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BEHAVIOR ANALYSIS OF CANTILEVER ARCHED RETAINING STRUCTURES IN FOUNDATION PITS*

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Abstract: The results of systemic behavior analysis of cantilever arched retaining structure reported in this paper have significant value for guiding the design and application of such structure.

Key words: foundation pit, cantilever arch retaining structure, behavior analysis, influencing factors
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INTRODUCTION

The arched retaining structure, a new type of retaining structure in foundation pits(Cai et al., 1992), has many virtues such as more reasonable structure shape, smaller deformation, lower cost, and so on. But it has not often been used in engineering because its analysis method is not ripe. To solve this problem, the arched retaining structure is divided into a series of horizontal arches and vertical beams, and analyzed according to the principle of the arch-beam method used for analyzing arched dams(Zhang, 2000). According to the reaction-parameter method (one of the arch-beam methods), the skewback reaction forces are taken as unknown quantities, and solved with conditions such as the compatibility condition of deformation, and so on. After the reaction forces are found, the internal forces and deformations of the whole arched retaining structure can also be calculated. After considering the characteristics of retaining structures in foundation pits, the vertical beams are calculated by the elastic-reaction method commonly used in retaining structure design. The arch-beam method was combined with the elastic-reaction method to form a new method for analyzing arched retaining structures. This method had been proved by actual cases analysis to be effective, reasonable and reliable, and can be used in engineering practice(Zhang, 2000).

In this paper, this method is used to systematically analyze the behavior of cantilever arched retaining structures (Fig. 1). The influencing factors considered in the behavior analysis included the embedded depth, the subgrade soil characteristics, the arches shape, the buttress stiffness, and so on. The governing laws on the influence of these factors have important value for the design and application of cantilever arched retaining structures; and are detailed in this paper.

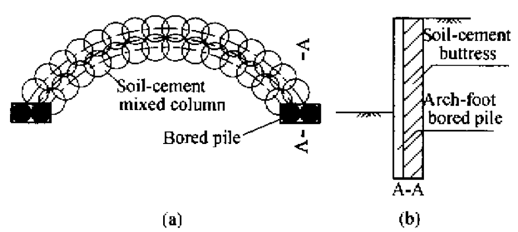

Fig.1 Sketch of arched retaining structure
(a) plan; (b) A-A section plane

BASIC PARAMETERS

The foundation pit parameters considered were: width = 20 m; length = 50 m; excavation depth = 6.0 m. The wall of the retaining structure (i.e. buttress) was formed by three rows of soil-cement columns arranged in an arch in a plane, and at each arch-foot were two $\Phi 600$ bored piles. The parameters of the arched retain-

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ing structure were as follows: radius of arch = 3.0 m; span of arch = 4.5 m; diameter of soil-cement columns = 500 mm, length of soil-cement columns = 12.0 m, center-to-center length of soil-cement columns = 350 mm. To simplify the calculation, the buttress thickness was taken to be equal to 1.2 m. Elastic modulus of the buttress = 120 MPa; elastic modulus of the arch-foot pile = 2.55×10^7 kPa. The parameters of the homogeneous subgrade soil were as follows: adhesive force c_{cu} = 10 kPa; angle of internal friction $\varphi_{cu} = 10°$; unit weight $\gamma = 17.0$ kN/m^3; proportion coefficient of subgrade soil reaction force m = 4000 kN/m^4. The earth pressure behind the retaining wall was Rakine active earth pressure above the excavation line, was constant below the excavation line, equaled to the pressure at the excavation line (Gong et al., 1998). The surcharge behind the wall was taken to be 30 kPa.

For comparison with other cantilever retaining structures, the behavior of a cantilever single-row pile retaining structure formed by Φ800 bored piles was also calculated. Its parameters were as follows: length of bored pile = 12.0 m, center-to-center length = 1.0 m. The characteristics of the subgrade soil were the same as those of the arched retaining structure. The calculation method was the "m" method that is one of the elastic-reaction methods.

BEHAVIOR ANALYSIS

Influcne of the embedded depth

Fig.2 shows the relation curves of the maximum deformation and maximum moment with the relative embedded depth d/h, where d is the embedded depth, and h is the excavation depth. Fig.2 (a) shows that the maximum deformation of the arched retaining structure slightly decreases at first with increasing of d/h, and then rapidly tends to constant, which indicates that the embedded depth has very small influence on the deformation; it also indicates that the maximum moment below the excavation line (abbreviated E. L. in Fig. 2 (a)) increases rapidly at first with increasing of d/h, but that the maximum moment (absolute value) above the excavation line decreases slightly. Both curves finally tend to constant. Fig.2 (a) also indicates that the total maximum absolute moment of the arch-foot pile takes place above the excavation line when d is small, and below it when d is large. Fig.2 (b) shows that in the case of the single-row pile retaining structure, the maximum deformation of the bored pile at first decreases rapidly with the increasing of d/h, and then tends to constant; and that the maximum moment of the bored pile

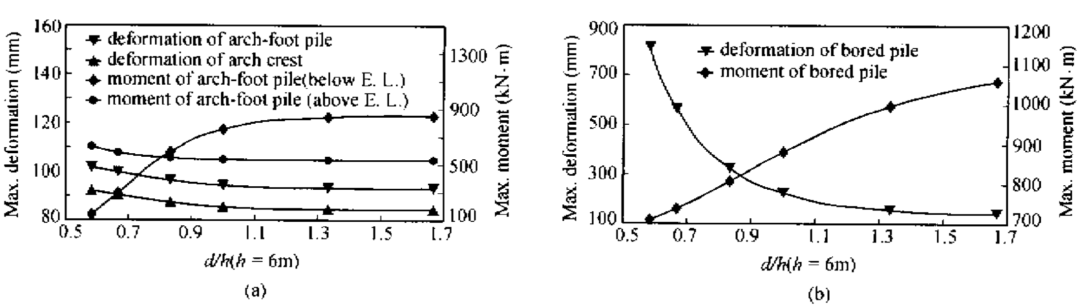

Fig.2 Relationship between the maximum deformation and moment with d/h
(a) arched retaining structure; (b) single-row pile retaining structure

increases with the increasing of d/h. At the same time, Fig.2 (b) indicates that the embedded depth should not be less than that of the excavation depth; otherwise, the deformation will be too large.

Influence of the subgrade soil characteristics

The relation curves of the maximum deformation and maximum moment of the arched retaining structure with m (where m is the proportion coefficient of subgrade soil reaction force) are shown in Fig.3 (a), where the maximum deformation decreases with increasing of m, at the same time, the maximum moment increases. Fig.3 (b) shows the relation curves of the maximum deformation and maximum moment of the bored pile of the single-row pile retaining structure with m. The maximum deformation at first decreases with increasing of m, and then tends to constant, but the influence of m on the maximum moment is very small.

In summary, m's influence on the deformation is larger than m's influence on the moment; on the single-row pile retaining structure is larger than that on the arched retaining structure; when m is small is larger than that when it is large.

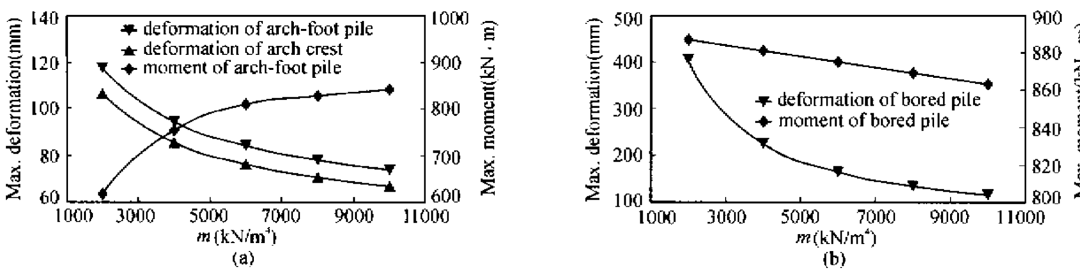

Fig.3 The relationship between the maximum deformation and moment with *m*
(a) arched retaining structure; (b) single-row pile retaining structure

Influence of the arches shape

The influence of the shape of arches includes two aspects, one is the influence of the type of arches when f/l is the same (where f/l is the ratio of arch height to arch span) and the other is the influence of f/l when the type of arches is the same. The types of arches considered in calculation include circle, parabola, catenary, ellipse, hyperbola, and logarithmic spiral. Calculation showed that the influence of the type of arches is very small when f/l is the same, but the influence of f/l is large. The relationships between the maximum deformation at the arch crest and arch-foot with f/l, and the maximum moment of arch-foot pile with f/l are shown in Fig.4, which shows that the maximum deformation and maximum moment at first decreases rapidly with increase of f/l; and that when f/l is larger than 0.3, the decreasing rate becomes small. Considering that if f/l is larger, the area for constructing is larger, so to economize on the construction field, the reasonable value of f/l of cantilever arched retaining structures should be about 0.3 ~ 0.35.

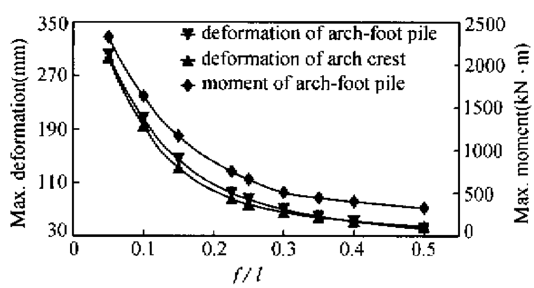

Fig.4 Relationships between maximum deformations and moment with *f/l*

Influence of the buttress stiffness

The relation of the maximum deformation of arch-foot pile and arch crest, and the maximum moment of arch-foot pile with the stiffness of the buttress are shown in Fig.5, where (a) is the

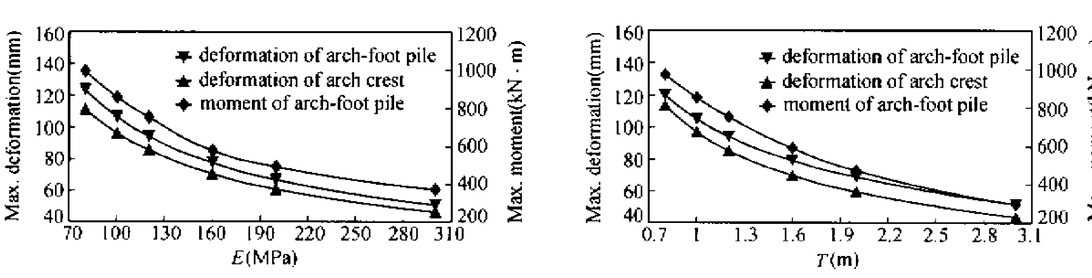

Fig.5 Relationship between the maximum deformation and moment with the stiffness of buttress
(a) influence of elastic modulus of buttress; (b) influence of thickness of buttress

relationship with the elastic modulus of the buttress, and (b) is the relationship with the thickness of the buttress, shows that: 1. When the buttress is stiffer the maximum deformation and maximum moment are smaller; 2. The decreasing of the maximum deformation and maximum moment when the stiffness is minimal is faster than that when the stiffness is considerable.

CONCLUSIONS

Behavior analysis of cantilever arched retaining structures led to the following conclusions:

1. The embedded depth has little influence on the behavior of cantilever arch retaining structures, and only need to satisfy the stability of the retaining structures, and so, can be of smaller value.

2. The influence of the value of m of subgrade soil on deformation is larger than that on the moment, on the single-row pile retaining structure is larger than that on the arched retaining structure; when m is small, is larger than that when m is large.

3. The type of arches has little influence when the ratio of arch height to arch span f/l is the same; but f/l has large influence on arched retaining structures; the reasonable value of f/l is about 0.3 ~ 0.35.

4. When the buttress is stiffer, the deformation and moment of cantilever arched retaining structure are smaller.

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