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Design and Reality of Landfill Anti-seepage System Considering Chemical Erosion

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The chemical etching liquid in landfills is very harmful to surface water and groundwater. At the same time, the chemical erosion effect will affect the stability of landfills. Thus, the liner structure design and realistic research of the anti-seepage system are the key. Aimed at the stability of the anti-seepage system, this paper analyzes the mechanical stability of the chemical anti-seepage material used in the anti-seepage layer of the landfill slope based on the limit equilibrium method, obtaining accurate safety coefficient of the liner damage of the landfill slope. On this basis, the anti-seepage chemical materials conforming to the safety coefficient standard are selected; in the design of the landfill anti-seepage system considering chemical erosion, there are holes or joint defects in the single-layer geomembrane liner, so the chemical etching liquid is likely to flow from the geomembrane hole. This paper proposes the practical anti-seepage scheme of HDPE geomembrane combined polymer chemical material GCL and compacted clay. At the same time, a three-dimensional composite geotechnical drainage net is added as a protective layer on the geomembrane, which can play an anti-seepage effect and guiding role for the landfill anti-seepage system under chemical erosion. The anti-seepage design proposed in this paper is of certain reference and guiding significance for the design of the landfill anti-seepage system considering chemical erosion.

1. Introduction

With the economic development, the annual output of domestic rubbish exceeds 100 million tons. The rubbish burial and improper disposal have brought serious environmental problems. Landfill is a cost-effective method for disposing municipal solid waste (Dincer et al., 2006). The landfill is built on the site where the liner with good anti-seepage performance is laid. The solid waste is laid into a thin layer of a certain thickness and then it is compacted and covered. The landfill anti-seepage system should be effectively planned, designed and managed to prevent the environmental pollution caused by chemical erosion from polluting the (Baedecker and Back, 2010).

The most critical of all landfill systems is the anti-seepage liner system and the reliability of the composite liner system is the key to the success of the landfill. The composite liner system using HDPE geomembrane + GCL + compacted clay is the optimal practical anti-seepage scheme at the current stage. Through the study of the structure of the anti-seepage layer in the anti-seepage system of landfills in developed countries (see Table 1 for details), it is concluded that Germany has strict requirements for anti-seepage pollution. Although there are holes on the geomembrane of the composite liner of geomembrane combined GCL chemical materials, under the premise of satisfying the permeability coefficient, a layer of chemical reaction between cheap materials and chemical etching liquid can be added in areas with special environmental requirements to ensure the chemical etching liquid will not pollute the groundwater.

In the design of landfill anti-seepage system considering chemical erosion (Zheng et al., 2004), there are holes and joint defects in single-layer geomembrane liner and chemical etching fluid is likely to flow from geomembrane holes (Balwant et al., 2010). This paper proposes the practical anti-seepage scheme of HDPE geomembrane combined polymer chemical material GCL and compacted clay. At the same time, a three-dimensional composite geotechnical drainage net is added as a protective layer on the geomembrane, , which can play an anti-seepage effect and guiding role for the landfill anti-seepage system under chemical erosion (Kim and Benson, 2004; Lin et al., 2014). The anti-seepage design proposed in this paper is of certain

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reference and guiding significance for the design of the landfill anti-seepage system considering chemical erosion.

Table 1: Comparison of landfill standards in different countries

Country	Thickness of drainage layer and protective layer/m	Permeability coefficient of drainage layer / (m.s^{-1})	Thickness of geomembrane /mm	Thickness of clay/cm	Permeability coefficient of clay/(cm.s^{-1})
USA	>0.5	>1×10^{-3}	1.5	60	<1×10^{-7}
Japan	>0.5		1.5	50	<1×10^{-6}
Germany	>0.3		2.5	75	<1×10^{-8}
China	>0.3		1.5	75	<1×10^{-7}

2. Theoretical Basis of Anti-Seepage Systems

2.1 Slope Stability Analysis of Chemical Composite Liner

In the design of the landfill anti-seepage system considering chemical erosion, it is necessary to analyze the compressive strength and tensile strength of chemical anti-seepage materials of the slope anti-seepage layer to ensure the strength demand so that there is no leakage source to affect the anti-seepage effect. The force analysis of the landfill slope is shown in Figure 1. Under the impact of cohesive force and internal friction angle between the interfaces, the stability of the landfill liner system is calculated by using the limit equilibrium method, obtaining accurate maximum safety coefficient S_{max} and the minimum safety coefficient S_{min} of the damage resistance of multi-layer liner of the landfill slope. The average safety coefficient $S_{ave} = (S_{max} + S_{min})/2$ is used to replace the real safety coefficient S_{true} (see Equation 1 to 5 for details). Then, the anti-seepage chemical material conforming to the safety coefficient standard is selected on this basis (Rowe and Rowe, 2005).

$$S_{\max} = \frac{-b+\sqrt{b^2-4ac}}{2a} \tag{1}$$

$$S_{\min} = \frac{-b-\sqrt{b^2-4ac}}{2a} \tag{2}$$

$$a = (G_A - F_{NA}\cos\beta)\cos\beta \tag{3}$$

$$-b = (G_A - F_{NA}\cos\beta)\sin\beta\tan\theta + (F_{NA}\tan\theta + F_{ca})\sin\beta\cos\beta + (F_c + G_p\tan\theta)\sin\beta \tag{4}$$

$$c = (F_{NA}\tan\theta + F_{ca})\sin^2\beta\tan\theta \tag{5}$$

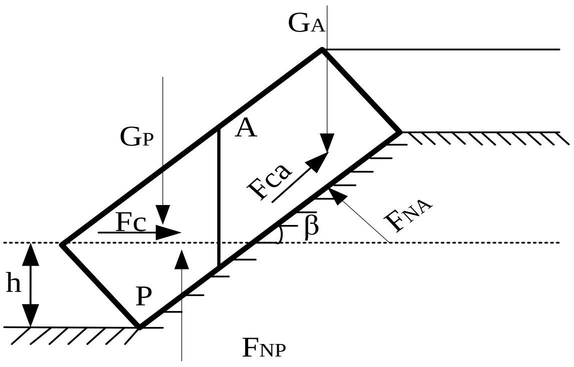

Figure 1: Limit equilibrium analysis of uniform cover soil of finite slope

From Equation 1 to 5, G_A represents the active wedge weight kN/m; G_p represents the active wedge weight kN/m; F_{NA} represents the normal force acting on the bottom of the wedge kPa; F_{ca} represents the total cohesive force kPa at the interface; F_c represents the total cohesive force kPa of the overburden soil; β represents the slope angle; θ represents the internal friction angle of the overburden soil.

Considering the stability of the slope and the bearing capacity of the foundation, the geomembrane structure is effectively protected from damage.

2.2 Darcy Penetration Theory

The design of landfill anti-seepage system considering chemical erosion requires that the permeability coefficient is higher than the standard and the seepage process follows the Darcy's law of penetration (see Equation 6 for details). The Darcy's law is used to calculate the permeability coefficient of the anti-seepage system. For the anti-seepage clay whose permeability coefficient is less than $1 \times 10^{-7} cm/s$, as shown in Table 1, the thickness of the liner layer can be appropriately increased and the permeation path of the residual chemical etching liquid can be prolonged. Through the adsorption property of the clay, the concertation and quantity of the contaminant can be gradually attenuated.

$$Q = kA\frac{\Delta h}{L} \tag{6}$$

In this equation, Q is the seepage discharge per unit time; k is the permeability coefficient; A is the seepage section; $\Delta \mathrm{h}$ is the total head loss; L is the length of the seepage path (ie the thickness of the GCL).

3. Design and Reality of Anti-Seepage System

3.1 Optimal Realistic Anti-Seepage Scheme by HDPE Membrane + GCL + Compacted Clay

(1) HDPE geomembrane

HDPE geomembrane is a high-density polyethylene resin. It is made of high-quality virgin plastic and carbon black particles and is an environment-friendly chemical material without preservative, which is commonly used in the landfill anti-seepage system; it is characterized by chemical erosion properties of heat resistance, cold resistance, strong acid resistance and strong alkali and physical and mechanical properties of high rigidity and toughness; the geomembrane has low permeability to water vapor and air and it is a flexible waterproof chemical plastic film with high anti-seepage coefficient (1×10-17cm/s).

The methods of hot-melt welding and extrusion welding are used to weld HDPE geomembranes and the laying quality directly affect the anti-seepage effect of the entire landfill.

(2) GCL polymeric chemical material

GCL is a polymeric chemical material between compacted clay and geomembrane (Louli and Tassios, 2000; Nguyen et al., 2011), which is an anti-seepage liner between the special composite geotextile and non-woven fabrics filled by high-expansion sodium bentonite. The needle punching method is used to construct the fiber space to prevent the bentonite soil particles from flowing in one direction, thereby forming a uniform high-density colloidal anti-seepage layer. The pH value of bentonite pulp generally exceeds 8, belonging to alkaline, so it has a good adsorption effect on the chemical etching liquid in the landfill and it can be used as the main anti-seepage component of the landfill anti-seepage system. Moreover, the higher the and the landfill The higher the pH and concentration C of the chemical etching liquid in the landfill, the better the anti-seepage effect of the anti-seepage system, as shown in Figure 2.

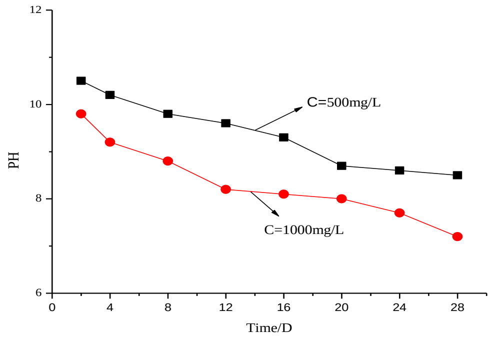

Figure 2: Chemical etching fluid PH and concentration C and time T curve

(3) Improving compacted clay layer

Considering the reality of landfill anti-seepage system considering chemical erosion, it is found that there are cracks or holes on the compacted clay layer, which severely influence the effectiveness of the anti-seepage layer. Therefore, this paper improves the compacted clay layer in actual landfill anti-seepage system. The fly ash is added to the natural clay under the consideration of chemical erosion, which can effectively improve the anti-seepage characteristics of the clay layer. The chemical structure of fly ash is essentially a volcanic ash mixture formed by high-temperature combustion of pulverized coal and it can be added to natural clay as a natural adsorbent material to enhance the anti-seepage effect of the clay layer. According to the Darcy's law of penetration, different proportions of fly ash are added to the natural clay and the permeability coefficient of different proportions of fly ash clay can be obtained through the penetration test, as shown in Fig. 3.

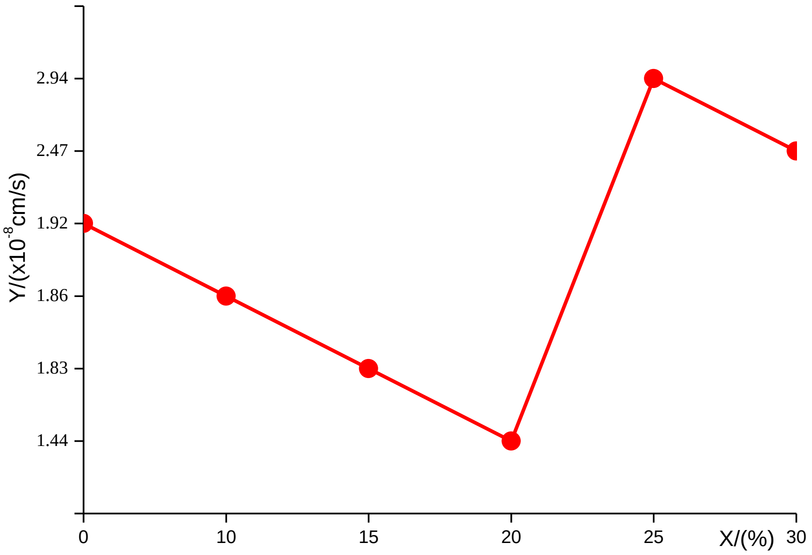

Figure 3: Permeability Coefficient of clay with different proportions fly ash

According to the experimental data in Fig. 3, when 10% to 20% of fly ash is added into the clay, the permeability coefficient presents a gradually declining trend. When the proportion of fly ash is 20%, the permeability coefficient reaches its nadir. When the addition ratio is greater than 20%, the permeability coefficient presents a gradually increasing trend, indicating that the optimal state is reached when the addition ratio of fly ash is 20%. After the clay with less than 30% of fly ash addition is fully saturated and stabilized, the experimental data of the permeability coefficient obtained are all above the standard order of magnitude of the engineering expectation, namely *10^{-8}cm/s. The main reason is that the fly ash particles are smaller enough to fill the voids of the clay, thereby reducing the void ratio of the clay. The chemically active constituents Al_2O_3 and CaO of the fly ash can reduce the permeability coefficient of the improved clay.

Referring to the international anti-seepage system structure and combined with leakage rate control, the composite anti-seepage liner system of high-density polyethylene geomembrane, polymer chemical material liner and compacted clay, namely the anti-seepage scheme of HDPE film + GCL + compacted clay, is adopted, which has better anti-seepage effect under the same anti-seepage construction quality control.

3.2 Structural Design of Anti-Seepage System

In the design of the landfill anti-seepage system considering chemical erosion, the multi-faced anti-seepage characteristics of HDPE geomembrane are used. At the same time, a three-dimensional composite geotechnical drainage net is added as a protective layer on the geomembrane, which can play an anti-seepage effect and guiding role for the landfill anti-seepage system under chemical erosion (Bhaumik et al., 2015). The property of chemical materials of the three-dimensional composite geotechnical drainage net is also high-density polyethylene. During the processing, three ribs are extruded by a special machine head, which are arranged according to a certain angle and spacing to form a three-dimensional structure of the drainage channel. This structure has a high tensile strength and compressive strength along the transverse and longitudinal direction and it is not likely to deform under high load. Also, it can also prevent the geotextile from being embedded in the net core, ensuring smooth drainage while protecting the underlying geomembrane from external damage.

The liner system plays a key role in the landfill anti-seepage system. The single-layer geomembrane liner has holes or joint defects, so the chemical etching liquid is likely to flow out of the geomembrane hole. Composite liners are often used in the actual landfill anti-seepage system and are coped with the chemical etching liquid shunt drainage system and decomposition purification so as to achieve the comprehensive control of the anti-seepage system. As shown in Figure 3, the first layer in the Figure indicates solid waste; the second layer represents the gravel drainage protection layer, with a thickness of 0.6m; the third layer represents the geomembrane, with a thickness of 1.5m (high density polyethylene); the fourth layer represents GCL (polymer chemical barrier material); the fifth layer represents compacted clay, with a thickness of 0.75m, whose saturated permeability coefficient is <1*10-7(cms-1) ; the sixth layer represents the foundation; and the seventh layer represents the geonet drainage, with a thickness of 6mm.

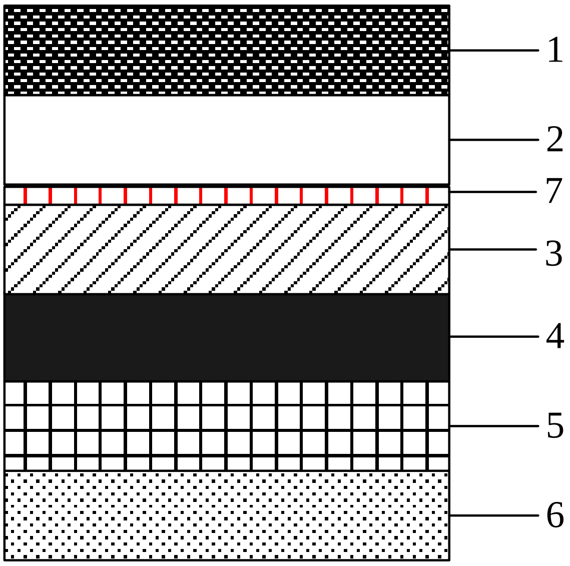

Figure 3: Anti-seepage structure diagram of landfill

4. Conclusion

The chemical etching liquid in landfills is very harmful to surface water and groundwater. At the same time, the chemical erosion effect will affect the stability of landfills. Thus, the liner structure design and realistic research of the anti-seepage system are the key. The content and conclusions of the study in this paper are as follows:

(1) Considering the impact of cohesive force and internal friction angle between the interfaces, the limit stability method is used to analyze the mechanical stability of the chemical anti-seepage material used in the anti-seepage layer of the landfill slope, obtaining accurate safety coefficient for the liner damage of the landfill slope, which provides a basis for the anti-seepage chemical material conforming to the safety coefficient standards.

(2) According to Darcy's law of penetration, in the design of the landfill anti-seepage system considering chemical erosion, there is holes or joint defects in the single-layer geomembrane liner, so the chemical etching liquid is likely to flow from geomembrane holes. The practical anti-seepage scheme of HDPE geomembrane combined polymer chemical material GCL and compacted clay is proposed.

(3) Aiming at the defects of geomembrane, a three-dimensional composite geotechnical drainage net is added as a protective layer on the geomembrane, which can play an anti-seepage effect and guiding role for the landfill anti-seepage system under chemical erosion while protecting the lower geomembrane from external force damage; the anti-seepage design proposed in this paper is of certain reference and guiding significance for the design of the landfill anti-seepage system considering chemical erosion.

(4) The practical problems such as cracks of the compacted clay layer in the landfill anti-seepage system are improved. The fly ash is added into the clay under the consideration of chemical erosion, which can effectively improve the anti-seepage characteristics of the clay layer. The anti-seepage design proposed in this paper is

of certain reference and guiding significance for the design of the landfill anti-seepage system considering chemical erosion

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