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◆Research Paper◆

Analysis of Lateral Soil Pressures for Reinforced Earth Retaining Wall Based on Tensile Failure

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Abstract: Considering the effect of reinforcement, and applying the cohesive force theory and Coulomb's earth pressure theory, thus the tensile failure theoretical formulae of lateral soil pressure for reinforced earth retaining wall is obtained. Analytical results show that cohesive force of reinforced earth has increment for the tensile failure. The lateral soil pressures value of wall back using proposed formula are smaller than using classical earth pressure theories of variable coefficient method. And the lateral soil pressure will increase with increasing of vertical spacing of reinforcement and decrease with increasing of the tensile strength of the reinforcement. The calculating results of this proposing method basically accord to results of the site tests in geogrid reinforced earth retaining wall.

Keywords: strength model, lateral soil pressure, reinforced earth retaining wall, vertical spacing, tensile failure

1 Introduction

The key of reinforced earth retaining wall's design is the calculation of reinforcement's tensile force. The tensile force is provided by the frictional resistance between there reinforcement sand soil. And soil pressure on the wall panel is equal to frictional resistance between there reinforcement sand soil[1-2]. Therefore, the key of reinforced earth retaining wall's design is to determine the soil pressure of wall back. There are the Coulomb force law, Coulomb method of moment, normal stress uniform distribution method, normal stress trapezoidal distribution method, Medvedev normal stress distribution method, Osman energy method, empirical method and highway variable coefficient method[2] and some other methods to calculate soil pressure of wall back currently. These methods almost adopt the Rankine's earth pressure theory formula and amended its coefficient of earth pressure. The highway variable coefficient method can explain some of the actual condition of earth pressure distribution more reason ably compared with other methods. So it is widely used in

the design of reinforced earth retaining wall. Yin Yaxiong[3],Wang Xiang [4], ,Yang Guangqing[5] etc. carried out the field study on reinforced earth retaining wall. AndT ang Huiming[6], Lin Tong[7] Zhou Shiliang[8] carried out the model test of reinforced earth retaining wall. These results showed that the wall back earth pressure shows curve distribution along with wall height. In 2009,Yang Guangqing and Zhou Yitao etc. compared the measured value with theoretical calculating value of the lateral soil pressure of reinforced earth retaining wall back and discovered that the measured value were small, and the distribution of soil pressure along with the wall height was great different from the actual measured data[9].

The effects of reinforcement was taken into consideration and the half-space theory was used to discuss the strength of reinforced earth under form of tensile failure. And then, the theory of quasi cohesive force and Coulomb were used to discuss the distribution and resultant force of wall back active earth pressure of reinforced earth retaining wall. And the calculation formula of soil pressure of reinforced earth retaining wall was proposed and tested under the condition of tensile failure.

2 Analysis of reinforced earth strength model

Assuming that the vertical layer spacing of reinforcement is h(m), thickness of reinforcement is t(m), and the tensile strength of reinforcement is R_T(kN/m). The filling earth is cohesionless soil and its volume-weight is γ (kN/m^3). Its internal friction angle is φ and reinforced soil interface friction coefficient is f.

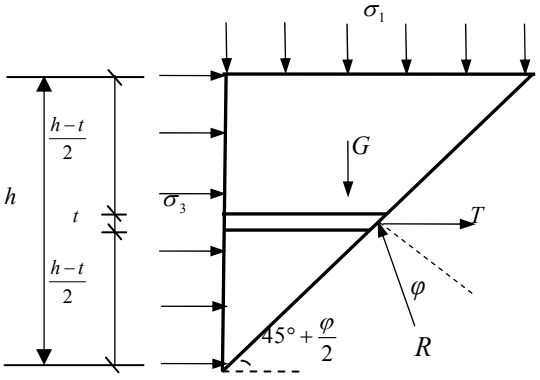

Fig.1 Strength model of reinforced soil

The unit width of reinforced earth as shown in Fig.1 is taken to study the reinforced earth retaining wall. Assuming that the angle between fracture surface and horizontal direction (angle of rupture) is 45°+φ/2, the shear force which reinforcement acting on the filling earth is T(kN), and the soil weight is $G=\gamma h^2 cot(45°+\varphi/2)/2$.Thereinforced earth failure can be divided into tensile failure and cohesive failure. In view of the two

cases, so the strength of reinforced earth was discussed from the two aspects respectively. Because the thickness of reinforcement is very small compared with its layer spacing, so the thickness of reinforcement is ignored in the following discussing.

The tensile failure is a kind of break resulted from the insufficient of tensile strength of reinforcement material when the reinforced earth arrives at its boundary state of stress.. So the shear force T which reinforcement acting on filling earth between reinforcement and earth is controlled by the tensile strength of reinforcement. That is,

$$T = R_T \tag{1}$$

The relational expression under the condition of tensile failure is obtained through the force analysis about Fig.1:

$$\sigma_3 = K_a(\sigma_1 + \frac{1}{2}\gamma h) - \frac{R_T}{h}$$

$$= K_a(\sigma_1 + 0.5\gamma h) - 2c_T\sqrt{K_a} \tag{2}$$

In the relational expression, K_a coefficient of active earth pressure, $K_a = \tan^2(45° - \frac{\varphi}{2})$

C_T is cohesion under the condition of tensile failure,

$$c_T = \frac{R_T}{2h}\tan(45° + \frac{\varphi}{2})\circ \tag{3}$$

The relational expression (2)illustrates that the cohesion of reinforced earth is stronger than the soil without reinforcement.

3 Soil pressure analysis of the reinforced earth retaining wall

3.1 Forced model based on quasi cohesive strength

Assuming that when the filling earth behind reinforced earth retaining wall arrives at the initiative ultimate equilibrium, it will slide along a certain BC plane which is enclosed by wall back, wall toe and standard plane. The sliding of ABC sliding wedge leads to the production of soil pressure on the retaining wall. There are gravel filling of 0.5m thickness behind the wall. And there is mismatch between reinforcement and gravel filling. So it can be assumed that there is no quasi cohesive strength on the interface between wall and soil. Quasi cohesive strength C is on the fracture surface and the thickness of rebar material is ignored. Considering the reinforced earth as homogeneous composite material. The force of the ABC sliding wedge are shown in Fig.2according to the Coulomb theory.

The height of reinforced earth retaining wall is H(m).Reinforcement is arranged with equal spacing $h(m)$. The filling earth surface is standard and under the uniform loading of $q_0(kN/m)$. The friction angle of wall earth is σ (°).

Through the force equilibrium analysis of reinforced earth on the horizontal

direction, it can be obtained,

$$E + cH\cot\theta = R\sin(\theta - \varphi) \tag{4}$$

Through the force equilibrium analysis of reinforced earth on the vertical direction, it can be obtained,

$$\frac{q_0 H + \gamma H^2/2}{\tan\theta} = E\tan\delta + cH + R\cos(\theta - \varphi) \tag{5}$$

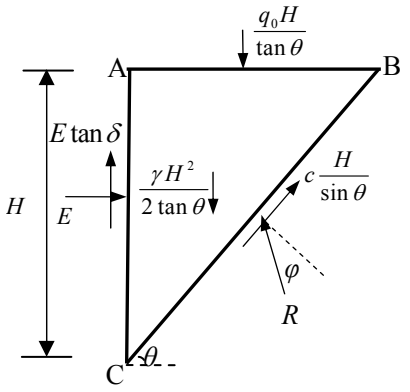

Fig.2 Stress diagram of the reinforced earth

Combining(4) and (5), the resultant force of lateral soil pressure on the wall back of reinforced earth retaining wall is *E*:

$$E = \frac{\cos\delta\sin(\theta-\varphi)}{\tan\theta\cos(\theta-\varphi-\delta)}(q_0 H + \frac{1}{2}\gamma H^2) - \frac{\cos\delta\cos\varphi}{\sin\theta\cos(\theta-\varphi-\delta)}cH \tag{6}$$

When the quasi cohesive strength *c* is 0, (6) is the Coulomb's earth pressure formula.

3.2 Soil pressure of reinforced earth retaining wall under the condition of tensile failure

Setting $c=c_T$, the resultant force E of standard soil pressure acting on the wall back of reinforced earth retaining wall under the condition of tensile failure can be obtained by (3) and (6) as following:

$$E = \frac{\cos\delta\sin(\theta-\varphi)}{\tan\theta\cos(\theta-\varphi-\delta)}(q_0 H + \frac{1}{2}\gamma H^2) - \frac{\cos\delta\cos\varphi\tan(45°+\frac{\varphi}{2})}{\sin\theta\cos(\theta-\varphi-\delta)}\frac{R_T H}{2h} \tag{7}$$

When δ=0,and θ=45°+φ/2 in (12), it can be obtained that,

$$E = K_a(q_0 H + \frac{1}{2}\gamma H^2) - \frac{H}{h}R_T \tag{8}$$

When RT=0, (13) is the Coulomb active earth pressure formula.

Coulomb's earth pressure theory believes that soil pressure σ_a shows linear distribution along wall height. According to $dE/dH=\sigma_a$ and setting δ=0 and θ=45°+φ/2. It can be obtained that,

$$\sigma_a = K_a(q_0 + \gamma H) - \frac{R_T}{h} \tag{9}$$

From the (7)-(9), it can be identified that the soil pressure (resultant force) acting on the wall back of reinforced earth retaining wall under the condition of tensile failure has one more item than Coulomb's earth pressure which is related with tensile strength and vertical spacing of reinforcement. And it decreases with the increase of tensile strength and increases with the growth of vertical spacing.

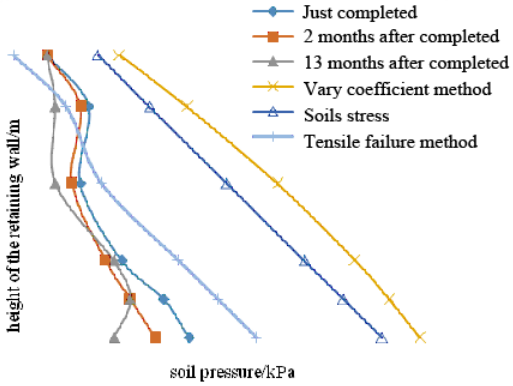

Fig.3 Distribution of lateral soil pressure of reinforced retaining wall along wall height

4 Analysis example

As shown in Fig.3, the proposed calculation method for soil pressure of reinforced earth retaining wall is compared with measured data. The parameters in references[9] areas following: the spacing between reinforcements is 0.6m when the height of wall is more than 3.2m, the spacing between reinforcements is 0.4m when the wall is shorter than 3.2m, the interface friction coefficient between the reinforcements and soil is f=0.3, the tensile strength of reinforcements is R_T=6kN/m(strength values of 0.5% reinforcements strain). γ=19 kN/m^3, φ=25°, q=15 kPa.

It can be seen from Fig.3 that the lateral soil pressure calculated through the tensile failure method and cohesive failure method proposed in this paper is smaller than the soil pressure which obtained by earth pressure at rest method and variable-coefficient. And the pressure is very close to the measured value. At the range of the 1/3 height from the top of the wall, the data received from the tensile failure method is smaller than measured value. At the rest of range the result is on the contrary. The measured values are enveloped in the results cohesive failure method. It illustrates that cohesive failure method is safe and reliable. And it is fit for the design of geogrid reinforced earth retaining wall.

5 Conclusion

Through the analysis above, the following conclusions can be received:

(1) Reinforced earth cohesion under increases under the tensile failure;

(2) The soil lateral pressure calculating formula proposed in this paper for the wall back of reinforced earth retaining wall takes a full consideration of reinforcements influence on the lateral soil pressure. The result is smaller than the classical soil pressure and variable-coefficient and very close to the measured value;

(3) Soil lateral pressure of reinforced earth retaining wall increases along with the increase of reinforcement's vertical spacing;

(4) Soil lateral pressure of reinforced earth retaining wall decreases along with the increase of reinforcement's tensile strength.

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