Development of a new type of impervious material of final landfill with heavy metal adsorption

Développement d'un nouveau matériau imperméable à haut taux d'absorption de métaux pour décharge finale

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ABSTRACT

We are developing a new type of clay liner with heavy metal adsorption. This material consists of zeolite, doromite, hydrotalcite and sludge. These additive agents have not only cation exchange capacity but also anion exchange capacity. On the other hands, we used dehydrated cake made from sludges of the quarry. Sludge is not suitable for effective recycling and utilization. Sludge has high water content and contains many fine-grained particles. The original condition of sludge can not be used as ground materials .However we pay attention to the capability of recycling use of sludge and suggest that sludge can be effectively used for construction in order to enhance recycle use. In this study, we examined the workability and the execution management method of 2 kinds of sludge using additional agents. This study investigated the physical properties, compaction characteristics, permeability, leachate behaviour and cone index of new type of clay liner material. Especially, this paper describes the results of the examination in terms of the following four points ((1) Confirmation of trafficability, (2) Permeability properties, (3) Proposal of mechanical quality management and (4) Evaluation of long-term durability).

RÉSUMÉ

Nous avons développé un nouveau type de revêtement argile à haut taux d'absorption de métaux. Ce matériau est composé de zéolite, de dolomite, d'hydrotalcite et de boue. Ces additifs ont non seulement une capacité d'échange cationique mais aussi une capacité d'échange anionique. L'utilisation de boues issues de gâteaux déshydratés produits sur les carrières est aussi considérée. Ces boues ne sont pas adaptés au recyclage et à l'usage à cause de leur haute teneur en eau et en particules à grains fins il est donc impossible de les utiliser telle-quelles en tant que matériau géotechnique. Nous nous sommes intéressés au recyclage de ces boues et nous considérons qu'il est nécessaire d'affirmer que celles-ci peuvent être utilisées efficacement en tant que matériau de construction.Cette étude montre la traficabilité et les techniques d'utilisation de deux types de boues auxquels on a mélangé des additifs. Nous avons aussi étudié les propriétés physiques, les caractéristiques de compaction, la perméabilité, les caractéristiques de lixiviation de ces nouveaux matériaux imperméables. Elle montre en particulier le résultat des recherches dans les 4 domaines suivants : (1) vérification de la traficabilité, (2) propriétés de perméabilité, (3) propositions pour des méthodes de contrôle de qualité des matériaux imperméables, (4) évaluation de la durabilité à long terme.

Keywords: landfill, clay liner, trafficability, permiabilty, durability, havey metal adsorption

1 INTRODUCTION

The landfill often has a leaching problem because of geo-membrane damage. There are several choices of soil and membrane for the barrier layer at the bottom of a waste landfill. If a clay liner is used, legal requirement in Japan stipulates that a minimum thickness is 50 cm and a hydraulic conductivity is less than1 x 10^{-6}cm/s (IGS, 2000). In well controlled landfill, bentonite mixed soil is generally used as a clay liner . Bentonite mixed soil has a self-sealing capability and a low hydraulic conductivity with swelling effect (Mizuno *et al.*,2003,2005). However, it is difficult to maintain complete protection against ground pollution from landfill leachate.

Therefore, we are developing a new type of impervious material with heavy metal adsorption. This material consists of zeolite, doromite, hydrotalcite and sludge. The standard additive rate of sealing soil is zeolite 2%, doromite 2% and hydrotalcite 5% respectively.These additive agents have not only cation exchange capacity but also anion exchange capacity. We used dehydrated cake made from sludge gained from a quarry. Sludge is not suitable for effective recycling and utilization so far. Because sludge has high water content and contains many fine-grained particles. The original condition of sludge can not be used for ground materials.However sludge should be effectively used for construction in order to enhance recycle use. In this study, we examined the workability and the execution management method of the sludge using additional agents. This study investigated the physical properties, compaction characteristics, permeability, leachate behaviour and cone index of a new type of clay liner material.

2 TEST PROCEDURE

2.1 *Soil properties*

We used two kinds of dehydrated cakes produced at a macadam factory (following: two kinds of dehydrated cakes are shown as Sludge A (Sa) and Sludge B (Sb)). This study uses two types of sludge. The characteristics of sludge from the macadam factory are different from a variety of rock.

The physical properties of this sludge are shown in Table 1. Figure 1 shows each grain size distribution curves of sludge, respectively.

Figure 2 shows the standard proctor compaction curve with distribution of natural water content. The maximum density of

Table 1. Physical properties

	Sa		Sb	
	Sa	Sa+A*	Sb	Sb+A*
Density of soil Particles ρ_s (g/cm^3)	2.631	2.693	2.946	2.944
Liquid limit ω_L (%)	39.90	39.90	42.20	53.80
Plasticlimit ω_P (%)	25.37	29.90	28.20	31.96
Plasticity index I_p	14.53	10.00	14.00	21.84
Fine content F_c (%)	100.00	96.80	99.00	93.90

Proceedings of the 17th International Conference on Soil Mechanics and Geotechnical Engineering
M. Hamza et al. (Eds.)

doi:10.3233/978-1-60750-031-5-209

Sludge B is larger than Sludge A. Each compaction property of sludge has changed by mixing additional agents. The soil particle density of sludge B is high, which shows difference of quality of ground. Both sludge have a low plasticity.

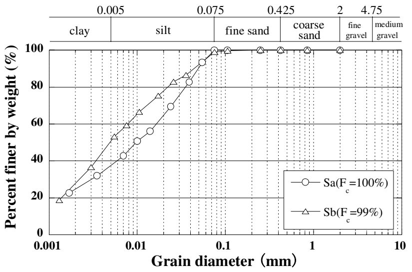

Figure 1. Grain size distribution curve

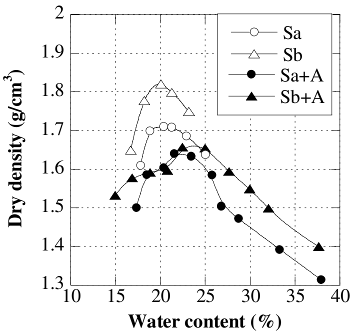

Figure 2. Standard proctor Compaction curve

2.2 *Additional agents*

This study used zeolite, doromite and hydrotalcite as additional agents for heavy metal adsorption. Table 2 shows the effect of each agent(A) and its additive ratio. These agents have not only cation exchange capacity but also anion exchange capacity. The standard additive rate for dry weight of dehydrated cake is zeolite 2%, doromite 2% and hydrotalcite 5%

Table 2. Additional agents

Addition agent	Additive rate (%)	Efficacy
Zeolite	2	Cation exchange capacity and heavy metal adsorption
Doromite	2	Ph control
Hydrotalcite	5	Anion exchange capacity

2.3 *Investigation contents*

2.3.1 *Confirmation of trafficability*

In order to use dehydrated cake with high initial water content, it is important to confirm trafficability of clay liner material. This study examines an effect of initial water content on traffic-ability. Confirmation of trafficability was done by cone penetration test. The test was carried out by using water contents and compaction density obtained from compaction curve (Figure 2) and density of the specimens was controlled by compaction degree (D'=(ρ_d/ρ_{dmax})) of 80, 90, 95 % obtained from Figure 2 using the mould which is 10cm in diameter and 12.5cm in height.

2.3.2 *Discussion of permeability*

In order to use permeable material for seepage control work, the coefficient of permeability below$1x10^{-6}$cm/s is required. Therefore this study was done by using flexible wall falling head permeability test apparatus. Paying attention to the effects of initial water content, the experiment was carried out by making the specimen under the same condition as confirmation of traffic-ability.

2.3.3 *Proposal of quality control method*

Considering test results from confirmation of trafficability and permeable characteristics and compaction characteristics, this study discusses optimum material condition for the seepage control work of final landfill. Especially we propose the method to control strength and permeability of seepage material by using test result of water contents and compaction properties of sludge

2.3.4 *Evaluation of long term durability*

A seepage control work at the landfill site is required to maintain its long-term sustainable function. This study investigated a long- term strength of impervious material and durability of heavy metal adsorption. In order to comprehend durability of heavy metal adsorption, equilibrium adsorption tests and column tests about Pb and Cr were carried out.

3 CONFIRMATION OF TRAFFICABILITY

Figure 3 and 4 show relationship between initial water content and q_c of compaction degree of dehydrated cakes Sludge A(Sa) and Sludge B(Sb) with additional agents. It was understood that in order to exceed q_c=1200(kN/m^2), it is necessary for water content in case of compaction degree of D=80% to be decreased to below w=25% and for water content in case of compaction degree of D= 95% to be decreased below w=30%. Especially compaction degree of D=80% extremely decreases its strength. This result shows that dehydrated cake with initial water content rate of 40% to 50 % needs to be decreased its water content ratio and to be compacted sufficiently by sun-drying and mixing surplus soil from in-situ. Sludge B gained the required strength more than Sludge A. This is due to its better quality that Sludge B has more maximum dry density and better compaction properties. Therefore, it is understood that it is important to comprehend properties of dehydrated cake to use.

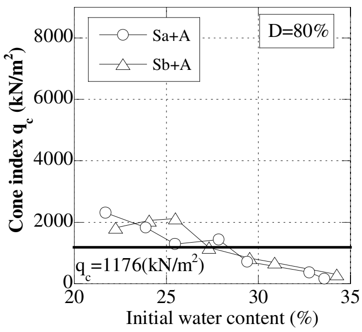

Figure 3. Relationship between w and q_c

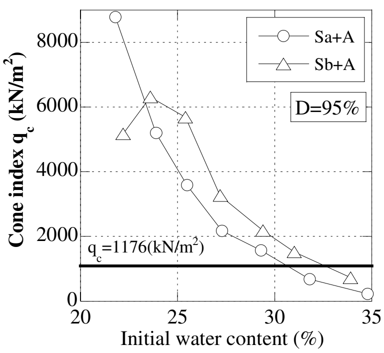

Figure 4. Relationship between w and q_c

4 PERMEABILITY PROPERTIES

In order to evaluate its application as seepage control material, the permeability test was done by using the flexible wall falling head permeability test apparatus. Figure 5 and 6 show relationship between coefficient of permeability and initial water content of Sludge A and B with additional agents. It was understood that the coefficient of permeability of both Sludge decreases as compaction degree increases and there was no effect of initial water content on the coefficient of permeability. Compared with Japanese regulation requiring below 1 x 10^{-6} cm/sec for clay type seepage control material, it is shown that both sludge with compaction degree of D=95% are applicable as seepage control material for the disposal site. Considering these results, it was shown that it is important to understand compaction properties of material in order to construct the disposal site which the coefficient of permeability is below 1x10^{-6}cm/sec by using dehydrated cake as seepage material. Furthermore it was understood that sufficient compaction satisfies the coefficient of permeability of below 1x10cm^{-6}/sec even if material has high water content.

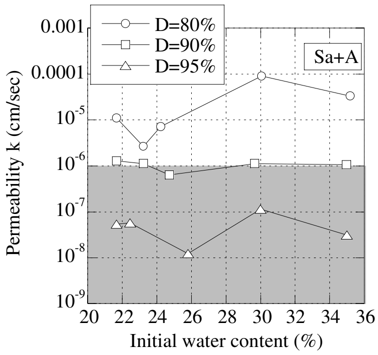

Figure 5. Relationship between k and w

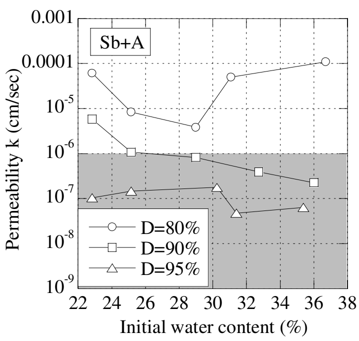

Figure 6. Relationship between k and w

5 PROPOSAL OF MECHANICAL QUALITY MANAGEMENT BY INITIAL WATER CONTENT AND DRY DENSITY

Using the cone penetration index (q_c) and the coefficient of permeability (k), we would like to propose the quality management method meets its required capabilities for seepage control material using dehydrated cake. Figure 3 and Figure 4 shows cone index q_c in accordance with change of the rate of initial water content and dry density in each compaction curve. Figure 5 and 6 also show the coefficient of permeability k in the same condition. Then Figure 7 and Figure 8 show a summary of results from Figure 3 to Figure 6 explaining conditions of specimens satisfies the required traffic-ability of above q_c=1200 (kN/m^2) and coefficient of permeability of below 1 x 10^{-6}cm/sec at the same time. As a result, it was understood that each dehydrated cake can meet its required capability as seepage control material by compacting with maximum dry density of more than 90% obtained under the conditions of initial water content of less than 30%. By using the method of arrangement, it can be considered that even dehydrated cake with high initial water content can be suitable to be used as seepage control material.

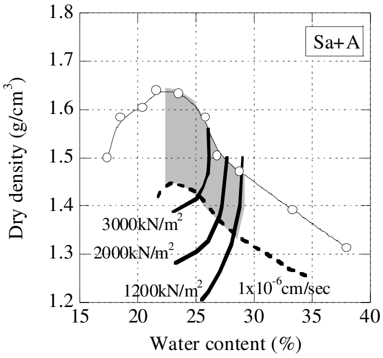

Figure 7. Summary of results

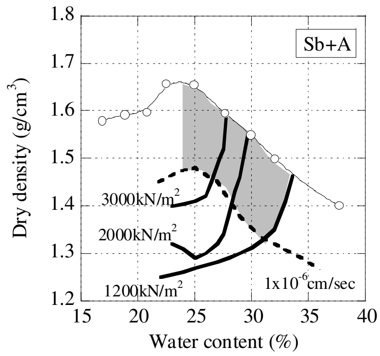

Figure 8. Summary of results

6 EVALUATION OF LONG-TERM DURABILITY

6.1 *Confirmation of long-term strength*

Figure 9 and Figure 10 show the relationship between qc and curing days of Sludge A and Sludge B with additional agents. Although each Sludge shows different strength until 84th day, it becomes showing almost same level strength after 84th day,. It is understood that each Sludge have sufficient long-term strength as cone index always shows more than 1200(kN/m^2).

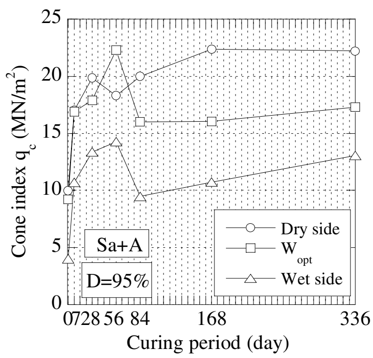

Figure 9. Relationship between q_c and curing days

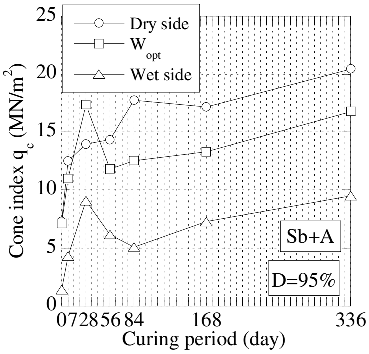

Figure 10. Relationship between q_c and curing days

6.2 *Evaluation of durability heavy metal adsorption*

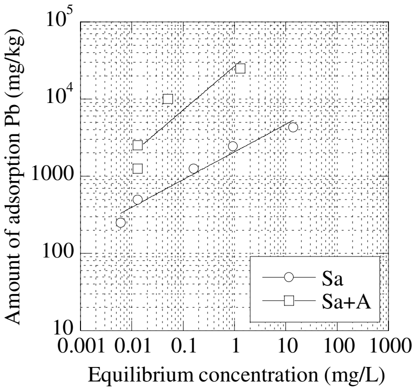

Figure 11. Results of equilibrium adsorption tests (Pb)

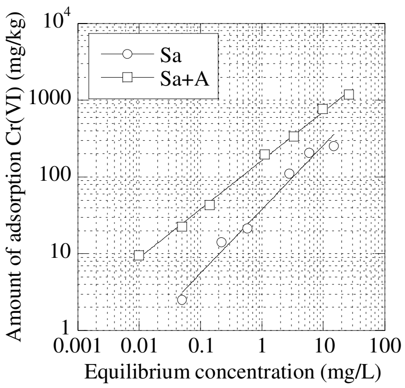

Figure 12. Results of equilibrium adsorption tests (Cr(VI))

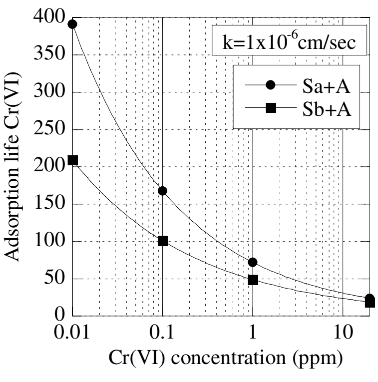

Figure 13. Relationship between Cr(VI) density and durable years

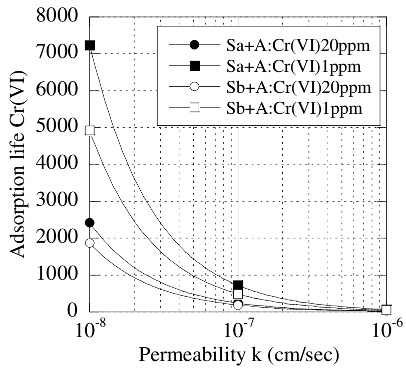

Figure 14. Relationship between Cr(VI) density and durable years

In order to confirm the effects of increase of heavy metal adsorption by using additive of seepage control material, equilibrium adsorption test was done by using Sludge A.

Figure 11 and 12 show the result of equilibrium adsorption tests of Pb and Cr(VI). Sludge A increases adsorption of Pb and Cr(VI) by adding additive. It was shown that additive is effective in an increase of heavy metal adsorption. Figure 13 and Figure 14 show the results from finding of durable years in case of using seepage control material at the disposal site considering the results from column tests for Sludge A and B with additive .As a result, regarding heavy metal adsorption, Sludge A is larger than Sludge B.

It can be said that each Sludge keeps enough heavy metal adsorption for more than 50 durable years if Cr(VI)density is below 0.1mg/L and the coefficient of permeability is below $1x10^{-6}$cm/sec. Considering this, heavy metal adsorption can be expected if required properties for the new seepage control material are satisfied.

7 CONCLUIONS

This paper concludes following points from the results of examination.

As trafficability of materials should be considered when we use dehydrated cake with initial high water content for the seepage control construction, we studied the effects of initial water content on trafficability.

New impervious material as a clay liner can satisfy its legal requirements, hydraulic conductivity of less than 1×10^{-6}cm/s.

Considering its permeability, compaction properties and a cone index of material in the optimum construction condition of new impervious material satisfies its legal requirement for final landfill site, we propose the execution management method.

The new impervious material has a vitality of heavy metal collecting ability.

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