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Compressibility and hydraulic conductivity of sand-attapulgite cut-off wall backfills*

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Abstract: Soil-bentonite cut-off walls have been used widely to control pollution in landfills but their antifouling property (their ability to prevent contaminants in landfills from polluting the surrounding environment) decreases significantly over time due to a variety of factors (e.g. contaminant concentrations). In recent years, attapulgite has been considered as a backfill material for cut-off walls, but relevant studies are lacking. In this study, the compressibility and hydraulic conductivity of sand-attapulgite backfills were investigated using consolidation and hydraulic conductivity tests. In these tests, attapulgite comprised 10%, 20%, 30%, 40%, 60%, 80%, or 100% (dry weight) of the backfills. The results showed that (1) the compression (C_c) and swell (C_s) indexes of the backfills increased linearly with increasing attapulgite content (A_p); (2) both the consolidation coefficient (C_v) calculated by the Casagrande and Taylor methods and the hydraulic conductivity (k_{theory}) calculated according to Terzaghi consolidation theory decreased with increasing attapulgite content. In the case of an effective consolidation stress σ'<100 kPa, k_{theory} <10^{-9} m/s when A_p≥30%, which was supported by the hydraulic conductivity tests. Two methods were developed based on laboratory data, for predicting the hydraulic conductivity of sand-attapulgite backfills. We conclude that the use of sand-attapulgite backfills applied to cut-off walls as substitutes for soil-bentonite backfills is technically feasible.

Key words: Attapulgite; Sand-attapulgite backfill; Cut-off wall; Compressibility; Hydraulic conductivity
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1 Introduction

According to the statistics of Professional Committee of Urban Domestic Refuse Treatment of China Association of Environmental Protection Industry (2017), the production of municipal solid wastes (MSWs) approached 200 million tons/year in 2015, and in China more than 60% of MSWs are disposed of in landfills. However, most landfills constructed early in China are relatively simple and have no seepage control systems (Xu et al., 2016). Leachates in the landfills contain a wide range of harmful substances released from MSWs, contaminating the surrounding soils and groundwater systems through lateral leakage (Xie et al., 2009; Laner et al., 2012). Therefore, it is necessary to construct vertical cut-off walls to prevent the leakage of leachates from the landfills (Evans et al., 1995; Sharma and Reddy, 2004; Zhu et al., 2014).

A variety of cut-off walls have been applied to existing landfill pollution control systems (Garvin and Hayles, 1999; Inazumi et al., 2006; Joshi et al., 2010; Takai et al., 2014; Xu et al., 2016). Among them, soil-bentonite cut-off walls are a popular choice

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because of their simple construction, low cost, and low permeability (D'Appolonia, 1980; Evans et al., 1995; Sharma and Reddy, 2004; Britton et al., 2005; Yeo et al., 2005; Malusis and McKeehan, 2013; Du et al., 2015a). In general, the construction process of a soil-bentonite cut-off wall consists of two steps: firstly, a trench is excavated and a bentonite-water slurry is added to maintain its stability; secondly, a backfill, which is mixed with trench spoils or other materials and bentonite-water slurry, is added to control contaminant migration as a low-permeability barrier in the trench (D'Appolonia, 1980; Rumer and Ryan, 1995; Malusis et al., 2009; Hong et al., 2012). The backfill slump is limited to a range of 100–150 mm (Yeo et al., 2005; Hong et al., 2012). However, the high concentrations of contaminants in the landfill leachates can cause a significant increase in hydraulic conductivity, thereby reducing the anti-fouling property (the ability to prevent contaminants in a landfill from polluting the surrounding environment) of a soil-bentonite cut-off wall (D'Appolonia, 1980; Lo and Yang, 2001; Mishra et al., 2009).

Attapulgite is a clay-type mineral similar to bentonite, but with the advantage of being less sensitive to chemical environments (Haden and Schwint, 1967; Galan, 1996; Tallard, 1997; Neaman and Singer, 2004). Attapulgite has been considered as a substitute for bentonite in cut-off wall backfills (Ryan, 1987; Day, 1994; Stern and Shackelford, 1998). Hydraulic conductivity is a critical characteristic of a vertical cut-off wall. Previous studies showed that the hydraulic conductivity of a sand-attapulgite cut-off wall is not significantly affected by high concentrations of contaminants (Ryan, 1987; Day, 1994; Stern and Shackelford, 1998; Zhu et al., 2016). For example, Stern and Shackelford (1998) concluded that the hydraulic conductivities of sand-bentonite mixtures are obviously affected by $CaCl_2$ concentrations, but those of sand-attapulgite mixtures are not. The experimental study of Zhu et al. (2016) reached a similar conclusion. Regarding the effect of different attapulgite additions, Zhu et al. (2014) considered that the hydraulic conductivity of a sand-attapulgite cut-off wall is lower than 1×10^{-9} m/s (the typical regulatory limit for in situ pollution control systems) when the amount of added attapulgite reaches 25%. However, previous findings are limited, so systematic and in-depth studies are required.

Compressibility is also an important characteristic of a vertical cut-off wall because it can greatly affect the lateral shift of the trench walls (Yeo et al., 2005; Malusis et al., 2009; Ruffing et al., 2010; Hong et al., 2012; Sreedharan and Puvvadi, 2013; Xu et al., 2016). Extensive studies of the compressibility of soil-bentonite backfills have been conducted (Yeo et al., 2005; Malusis et al., 2009; Hong et al., 2012; Fan et al., 2014a; Du et al., 2015b; Keramatikerman et al., 2017; Chegenizadeh et al., 2018). However, few studies have explored the compressibility of sand-attapulgite backfills.

In this paper, we described a detailed experimental study of the compressibility and hydraulic conductivity of different sand-attapulgite mixtures used as vertical cut-off wall backfills. The aims of this study were (1) to explore the effect of different attapulgite additions on the compressibility and hydraulic conductivity of sand-attapulgite cut-off walls, and (2) to develop empirical methods, based on laboratory data in the framework of the Kozeny-Carman equation, for predicting the hydraulic conductivity of sand-attapulgite backfills.

2 Materials and methods

2.1 Materials

The sand-attapulgite backfills consisted of Fujian Standard Sand and powdered attapulgite clay. The basic physical properties of Fujian Standard Sand were given by Xu et al. (2016). The powdered attapulgite clay was from Xuyi County, Jiangsu Province, China. The pH (ASTM, 2001) and specific gravity (ASTM, 2014) of attapulgite are 7.4 and 2.60, respectively. The liquid limit (w_L, %) and plasticity index (I_P, %) of attapulgite are 94.8% and 56.2%, respectively, according to ASTM D4318 (ASTM, 2010).

The particle size distribution (PSD) curves of Fujian Standard Sand and attapulgite are plotted in Fig. 1. The PSD of Fujian Standard Sand was tested using sieve analysis (Xu et al., 2016). The PSD of attapulgite was determined using a laser particle size analyzer (Mastersizer 2000). The pretreatment procedure of Xu et al. (2015) was used for grain size determination in this study. Fujian Standard Sand is a poorly graded sand (SP) and attapulgite is classified

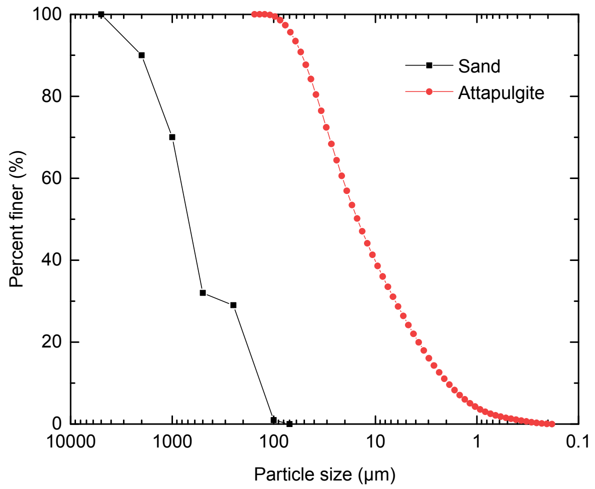

Fig. 1 Particle size distributions of Fujian Standard Sand and attapulgite

as a high-plasticity clay (CH) according to the unified soil classification system (USCS) (ASTM, 2011b).

2.2 Sample preparation

Sand-attapulgite mixtures were prepared for tests. The dry weight percentages of attapulgite (A_p) in the mixtures were set to be 10%, 20%, 30%, 40%, 60%, 80%, and 100%, and the corresponding samples were coded A10S90, A20S80, A30S70, A40S60, A60S40, A80S20, and A100, respectively. The liquid limits (w_L, %) of these samples were measured to be 17.5%, 26.2%, 28.8%, 36.9%, 53.7%, 68.3%, and 94.8%, respectively, according to ASTM D4318 (ASTM, 2010).

2.3 Slump tests

Slump tests were performed to determine the water content of the backfills when reaching a slump (ΔH) of 100 mm, according to the method described by Yeo et al. (2005). Deionized water was used instead of bentonite-water slurry to eliminate a slurry effect on the test results in this experiment (Fan et al., 2014b). When the attapulgite content (A_p) increased from 10% to 100%, the water content at ΔH=100 mm rose from 20.5% to 85.7%. The water contents at ΔH=100 mm were selected as the initial water contents of the samples used for consolidation and hydraulic conductivity tests.

2.4 Consolidation tests

In accordance with ASTM D2435 (ASTM, 2011a), 1D consolidation tests were performed on each group of backfills. To avoid squeezing the sample out of the gap between the ring and porous stone, the pre-consolidation pressure of the sample was set to 3.125 kPa (Hong et al., 2010; Fan et al., 2014b; Xu et al., 2016). Then, the sample was loaded step by step starting from 25 kPa, and the load at each stage was twice that of the previous loading until the maximum load reached 1600 kPa. After that, the sample was unloaded by a decreasing factor of 4, relative to the former loading. Each stage of loading and unloading lasted 24 h. The hydraulic conductivity of each sample at each stage of loading was calculated according to Terzaghi consolidation theory (Du et al., 2015b), as expressed by

$$k_{\text{theory}}=C_v m_v \gamma_w, \tag{1}$$

where k_{theory} is the hydraulic conductivity (m/s), C_v is the calculated consolidation coefficient (m^2/s) in terms of the Taylor method, m_v is the volume change coefficient (kPa^{-1}), and γ_w is the water weight per m^3 (kN/m^3).

2.5 Rigid-wall hydraulic conductivity tests

Rigid-wall hydraulic conductivity tests were performed according to the method described by Tong (2017) to verify the calculated hydraulic conductivity (k_{theory}) based on Terzaghi consolidation theory. Unlike in the study of Tong (2017), in this study the samples were consolidated at a consolidation stress of 50 kPa for 24 h before testing. Deionized water was used as the permeating liquid. Data were recorded when the effluent outflow was stable. Similar to the method of Chegenizadeh et al. (2018), the hydraulic conductivity of each sample was tested three times under roughly the same conditions (i.e. room temperature and hydraulic gradient), and the average value of the three results was regarded as the final value of hydraulic conductivity (k_f).

3 Results and discussion

3.1 Consolidation tests

3.1.1 Compression index (C_c) and swell index (C_s)

The effective consolidation stress (Fig. 2) did not include the pre-consolidation stress because all the samples were remolded (Olson, 1986; Yeo et al., 2005). The compression (C_c) and swell (C_s) indexes of the sand-attapulgite backfills ranged from 0.081 to 0.36 and from 0.0091 to 0.048, respectively (Fig. 3). Yeo et al. (2005) reported that the compression (C_c) and swell (C_s) indexes of Nelson Farm Clay (NFC)-sand backfills with different fines contents (20%, 40%, 60%, 75%, and 89%) varied from 0.058 to 0.27 and from 0.0054 to 0.023, respectively. The compression (C_c) and swell (C_s) indexes of sand-attapulgite backfills were larger than those of NFC-sand backfills under the condition of the same fine particle percentage. This may have been because attapulgite has a higher plasticity than NFC.

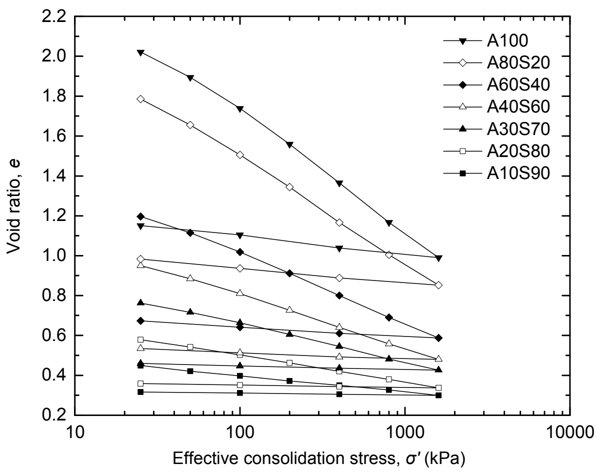

Fig. 2 Void ratio (e) versus effective consolidation stress (σ') curves for sand-attapulgite backfills at 100 mm slump

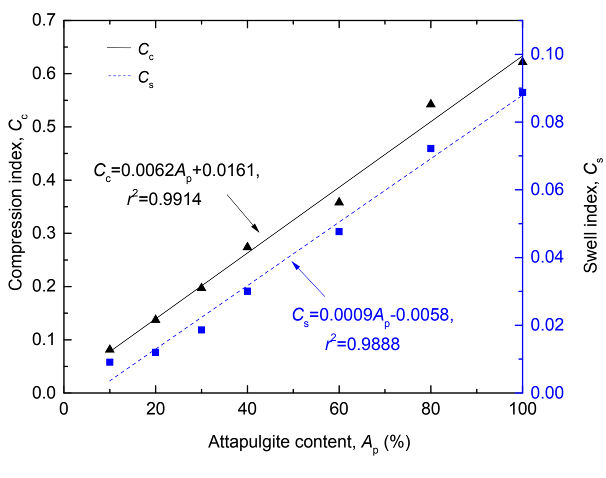

Fig. 3 Variation of compression index (C_c) and swell index (C_s) versus attapulgite content (A_p)

Both the compression (C_c) and swell (C_s) indexes of the backfills increased with increasing attapulgite content (A_p) and had a good linear relationship with A_p: C_c=0.0062A_p+0.0161 (r^2=0.9914), C_s=0.0009A_p−0.0058 (r^2=0.9888), respectively (Fig. 3). This is due to the increased compressibility and swelling of the fines in the backfills (Yeo et al., 2005).

3.1.2 Coefficient of consolidation (C_v)

The consolidation coefficients (C_v) calculated by the Casagrande (logarithm-of-time) and Taylor (square-root-of-time) methods had similar ranges, between 10^{-6} and 10^{-8} m^2/s, and increased with increasing effective consolidation stress (σ') (Figs. 4a and 4b), which is consistent with the findings of Yeo et al. (2005) on NFC-sand backfills. At all stages of the effective consolidation stress (σ'), the consolidation coefficients (C_v) calculated by the Casagrande and Taylor methods decreased as attapulgite content increased (Figs. 4c and 4d). This finding agrees with the conclusion of Yeo et al. (2005) on the effect of NFC contents on consolidation coefficients (C_v) of NFC-sand backfills, and the study of Keramatikerman et al. (2017) regarding the effect of sawdust treatment on the consolidation coefficient (C_v). The consolidation coefficient (C_v) varied in association with the change of hydraulic conductivity of backfills with attapulgite content (Yeo et al., 2005). However, when the percentage of zeolite is <10% in zeolite-amended soil-bentonite backfills, it has no significant effect on the consolidation coefficient (C_v) (Hong et al., 2012).

3.2 Hydraulic conductivity tests

3.2.1 Terzaghi hydraulic conductivity (k_{theory})

The hydraulic conductivity (k_{theory}) decreased with increasing effective consolidation stress (σ') due to the inverse relationship of the void ratio (e) with effective consolidation stress (σ') in the backfills (Figs. 2 and 5a).

The k_{theory} at each stage of σ' decreased as attapulgite content (A_p) increased (Fig. 5b). There are two main reasons for this result. First, the large pores between sand particles in the backfills were gradually filled with fines (attapulgite) as attapulgite content increased, which narrowed the passage of water in the backfills, thereby reducing the hydraulic conductivity

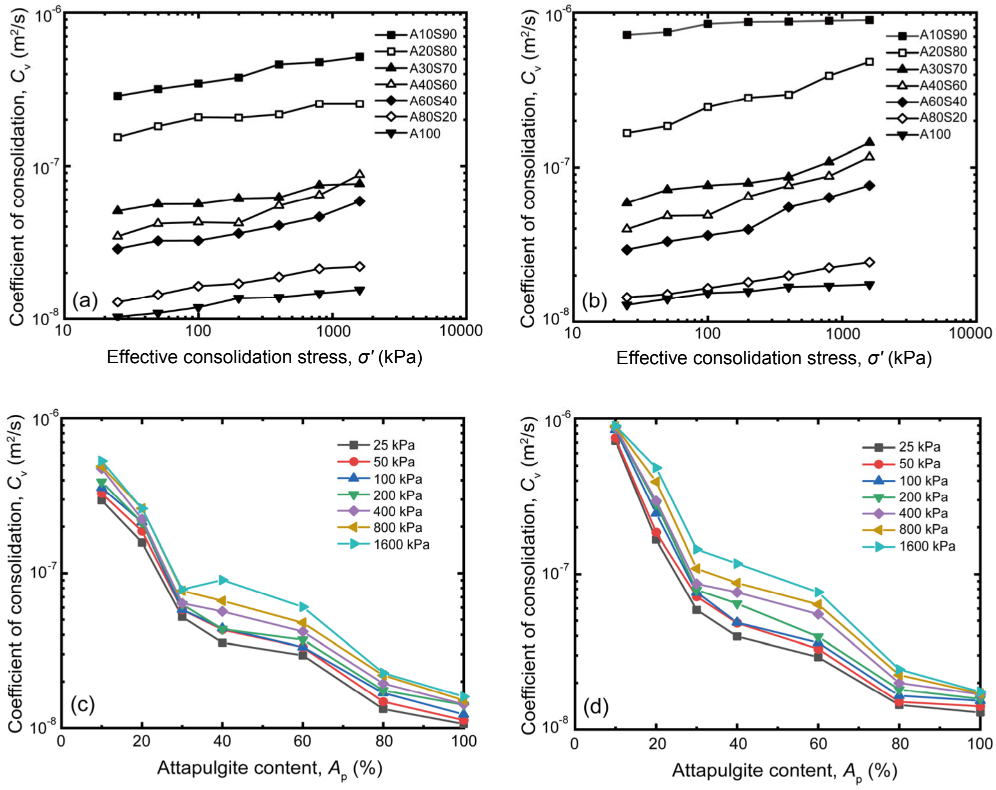

Fig. 4 Coefficient of consolidation (C_v) versus effective consolidation stress (σ') (a and b) and attapulgite content (A_p) (c and d) for sand-attapulgite backfills, where C_v was calculated by the Casagrande method (a and c) and the Taylor method (b and d)

of the backfills (Kenney et al., 1992). Second, bound water could have blocked a part of the pores and reduced water passage in the backfills (Wang et al., 2016). The <2-μm clay particles have some amount of external and internal specific surface areas which have strong abilities to bind water (Dolinar, 2006; Dolinar and Macuh, 2016). The particle size determination shows that the <2-μm fraction accounted for 11% of the whole sample (Fig. 1), probably affecting the hydraulic conductivity of the sand-attapulgite backfills. Therefore, the content of bound water increased, reducing the hydraulic conductivity, as attapulgite content increased in the backfills.

For the samples with 10% and 20% attapulgite, the k_{theory} values were more than 10^{-9} m/s when the effective consolidation stress (σ') was between 25 kPa and 100 kPa (Fig. 5b). When the attapulgite content added in the backfills was not less than 30%, the k_{theory} of the sample was lower than 10^{-9} m/s within the effective consolidation stress range (25–1600 kPa). Previous studies showed that the stress did not exceed 100 kPa in a typical soil-bentonite cut-off wall (Evans et al., 1995; Filz, 1996; Ruffing et al., 2010; Li et al., 2015). Therefore, only when attapulgite content in the backfill was not less than 30%, the hydraulic conductivity of the cut-off wall met the lowest requirement of practical projects (hydraulic conductivity of $<10^{-9}$ m/s). Ryan (1987) pointed out that at least 15% to 20% of low-plasticity fines were needed for a soil-bentonite backfill to achieve a hydraulic conductivity of $<10^{-9}$ m/s. Zhu et al. (2014) and Xu et al. (2016) believed that the clay content in the sand-clay vertical cut-off backfill should not be less than 25% for reaching a hydraulic conductivity of $<10^{-9}$ m/s. Yeo et al. (2005) suggested that the hydraulic conductivity was lower than 10^{-9} m/s when the content of fines in the sand-clay backfill was not less than 40%. There are some differences between previous results and the present findings, probably due to the properties of the fines added in the backfills (e.g. their type, texture, and water adsorbability).

3.2.2 Rigid-wall hydraulic conductivity tests (k_f)

The rigid-wall hydraulic conductivity tests for all the backfills showed that the hydraulic conductivity (k_f) decreased from 5.9×10^{-9} m/s to 9.7×10^{-11} m/s when attapulgite content in the backfill increased from 10% to 100% (Table 1). The k_f was lower than 10^{-9} m/s when attapulgite content in the backfill was not less than 30%, agreeing with the result obtained through calculation based on Terzaghi consolidation theory (Fig. 5).

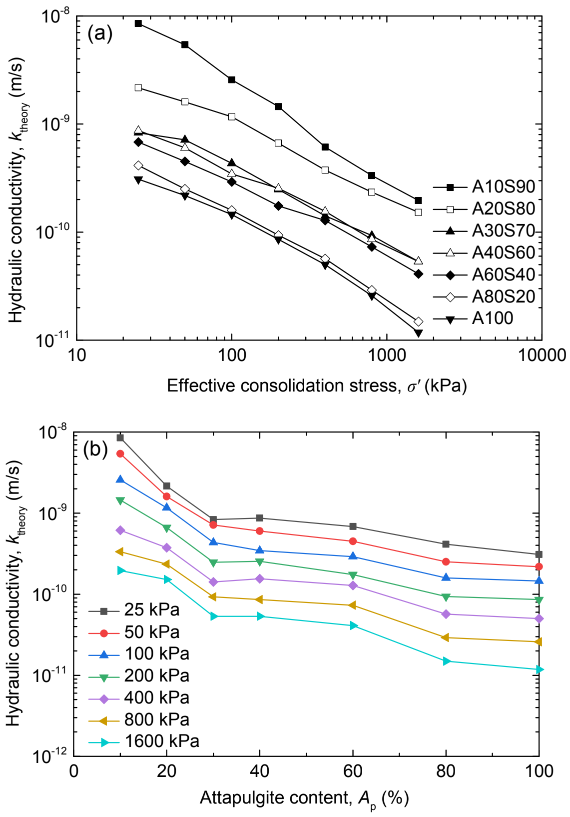

Fig. 5 Computed hydraulic conductivity (k_{theory}) changes as a function of effective consolidation stress (σ') (a) and attapulgite content (b) respectively for sand-attapulgite backfills

3.3 Prediction of hydraulic conductivity (k_p)

The hydraulic conductivities of most saturated soils (e.g. natural clays and sandy soils) have widely been predicted by the Kozeny-Carman (KC) equation (Chapuis and Aubertin, 2003; Sanzeni et al., 2013). However, inaccuracy of the specific surface area (SSA) would lead to a significant discrepancy of the predicted hydraulic conductivity of soils in this equation (Sanzeni et al., 2013). The liquid limit (w_L) was proposed by Fan et al. (2014a) to replace the SSA in the KC equation because (1) w_L is easily determined and (2) w_L can be used to estimate the SSA (Chapuis and Aubertin, 2003).

In this study, two empirical methods were developed, based on laboratory data in the framework of the KC equation, for predicting hydraulic conductivity k_p of sand-attapulgite backfill.

3.3.1 Method 1

Using the liquid limit (w_L) to replace SSA in the KC equation, the relationship between $\log(k_{theory})$ and $\log[e^3/(w_L^6\times(1+e))]$ of all backfills at the effective consolidation stress (σ') between 25 kPa and 100 kPa was expressed by the following linear equation with a correlation coefficient (R) value of 0.875 (Fig. 6):

$$\log(k)=0.46\log[e^3/(w_L^6\times(1+e))]-10.07, \quad (3)$$

where k is the hydraulic conductivity (m/s).

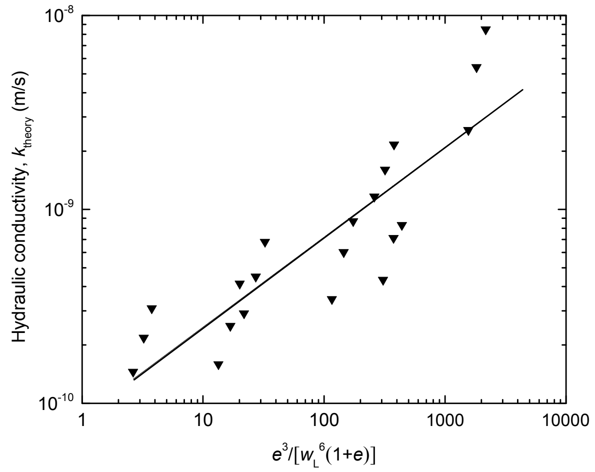

Fig. 6 Relationship between hydraulic conductivity k_{theory} calculated based on Terzaghi consolidation theory and $e^3/[w_L^6(1+e)]$ of all backfills at an effective consolidation stress (σ') between 25 kPa and 100 kPa

The hydraulic conductivity k_p values predicted by Eq. (3) were in the range of 1/3 to 3 times the hydraulic conductivity k_{theory} values calculated based on Terzaghi consolidation theory and the hydraulic conductivity k_f values measured by the rigid-wall hydraulic conductivity test (Fig. 7). Thus, this method is suitable for predicting the hydraulic conductivity of sand-attapulgite backfills.

Table 1 A summary of hydraulic conductivity tests

Specimen	Porosity, n	Dry unit weight, γ_d (kN/m^3)	Measured hydraulic conductivity (m/s)	
			k_f	Average k_f
A10S90	0.28	18.3	5.7×10^{-9}	5.9×10^{-9}
			5.8×10^{-9}	
			6.1×10^{-9}	
A20S80	0.33	17.0	2.8×10^{-9}	3.0×10^{-9}
			2.9×10^{-9}	
			3.2×10^{-9}	
A30S70	0.40	15.3	5.9×10^{-10}	6.4×10^{-10}
			6.3×10^{-10}	
			6.9×10^{-10}	
A40S60	0.45	14.1	4.6×10^{-10}	4.9×10^{-10}
			5.1×10^{-10}	
			5.1×10^{-10}	
A60S40	0.50	12.6	2.1×10^{-10}	2.3×10^{-10}
			2.4×10^{-10}	
			2.5×10^{-10}	
A80S20	0.60	10.1	1.1×10^{-10}	1.3×10^{-10}
			1.3×10^{-10}	
			1.6×10^{-10}	
A100	0.63	9.2	9.6×10^{-11}	9.7×10^{-11}
			9.7×10^{-11}	
			9.9×10^{-11}	

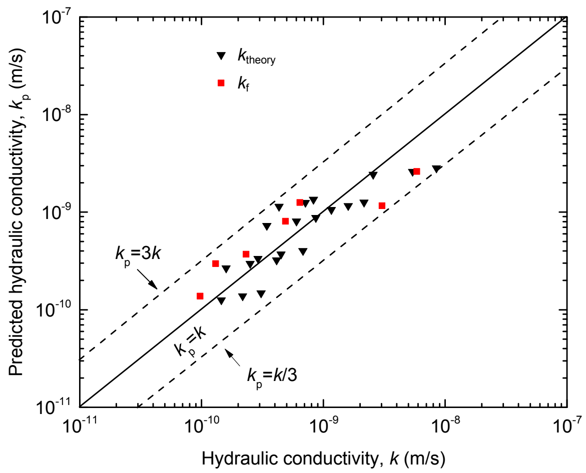

Fig. 7 Relationship between the hydraulic conductivity k_p predicted by method 1 and the hydraulic conductivity k_{theory} calculated based on Terzaghi consolidation theory and the hydraulic conductivity k_f measured by the rigid-wall hydraulic conductivity test

3.3.2 Method 2

Considering that (1) the void ratio (e) of sand-attapulgite backfill is affected mainly by the effective consolidation stress (σ') and (2) the liquid limit (w_L) depends on attapulgite content (A_p), the k_p was predicted according to the relationship of log(k) with $\log[(\sigma')^3/(A_p^6\times(1+\sigma'))]$. The relationship between log(k_{theory}) and $\log[(\sigma')^3/(A_p^6\times(1+\sigma'))]$ of the sand-attapulgite backfills at an effective consolidation stress (σ') between 25 kPa and 100 kPa was described by the following equation, with a correlation coefficient (R) value of 0.818 (Fig. 8):

$$\log(k)=0.19\log[(\sigma')^3/(A_p^6\times(1+\sigma'))]-10.28. \quad (4)$$

The k_p values predicted by Eq. (4) were in the range of 1/3 to 3 times the hydraulic conductivity k_{theory} values calculated based on Terzaghi consolidation theory and the hydraulic conductivity k_f values measured by the rigid-wall hydraulic conductivity test (Fig. 9). Thus, this method is also suitable for predicting the hydraulic conductivity of sand-attapulgite backfills.

In short, the two methods could well predict the hydraulic conductivity of the sand-attapulgite backfills. Method 2 is more convenient than method 1 for predicting k_p because the effective consolidation stress (σ') and attapulgite content (A_p) are more easily obtained than the void ratio (e) and liquid limit (w_L). As a result, we recommend method 2 as the preferred tool for predicting the hydraulic conductivity of sand-attapulgite backfills. However, these methods are empirical and further study is required to determine whether they can be successfully applied to in-situ fields and other types of backfills.

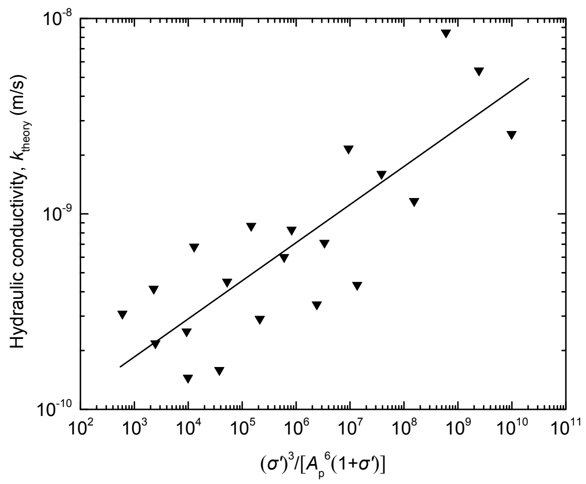

Fig. 8 Relationship between hydraulic conductivity k_{theory} calculated based on Terzaghi consolidation theory and $(\sigma')^3/[A_p^6(1+\sigma')]$ of the sand-attapulgite backfills at an effective consolidation stress (σ') between 25 kPa and 100 kPa

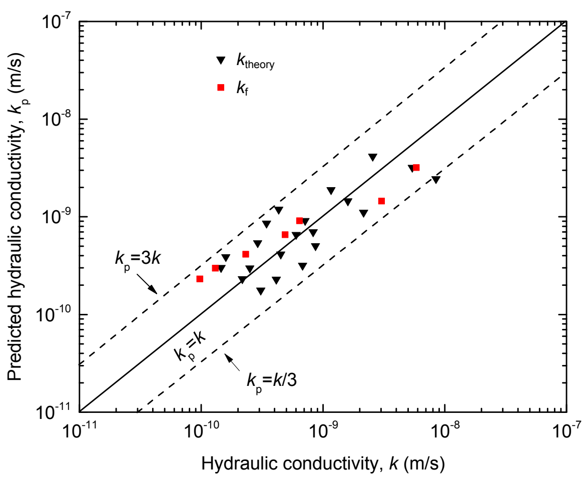

Fig. 9 Relationship between the hydraulic conductivity k_p predicted by method 2 and the hydraulic conductivity k_{theory} calculated based on Terzaghi consolidation theory and the hydraulic conductivity k_f measured by the rigid-wall hydraulic conductivity test

4 Conclusions

In this paper, the compressibility and hydraulic conductivity of sand-attapulgite cut-off walls were studied using consolidation tests and rigid-wall hydraulic conductivity tests. The main conclusions are as follows:

1. The compression index (C_c) and swell index (C_s) increased with increasing attapulgite content (A_p) in the backfills, and both C_c and C_s had good linear relationships with A_p: C_c=0.0062A_p+0.0161 (r^2=0.9914); C_s=0.0009A_p−0.0058 (r^2=0.9888).

2. The consolidation coefficient (C_v) values calculated by the Casagrande and Taylor methods were consistent with the range and trend of values for other materials reported in the literature, and decreased with increasing attapulgite content in the sand-attapulgite backfill.

3. The hydraulic conductivity (k_{theory}) calculated according to the Terzaghi consolidation theory decreased with increasing attapulgite content in the sand-attapulgite backfill. When the attapulgite content A_p≥30%, k_{theory} was less than 10^{-9} m/s at the effective consolidation stress (σ') of <100 kPa. The hydraulic conductivity (k_f) measured by the rigid-wall hydraulic conductivity test had the same variation as k_{theory}.

4. Two methods based on laboratory data were developed for predicting the hydraulic conductivity of sand-attapulgite backfill. Method 2 was preferred. However, these methods are empirical and whether they can be successfully applied to in-situ fields and other types of backfills needs to be examined in future studies.

A sand-attapulgite cut-off wall was considered to be technically feasible as a substitute for a soil-bentonite cut-off wall. The attapulgite content was a key factor in determining the compressibility and permeability of the backfill. An attapulgite content of not less than 30% of the backfill was considered advisable in practical projects.

Acknowledgments

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中文概要

题　目： 砂-凹凸棒土竖向隔离墙材料的压缩及渗透特性试验研究

目　的： 压缩性和渗透性是垃圾填埋场竖向隔离墙材料的2个重要指标。本文旨在探讨不同凹凸棒土添加量对砂-凹凸棒土隔离墙材料压缩性和渗透性的影响，并在Kozeny-Carman方程的框架下建立经验公式来预测砂-凹凸棒土隔离墙材料的渗透系数。

创新点： 1. 系统全面地研究了不同凹凸棒土添加量对砂-凹凸棒土隔离墙材料压缩性和渗透性的影响；2. 建立经验公式，预测砂-凹凸棒土隔离墙材料的渗透系数。

方　法： 1. 通过固结试验和刚性壁渗透试验，得出不同凹凸棒土添加量对砂-凹凸棒土隔离墙材料压缩性和渗透性的影响（图3和4，表1）；2. 通过公式推导，建立经验公式来预测砂-凹凸棒土隔离墙材料的渗透系数（公式（3）和（4））。

结　论： 1. 压缩指数（C_c）和回弹指数（C_s）均随回填料中凹凸棒土含量（A_p）的增加而增大，且 C_c 和 C_s 与 A_p 均有很好的线性关系：C_c=0.0062A_p+0.0161 (r^2=0.9914), C_s=0.0009A_p−0.0058 (r^2=0.9888)。2. 用Casagrande和Taylor方法计算的固结系数（C_v）值均随回填料中凹凸棒土含量的增加而降低。3. 利用太沙基固结理论计算的回填料渗透系数（k_{theory}）随回填料中凹凸棒土含量的增加而降低；在有效固结压力 σ'<100 kPa的情况下，只有凹凸棒土含量 A_p≥30%，k_{theory} 才会低于 10^{-9} m/s；用刚性壁渗透试验测得的渗透系数 k_f 与 k_{theory} 有相同的变化特征。4. 基于试验数据提出了2种预测砂-凹凸棒土回填料渗透系数的方法，其中方法2更好；由于这些方法都是经验公式，所以它们能否应用于原位场地或其它类型回填料仍需进一步的研究。

关键词： 凹凸棒土；砂-凹凸棒土回填料；隔离墙；压缩性；渗透性