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Sensitivity Analysis on Stability Parameters in Landfill

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Abstract: To study the stability of waste body failure in landfill, the landfill was divided into two parts: an active wedge and a passive wedge. A limit equilibrium analysis was used to calculate the safety factor of stability in landfill. The parameters which affected the stability of the landfill were discussed. Sensitivity curves of each parameter were proposed and effect trends of various parameters on safety factor were analyzed. Cohesion c and internal friction angle φs increases linearly with the safety factor. The safety factor decreases with increasing slope angle β and filled height H. The safety factor of after landfill settlement was higher than the safety factor of settlement which did not occur. It increases the overall stability about 16%.

Keywords: Cohesion, filled height, internal friction angle, landfill, safety factor, sensitivity analysis, settlement, stability.

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1. INTRODUCTION

Urban landfill already became one of the effective means to deal with urban living garbage for its economy and the advantage of convenient in various countries. Because of the stringent environmental requirements, the system to collection and treatment the waste leachate and the channel to exclude and collection the waste gas must be equipped. Nowadays the most common and effective method of dealing with solid waste is urban landfill. In the landfill, the liner and the mulch are clayey soil, geosynthetic materials (such as geomembrane, geotextile fabric and geogrid), or their combination and so on. The shear strength of these protective material interface is less than the garbage body itself, which lead to sliding surface between protective system and garbage body easily. Liner system can prevent waste body, while it does increased the likelihood of landfill instability and deformation [1]. In the event of landfill site buckling failure, in addition to causing casualties, it will seriously pollute environment caused by the instability of diffusion, garbage leachate leakage, gas emissions. Landfill site, therefore, no matter size, its stability is one of the most important factors to consider in the process of design, construction operation and after the field sealing [2].

Foreign scholars mainly studied internal liner block system in terms of the stability of landfill site, and Howland *et al.* analyzed the stability of landfill in the of terms geotechnical to guide the design and construction of the landfill body and the liner system. Shear tests have been carried out using torsion ring shear apparatus by Stark and others, on contact surface between HDPE film using three different techniques and non-woven geotextiles. Danel and others do some partition testing and analysis about the stability of block system. Giroud and Beech put forward the calculation formula of the composite static static stability of composite slope safety factor and geogrid reinforced force using rigid body limit equilibrium method and based on the theory of double sliding wedge. Domestic scholars Li Zhibin and others have studied on the experimental methods of the stability of landfill liner block system. Wang Xiequn and others, respectively, analyzed landfill block stability of slope under the influence of seepage using the limit equilibrium method and finite element method. Feng Shi-jin analyzed the stability of the under seismic action for landfill capping system using the limit equilibrium method.

Due to the complexity of garbage body composition and constantly changing over time, its physical and mechanical parameters is also changing. And parameters values in the stability analysis of landfill site is fixed, so it is necessary to analyze the influence of various parameters on the stability of landfill and sensitivity analysis by changing the parameter size [3].

2.MODEL BUILDING

As most of the landfill sites are valley landfill in china, waste dam built in the slope toe of landfill, so it may be sliding failure as shown in Fig. (**1**).

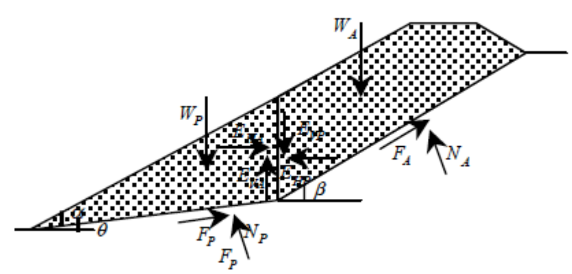

Fig. (1). Profile diagram of waste body and stress analysis.

2.1. Fundamental Assumption

As shown in Fig. (**1**), the sliding landfill body along the top to the bottom of valley type of landfill trade treat as rigid

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body and dissected it in the vertical direction and divided into active and passive two wedge. To establish limit equilibrium equation on the wedge, make some assumptions as follows [4]:

Assuming that the safety factor along the slip surface is equal in the body of landfills;

Assuming that the mutual effect resultant force is equal between the active wedge body and passive wedge body, namely $E_{HA} = E_{HP}$, $E_{VA} = E_{VP}$;

Assuming that the rationality requirement of limit equilibrium method is satisfies, namely, the safety factor of the interface between the wedges, not less than the landfill [5];

Assuming that the leachate water head is low, so don't consider the effect of seepage [6].

2.2. Establishment The Equilibrium Equation

Force acting on active the wedge and passive wedge is shown in Fig. (**1**), the meaning of the relevant parameters in the figure as follows [7]: W_A is the weight of the active wedge; W_P is the weight of the passive wedge; N_A is the normal force acting on the bottom of the active wedge; N_P is the normal force acting on the bottom of the passive wedge; F_A is the friction force acting on the bottom of the active wedge; F_P is the friction force acting on the bottom of the passive wedge; E_{HA} is the normal force that the passive wedge acted on the active wedge (direction perpendicular to the surface between wedges); E_{HP} is the normal force that the active wedge acted on the passive wedge (direction perpendicular to the surface between wedges); E_{VA} is the friction acting on the edge of the active wedge; E_{VP} is the friction acting on the edge of the passive wedge; δ_A is the smallest friction Angle of each interface multilayer composite liner under the active wedge; δ_P is the smallest friction Angle of each interface multilayer composite liner under the passive wedge; φ_S is the internal friction Angle garbage body in the landfill site; α is the slope Angle of garbage body slope; θ is the dip angle of landfill base; β is the slope Angle of landfill slope; F_S is the safety factor of the landfill waste body.

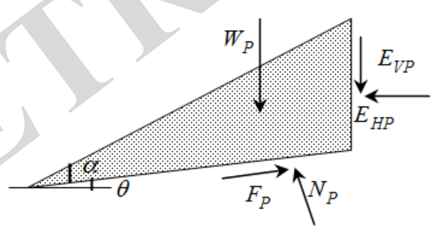

Fig. (2). Stress analysis of the wedge.

As shown in Fig. (**2**), given the equilibrium of forces on the passive wedge body, column,respectively, balance equation in the direction of

$\sum F_Y = 0$ and $\sum F_x = 0$, thus :

$$W_P = N_P\left(\cos\theta + \sin\theta\tan\delta_P / F_S\right) - E_{HP}\tan\varphi_S / F_S \tag{1}$$

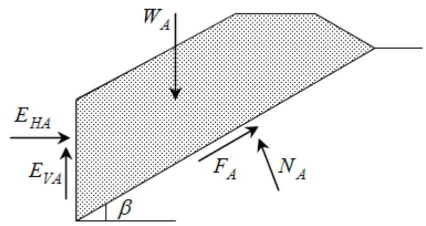

Fig. (3). Stress analysis of the active wedge.

As shown in Fig. (**3**), given the equilibrium of forces on the active wedge body, column,respectively, balance equation in the direction of

$\sum F_Y = 0$ and $\sum F_x = 0$,thus:

$$W_A = N_A\left(\cos\beta + (\sin\beta\tan\delta_A / F_S)\right) + E_{HA}\tan\varphi_S / F_S \tag{2}$$

2.3. Determine The Safety Factor

Due to $E_{HA} = E_{HP}$ and $E_{VA} = E_{VP}$ between the active wedge and passive wedge, at the same time, assume that both of the safety factor are F_S in active wedge and passive wedge, thus :

$$\begin{aligned} & W_A\left[\sin\beta - \left(\cos\beta\tan\delta_A / F_S\right)\right]\{\cos\theta + \\ & \left[\left(\tan\delta_P + \tan\varphi_S\right)\sin\theta / F_S\right] - \cos\theta\tan\delta_P\tan\varphi_S / F_S^2\} \\ & = W_P\left[\left(\cos\theta\tan\delta_P / F_S\right) - \sin\theta\right]\{\cos\beta + [(\tan\delta_A + \\ & \tan\varphi_S)\sin\beta / F_S] - \cos\beta\tan\delta_A\tan\varphi_S / F_S^2\} \end{aligned} \tag{3}$$

Which make $W_T = W_A + W_P$, W_T is the total weight of garbage body between active wedge and passive wedge, the type can be simplified to

$$A \cdot F_S^3 + B \cdot F_S^2 + C \cdot F_S + D = 0 \tag{4}$$

In the type

$$A = W_A\sin\beta\cos\theta + W_P\cos\beta\sin\theta \tag{5}$$

$$B = \left(W_A\tan\delta_P + W_P\tan\delta_A + W_T\tan\varphi_S\right)\sin\beta\sin\theta - \left(W_A\tan\delta_A + W_P\tan\delta_P\right)\cos\beta\cos\theta \tag{6}$$

$$\begin{aligned} C = -[&W_T\tan\varphi_S(\sin\beta\cos\theta\tan\delta_A \\ &+ \cos\beta\sin\theta\tan\delta_A) + (W_A\cos\beta\sin\theta \\ &+ W_P\sin\beta\cos\theta + \tan\delta_A\tan\delta_P] \end{aligned} \tag{7}$$

$$D = W_T\cos\beta\cos\theta\tan\delta_A\tan\delta_P\tan\varphi_S \tag{8}$$

3. SENSITIVITY ANALYSIS OF STABILITY PARAMETERS

In this article, the minimum Angle of internal friction on the bottom of the landfill field δ_P is 20°; the minimum residual slope Angle of internal friction in the slope seepage control system δ_A is 14°; the internal friction Angle of landfill waste φ_S is 33°; the Garbage density γ is $10.2kN/m^3$; landfill bottom slope is 2%;the bottom length is $54m$; the slope

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dump body is 4:1;the landfill slope β is 18.4°; The slope height is $30m$; The length of the pile body top level section is $20m$ (the distance between the pile body top and the original slope top). Due to the indicators change range of garbage body stability parameter is large, and a certain index changes will affect the calculation results, we will know the stability sensitivity of garbage body on this index by the different degree influence [8]. When calculating the sensitivity of an indicator, the rest of the parameters are calculated according to fixed value.

3.1. The Influence On The Stability Of Cohesive Force c

Calculate the Safety factor F_S on stability of the dump body by changing the values of cohesive force c, while other parameters values are fixed, the relation curve of different cohesion corresponding safety factor is shown in Fig. (**4**). The Fig. (**4**) shows that, basically, the safety factor increases linearly with the increasing of cohesion. When the cohesive force is less than $14.1Kpa$, the safety factor of slope is less than 1.25, and the slope is in a state of insecurity.

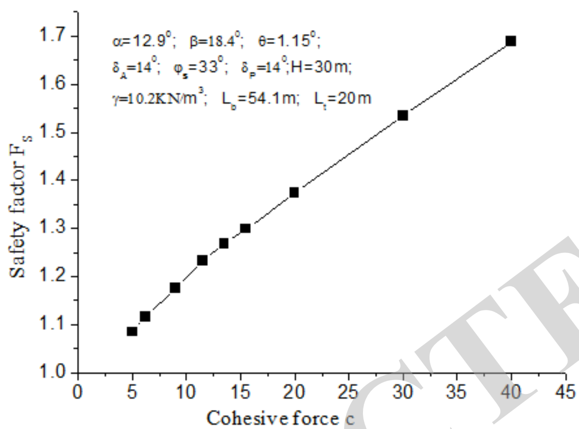

Fig. (4). Curve of Cohesion c and safety factor.

3.2. The Influence On The Stability Of Internal Friction Angle φ_S

Calculate the Safety factor F_S on stability of the dump body by changing the values of internal friction Angle φ_S, while other parameters values are fixed. When internal friction Angle is greater than the 17°, the safety factor on stability is greater than 1.25, and the dump body is in a safe state. When internal friction Angle is less than the 17°, the safety factor on stability is less than 1.25, and the dump body is in a state of insecurity. When internal friction Angle is less than the 12°, the garbage body will be mass destruction. The Fig. (**5**) shows that the safety factor increases linearly with the increasing of internal friction Angle.

3.3. The Influence On The Stability Of The Slope Angle β

The slope Angle β mainly refers to the Angle between the active wedge and horizontal plane. In the case of other parameters are fixed, the relation curve of the slope Angle and the sensitivity of the safety factor is shown in Fig. (**6**). With the increase of the slope Angle β, the safety factor F_S gradually reduce, when the slope Angle β is less than 22°, the safety factor is less than 1.25, the garbage body shows the tendency of instability.

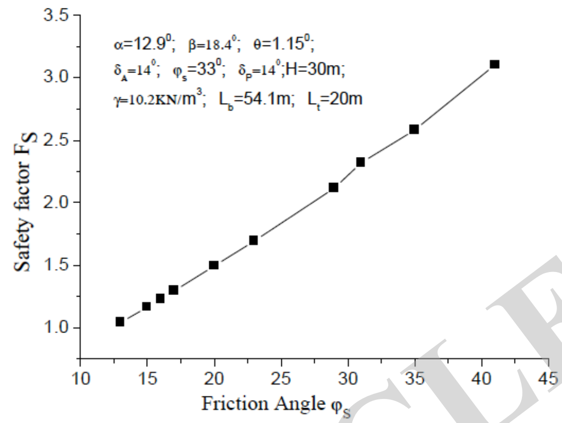

Fig. (5). Curve of internal friction angle φ_s and safety factor.

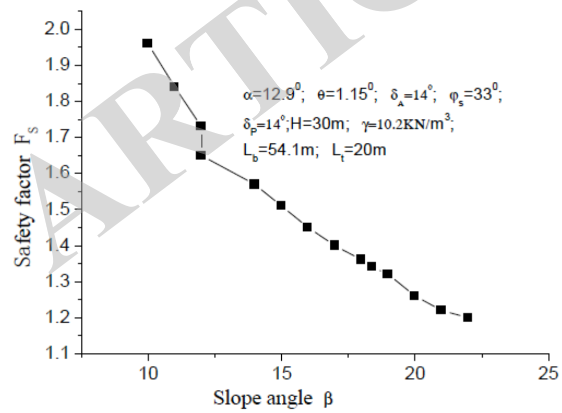

Fig. (6). Curve of slope angle β and safety factor.

3.4. The Influence On The stability Of Landfill Height H

The height of the garbage body in the landfill site is limited, so the total capacity for a specific landfill site is limited. Through calculating the slope stability of different heights to study the influence on stability of Landfill height, the curve of height and the safety factor of garbage body as shown in Fig. (**7**).

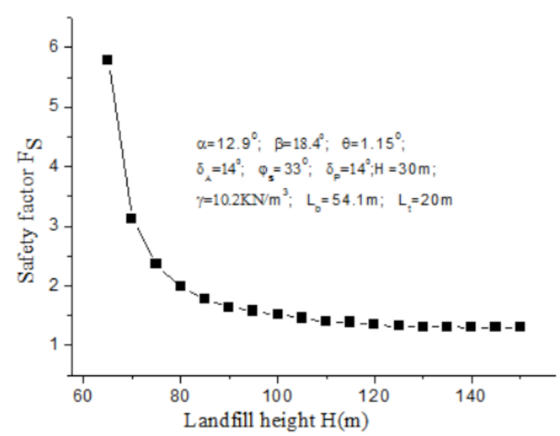

Fig. (7). Curve of filled height H and safety factor.

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The figure shows that the safety factor of slope reduce rapidly in the early process of landfill. When the slope height is less than 80 meters, the safety factor is greater than 2; when the slope height is greater then 80 meters, the safety factor of slope decrease slow down.

3.5. The Influence On The Stability Of The Garbage Settlement

To study the influence on the stability of the garbage Settlement, we calculate the actual height of the landfill site using soil compression theory after each layer garbage landfill. Through the study of the comparison analysis on stability after the settling and no settling, as shown in Fig. (**8**), we know that the safety factor of stability decreases with the passage of time [9,10]. And the stability of landfill body was improved after sedimentation, as the safety factor of after settling is about 16% greater than not settling.

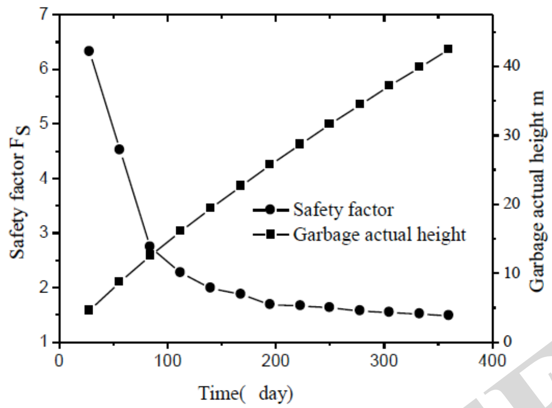

Fig. (8). Curve of landfill settlement and safety factor with time.

It is necessary to explain that: most of the existing and newly built large landfills are valley landfill in our country; In the slope toe of landfill waste dam were built which improved the safety factor of the landfill body; And the height of waste dam is higher, the more conducive to the stability of landfill. As a result the waste dam project cost will be increased accordingly.

CONCLUSION

The landfill can be divided into two parts of the active wedge and passive wedge to study the overall stability of the landfill pile body. Establish the equilibrium equation on the base of limit equilibrium method and solve the landfill stability safety factor.

Draw the sensitivity curve of each parameter and analyze the influence of various parameters on the safety factor to study the influence of various parameters on the stability of landfill.

To a certain extent, waste dam can improve the safety factor of the landfill body and the dam is higher, the more conducive to the overall stability of the landfill site.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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