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Research on the Plate Cavity Geometry of the Squeezed Branch Pile

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Abstract

This paper deduced the cavity geometry of the plate under the action of one-way and two-way squeeze equipment which is hyperbolic for two-way squeezed, hyperbolic and arc for one-way squeezed. This paper points out the different stress characteristics and applicable conditions of bearing plate for the two kinds of squeezed branch pile, and provides references for the development of the squeezed branch pile.

Keywords: Squeezed Branch Pile; Plate Cavity Curve; Hyperbolic Curve

1. Introduction

Since 1992, the squeezed branch pile has been applied in the domestic civil engineering, municipal, shipping, aviation and highway, which bring the enormous social benefit and economic benefit. The invention of this pile is a great improvement and innovation for the traditional uniform section, renovates the pile structure, and makes fundamental changes on stress behavior and load transfer mechanism[1].

The squeezed branch pile is composed of the main pile, bearing plate, several numbers of branches and is surrounded by dense extrusion soil. The squeezed branch pile transfer the only one end bearing point of the end bearing friction pile into the pile body provided with a plurality of end bearing point of friction and end bearing piles, so that the ultimate bearing capacity of single pile is greatly increased. The geometry of the bearing disk is formed

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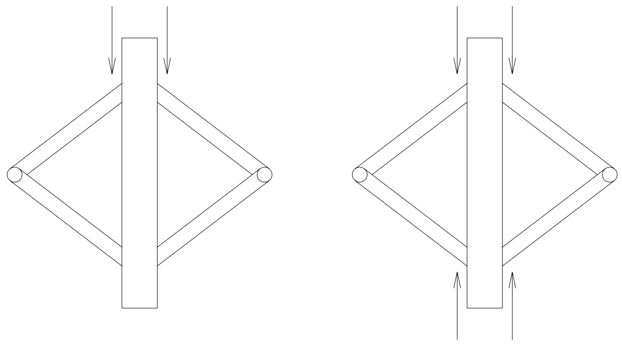
by the squeezed machine for multiple extrusions. The physical and mechanical properties of the undisturbed soil under the extrusion force is changed[2].

2. Analysis on Disc Cavity Curve

For forming a bearing disk, variety of squeezed branch disk machine, which it's working principle are basically the same, can be used. The squeezed form is divided into two kinds, one kind is unidirectionally squeezed, another is bidirectionally squeezed.



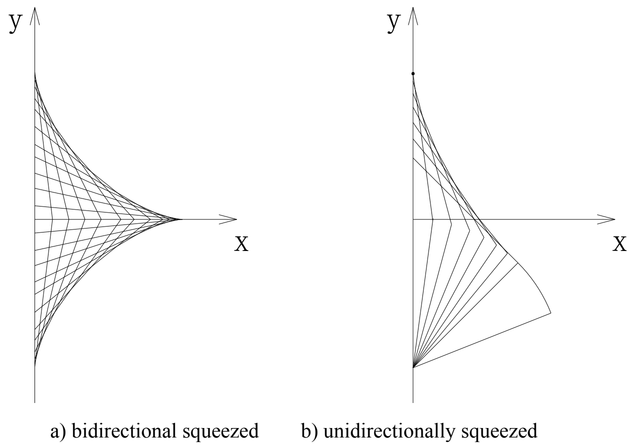
a) unidirectionally squeezed b) bidirectionally squeezed

Fig.1 The schematic diagram of the squeezed machine

When using bidirectional squeezed machine, hydraulic equipment push the bow pressing arm from two directions. The force of the upper arm and the lower arm is symmetric, which are symmetrically outward expansion, and to move equipment center. In this process, the soil is squeezed by the bow pressing arm. The soil produces a certain plastic deformation.

When using the one-way squeezed machine, lower fulcrum remained stable under bow pressing arm, hydraulic cylinder applied thrust from the upper bow pressing arm, push and squeezed the soil. At this time, compared with the upper soil, the soils under the bow arm deserve the bigger pressure and the better compacting effect.

The length of bow pressing arm is unchanged in the squeezing process, while only the angle of the arm is changed. Two kinds of outline of disc cavity after squeezed can be showed by drawing, as shown in Fig.2.



a) bidirectional squeezed b) unidirectionally squeezed

Fig. 2 disc cavity outline

3. Disc Cavity Curve Derivation

（1）When bidirectional expanded, upper and lower arm are symmetric. Because of the movement of the upper arm, the profile of disc cavity can be drawn.

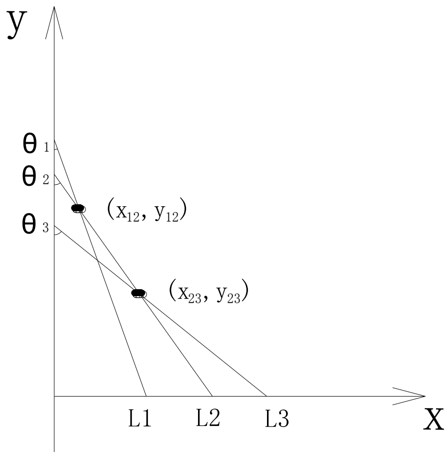


Fig.3 general gesture of bow pressing arm

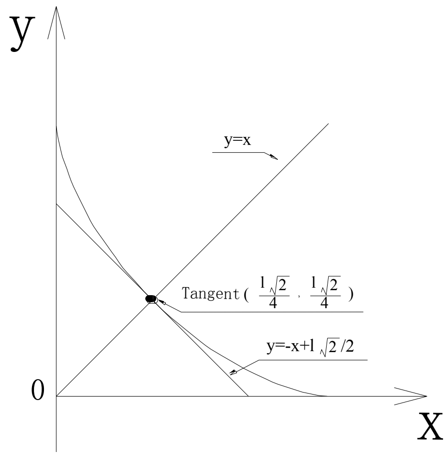


Fig.4 especial gesture of bow pressing arm

As shown in figure 3, the length of the bow pressing arm is l. At the moment t_1, t_2, t_3, the gesture line of the arm are L_1、L_2、L_3. The intersection of L_1 and L_2 are (x_{12}, y_{12}). The intersection of L_2 and L_3 are (x_{23}, y_{23}). The angle between arms and the vertical axis are θ_1、θ_2、θ_3. The slope of the three line k_1, k_2, k_3 are $-\cot\theta_1$, $-\cot\theta_2, -\cot\theta_3$.

When $\begin{cases}\theta_1 = \theta_2 - \Delta\theta \\ \theta_3 = \theta_2 + \Delta\theta\end{cases}$,and $\Delta\theta \to 0^+$, then $(x_{23}, y_{23}) \to (x_{12}, y_{12})^+$. The line between (x_{12}, y_{12}) and (x_{23}, y_{23}) is the tangent of the outer contour line.

Let $k = \lim_{x_{23} \to x_{12}^+} \frac{y_{23} - y_{12}}{x_{23} - x_{12}}$, which is the tangent slope of outer contour line at point (x_{12}, y_{12}). As shown in figure 3, $k = k_2$, and $k = -\cot\theta_2 = -\frac{y}{x}$, then :

$$\frac{dy}{dx} = -\frac{y}{x} \tag{1}$$

Solute the differential equation above, the general solution of contour equation:

$$y = \frac{c}{x} \tag{2}$$

As shown in figure 4, because of the symmetry, contour and the line $y = -x + l\sqrt{2}/2$ tangent to the point

$(\frac{l\sqrt{2}}{4},\frac{l\sqrt{2}}{4})$, tangent slope $k=-1$, then:

$$k=y'=-\frac{c}{x^2}\Big|_{x=l\sqrt{2}/4}=-1 \tag{3}$$

$$c=\frac{l^2}{8} \tag{4}$$

Therefore, expanded by the two-way squeezed machine, the disc cavity contour curve is hyperbola, curve equation as follows:

$$xy=\frac{l^2}{8} \tag{5}$$

（2）When unidirectional squeezed, the lower arm under constraint of the lower fulcrum . The lower arm is in circular motion when the lower fulcrum is fixed as center of the circle. This trajectory is relatively simple. The two endpoint of the upper arm are in the changing, the trajectory of the contour curve needs to be calculated.

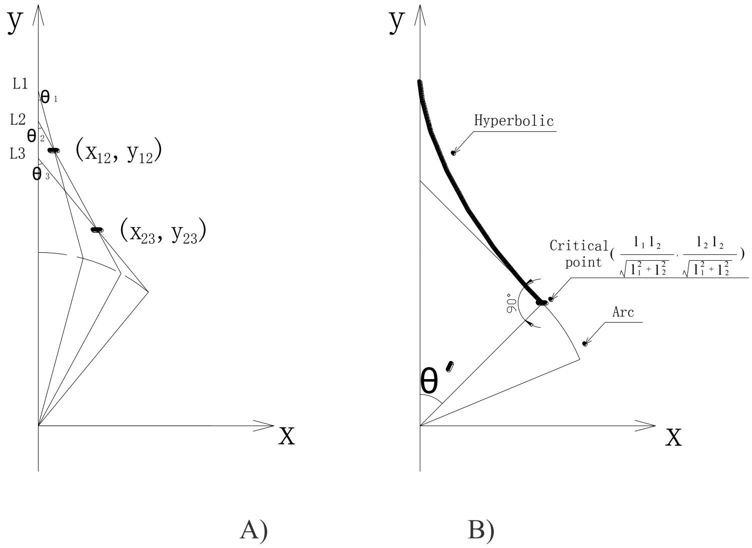


Fig. 5 bow pressing arm gesture of one-way squeezed machine Fig. 6 one-way squeezed machine disc cavity contour

As shown in figure 5, the length of the upper arm is l_1, the length of the lower arm is l_2 .At the moment t_1,t_2,t_3, the gesture line of the arm are L_1、L_2、L_3. The intersection of L_1 and L_2 are (x_{12},y_{12}). The intersection of L_2 and L_3 are (x_{23},y_{23}). The angle between arms and the vertical axis are θ_1、θ_2、θ_3. So the slope of the three line k_1,k_2,k_3 are $-\cot\theta_1,-\cot\theta_2,-\cot\theta_3$.

When $\begin{cases}\theta_1=\theta_2-\Delta\theta\\ \theta_3=\theta_2+\Delta\theta\end{cases}$, and $\Delta\theta\to 0^+$, then $(x_{23},y_{23})\to(x_{12},y_{12})^+$. So the line between (x_{12},y_{12}) and

(x_{23}, y_{23}) is the tangent of the outer contour line.

Let $k = \lim_{x_{23} \to x_{12}^+} \frac{y_{23} - y_{12}}{x_{23} - x_{12}}$, which is the tangent slope of outer contour line at point (x_{12}, y_{12}). As shown in figure 3, $k = k_2$, and $k = -\cot\theta_2 = -\frac{y}{x}$, then :

$$\frac{dy}{dx} = -\frac{y}{x} \tag{6}$$

Solute the differential equation above, the general solution of contour equation:

$$y = \frac{c}{x} \tag{7}$$

As shown in figure 6, with the angle between the upper arm and the vertical axis becomes larger and larger, the angle between lower arm and the vertical axis becomes larger, until the upper and lower arms is orthogonal when they are in the critical state. At the moment, θ_{up} is the critical angle $\theta' = \arctan\frac{l_1}{l_2}$. With θ_{up} becomes larger, the upper arm and the soil out of contact, only the lower arm squeeze soil. The lower arm continues to squeeze the soil to be a sector whose side profile is arc.

When in a critical state, activities endpoint of the lower arm l_2 is the critical point whose coordinate is:

$$(x, y) = \left(\frac{l_1 l_2}{\sqrt{l_1^2 + l_2^2}}, \frac{l_2 l_2}{\sqrt{l_1^2 + l_2^2}} \right) \tag{8}$$

This point is the intersection of side profile which squeezed by line l_1 and l_2. Because $y = \frac{c}{x}$, then:

$$c = xy = \frac{l_1 l_2}{\sqrt{l_1^2 + l_2^2}} \frac{l_2 l_2}{\sqrt{l_1^2 + l_2^2}} = \frac{l_1 l_2^3}{l_1^2 + l_2^2} \tag{9}$$

When the upper and the lower arm lengths are equal, that is $l_1 = l_2 = l$, then :

$$xy = \frac{l^2}{2} \tag{10}$$

Therefore, expanded by the one-way squeezed machine, the disc cavity contour curve is combination of hyperbolic line and arc:

$$xy = \frac{l_1 l_2^3}{l_1^2 + l_2^2} \text{ when } \theta \le \theta' = \arctan\frac{l_1}{l_2} \tag{11}$$

$$x^2 + y^2 = l_2^2 \quad \text{when } \theta > \theta' = \arctan\frac{l_1}{l_2} \tag{12}$$

4. Analysis on Applicability

Squeezed by two-way squeeze machine, the side profile of soil under the plate and soil above plate is hyperbola. The soil far which is away from the hole wall soil is under the higher level of compression which can obtain better bearing capacity. But the soil which is close to borehole wall is under the lower level of compression. By Contrast, its force performance is not good.

Squeezed by one-way squeeze machine, the situation of the soil is: the disc cavity contour curve is combination of hyperbolic line and arc. The length of the arc is relative of the critical angle and finally squeezed angle . Disc bottom is straight. The level of compression of disc bottom is higher than disc upper. It meets the requirement of that disc bottom soil bearing most of the force. So when they are same of arm length, soil can be more close-grained which is squeezed by one-way squeeze machine. So the bearing capacity of soil under the plate increase more than two-way squeeze machine.

Overall, the pile which its plate is squeezed by one-way machine is more suitable for compressive pile because of higher level of the compressive degree of soil under the plate. When squeezed by the two-way squeeze machine, the level of compression of the soil under the plate and above the plate is equal. Compare with squeezed by one-way squeeze machine, the compressive degree of soil above the plate squeezed by two-way squeezed machine obtain higher bearing capacity, so it is more suitable for uplift pile.

5. Conclusion

(1) The disc cavity curve is hyperbola when squeezed by two-way squeeze machine, which is different from the combination of hyperbolic line and arc when squeezed by one-way squeeze machine.

(2) The pile which its plate is squeezed by one-way machine is more suitable for compressive pile, while pile which its plate is squeezed by two-way machine is more suitable for uplift pile.

(3) Through the analysis of different squeeze ways of squeezed branch pile and their disc cavity curve, enhance mutual understanding to the structure of this pile and its bearing feature, which provide a reference for development of the squeeze branch pile technology.

References

[1] Wang Mengshu, He Dexin, Tang Songtao. the New Pile Technology of 21 Century-DX Rotary Drilling Squeezed Branch Pile[J]. Engineering Science.2012,14(1):5-11.

[2] Zhang Yanqing, Zhou Mingfang. Study on the Molding Process of the Hydraulic Pressure Squeezed Branch Pile[J]. Journal of Beijing University of Technology.2001,27(1):54-56.