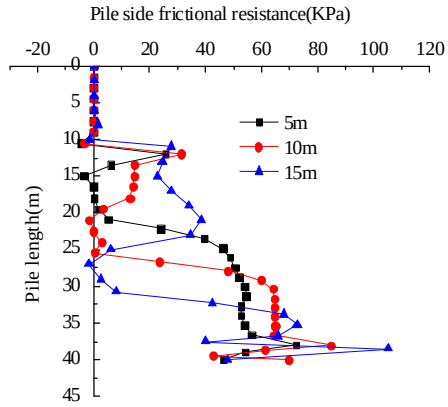

Fig. 3 Comparison of pile friction

Influence of rocked-socketed depth of pile tip. There is a karst cave with a radius of 6.25m and a height of 5m, the roof of which is 10 m below the covering layer. The pile goes through the cave center. Three cases that the rocked-socketed depth of the pile tip is 2.5m, 5m and 10m are analyzed.

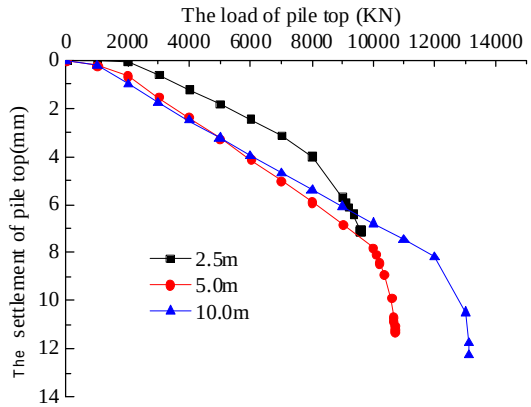

Fig. 4 Comparison of load-settlement curve of pile top

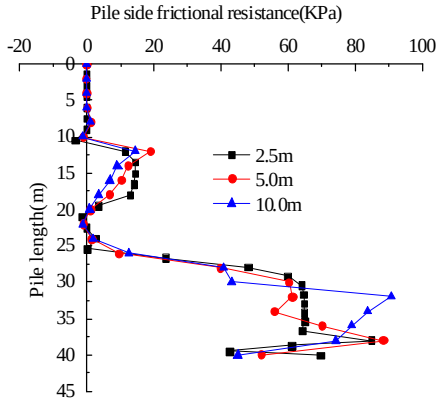

Fig. 5 Comparison of pile friction

It can be seen from Fig.4, the rocked-socketed depth of the pile tip has obvious influence on its bearing capacity. Overall, the bearing capacity increases with the rocked-socketed depth of the pile tip. When the rocked-socketed depth is 1d (2.5m), the ultimate bearing capacity is 8000kN. And the value reaches 9000kN and 12000kN as the rocked-socketed depth is 2d (5m) and 4d (10m). The characteristics of the rock-socketed pile are also more and more obvious. P-S curve of piles is similar to proportional deformation at the beginning. Steep drop section suddenly appears when the load reaches a certain value and the pile reaches the failure state. The deepening of the rock-socketed depth can improve the bearing capacity of single pile. On the one hand, the larger the bedrock densities, the larger the friction of rock-socketed section, and, on the other hand, that the constraint affects of the rock-socketed section is enhanced can also improve the bearing capacity of the pile.

Fig. 5 shows the changes of the pile friction along with the length of the pile in three cases with the pile top loaded with 8000kN. It can be seen from Fig.5 that the pile friction above the cave reduces with rock-socketed depth's deepening. While within rock-socketed depth, the pile friction increases with rock-socketed depth's deepening. The values of the bearing capacity are closely related to this part of the bearing capacity.

Influence of distance from cave to pile. There is a karst cave with a radius of 6.25m and a height of 5m, the roof of which is 10 m below the covering layer. And the pile, with the rocked-socketed depth of its tip is 2.5 m, goes through the cave center. Three cases that the distances from the cave to the pile are 0m, 3m and 5m are analyzed.

It can be seen from Fig.6, for the two cases of the pile with the same rock-socketed depth not going through the cave, the characteristics of the rock-socketed pile are more obvious, and the ultimate

bearing capacity of the pile is basically the same. But the pile top settlement is smaller in the case that the distance is 0 m.

Fig.7 shows the changes of the pile friction along with the length of the pile in three cases when the pile top load is 7000kN. For the three conditions, the effects of the pile friction are basically consistent. In the parts where the cave is, the pile friction is 0 when pile body goes through the cave. With the cave further from the pile, the effect of pile friction becomes greater. For the lower part of the cave, the effect of the pile friction is greater in the case the pile body goes through the cave. A conclusion is with the same rocked-socketed depth of the pile tip, the effect of the pile friction is basically the same.

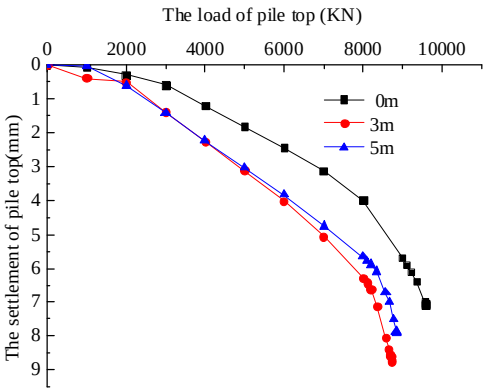

Fig. 6 Comparison of load-settlement curve of pile top

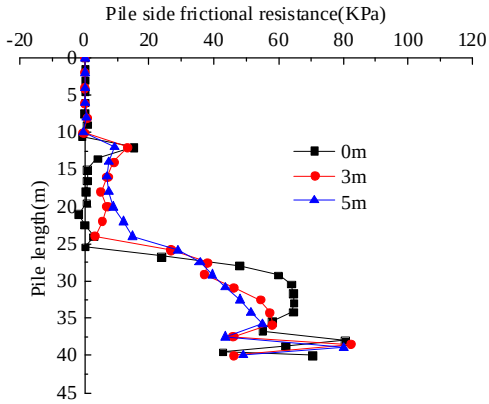

Fig. 7 Comparison of pile friction

Conclusion

Cave buried depth influences the bearing capacity of a pile, hallow buried depth of the karst cave, has great effect on the friction of the upper part of the pile, and, when the cave is lower, the bearing capacity of the pile increases.

Rocked-socketed depth of the pile tip has obvious influence on pile bearing capacity. In generally, the deeper the socketed depth of the pile, the higher it's bearing capacity. The deepening of the rocked-socketed depth can improve the bearing capacity of single pile.

Supposing the cave is far away from the pile at three different distances, the effect of friction is basically the same.

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