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Feasibility Study on the Applicability of Fly Ash as a Barrier Material in Containment System

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요 약 문

In this study, the fly ash was employed as a possible alternative to the bentonite for its high sorption capacity against cationic heavy metal. To consider the constituents of barrier possibly used, the specimens were mixed with different material contents (fly ash : weathered soil : bentonite), then sorption test was performed. Also the specimens were molded on the wet side of optimum moisture contents like mixing ratio of sorption test and their hydraulic conductivities were measured in flexible-wall permeameters. And to confirm the effect of dissolved cations, the hydraulic conductivity tests were repeated by converting the permeant liquids from water to Cd^{2+}solution. Finally, the Cd-concentration at the effluent was analyzed for 500hrs to compare the effectiveness of each specimen in contaminant retardation. Test results showed that the more the ratio of fly ash increase, the more K_d value increase, and the hydraulic conductivity of weathered soil/bentonite (95:5) mixture was the lowest ($2.9*10^{-8}$cm/sec), and specimens made of fly ash and fly ash/weathered soil mixtures showed similar hydraulic conductivity. Although the permeant liquid was changed from water to Cd^{2+} solution, the hydraulic conductivity of all specimens except for weathered soil maintained similarly like before. Consequently, the initial breakthrough point of Cd in weathered soil specimen was observed at about 5hrs after the test started while that of fly ash specimens was not observed during the whole test period of 500hrs. The results implied that fly ash had a sufficient retardation capacity against contaminant transport possibly by its high sorption capacity although it showed little effect on the reduction of hydraulic conductivity. Based on the test results, it could be concluded that the fly ash can be possibly used as a suitable barrier material in containment system to attenuate the contaminant transport for its high retardation capacity and for the low cost.

key word : fly ash, containment barriers, hydraulic conductivity,

1.서론

The amount of fly ash, produced in thermal power plants throughout the world, dramatically increasing as advanced industrialization and most of the fly ash is disposed of by land filling. Every year, recycling rate of fly ash is gradually increasing, however the portion of land filling is as high as ever. In the future, considering difficulty of obtaining land space for disposal of fly ash and social and environmental problems, an exigent countermeasure for recycling fly ash is needed.

Investigation on an effort for recycling fly ash is continuously going on, especially fly ash has been applied to various geoenvironmental engineering partsuch as sorbent, soil improvement, neutralization of acidic waste water due to the characteristics of large specific area and cation exchange capacity (CEC).Also, fly ash is a fine-grained material that previous research has shown to have potential for constructing containment system (Edil et al). Previous containment system had prevented the contaminant leakage by its low hydraulic conductivity (below $1*10^{-7}$ cm/sec) obtained from bentonite contents in it. However, the cation-dissolved leachate could increase the hydraulic conductivity of bentonite-containing barrier by changing the thickness of the diffused double layer.

In this study the applicability of fly ash was estimated as a barrier material in containment system. To examine sorption capacity and the effect of fly ash contents on the hydraulic conductivity for the specimens mixed with different material contents, the sorption test and hydraulic conductivity test were performed, respectively. And to confirm the effect of dissolved cations, the hydraulic conductivity tests were repeated by converting the permeant liquids from water to Cd^{2+}solution. Finally, the Cd-concentration at the effluent was analyzed to compare the effectiveness of retardation capacity against contaminants.

2. 본론

2.1 Materials

2.1.1 Fly ash

Fly ash used in this experimentwas produced from Tae-an thermal power plant. The chemical composition property of the fly ash is given in Table 1. The predominant chemical constituents in the fly ash were silica, alumina, and iron. Calcium which has relation with pozzolanic reaction was present in low percentage.

Table 1: The predominant chemical constituents in the fly ash

sample	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	MgO	CaO	Na_2O	K_2O	MnO	P_2O_5	LoI	total
T flyash	51.88	23.37	0.89	8.68	1.55	4.46	0.59	1.13	0.06	0.8	5.74	99.15

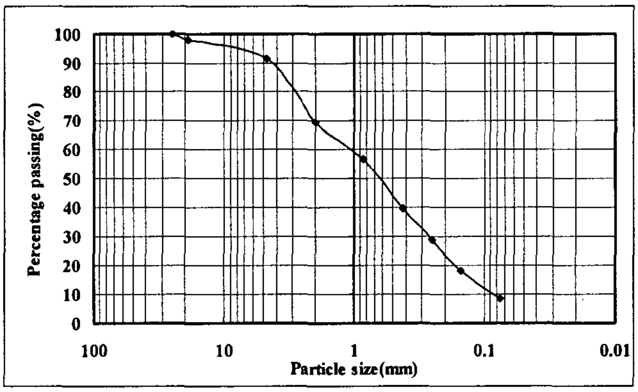
2.1.2 Soil

Soil was collected from the vicinity of a dormitory at Seoul National University. SNU soil is weathered granite soil which is commonly found around the Korea. Therefore, SNU soil is regarded as one of typical field soil types in Korea. SNU soil was classified as poorly graded sand (SP) under the Unified Soil Classification System. The physical properties of the SNU soil are given in Table 2 and the grain size distribution curve of the SNU soil is shown in Figure 1, and SNU soil passing the U.S. Standard No. 4 sieve is used in this study.

Table 2. The physical properties of the weathered soil

property	SNU soil
Specific gravity	2.61
Coefficient of gradation	0.88
Uniformity gradation	11.8
USCS	SP
Percentage passing sieve No.200 (0.075 mm)	8.2%

Figure 1 Particle size distribution of the weathered soil



2.1.3 Bentonite

Information on the physical properties of the sodium bentonite used in this experiment are given in Table 3.

Table 3: Physical properties of the sodium bentonite

Properties	Bentonite
Specific gravity	2.65
Liquid (%)	393
Plasticity Index (%)	351
Specific surface area (m^2/g)	42

2.2 Experiment Procedure

2.2.1 Sorption Test

To consider the constituents in barrier possibly usedduring in-situ construction, the specimens such as fly ash, mixture of fly ash and weathered soil (80:20, 60:40, 40:60), weathered soil/bentonite (95:5), weathered soil were mixed. And then a constant amount (3g) of specimens were mixed with 30ml solution in vial, which have the initial concentration, 20, 40, 80, 160, 320, 640, 1280, 2560, and 5120 ppm respectively, then the specimens were shaken for 24hrs.

2.2.2 Hydraulic Conductivity Test

To examine the effect of fly ash contents on the hydraulic conductivity, the specimens were molded on the wet side of optimum moisture contents like mixing ratio of sorption test. Afterwards, hydraulic conductivity tests were performed using flexible wall permeameters. Tap water was used as the permeant liquid. The applied pressure for confining specimens in the cell and injecting solution through the specimens were 10psi and 3psi, respectively. No backpressure was used. And to confirm the effect of dissolved cations, the hydraulic conductivity tests were repeated by converting the permeant liquids from tap water to Cd^{2+}solution (30ppm).

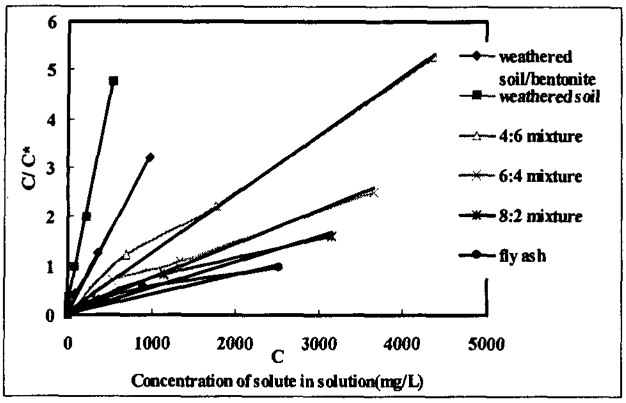
2.2.3 Leachate Effluent Analysis

All effluent samples from the specimens were collected in vial. And then the Cd-concentration at the effluent was analyzed with AAS (Atomic Absorption Spectrophotometer) to compare the effectiveness of each specimen in contaminant retardation.

2.4 Results and Discussion

2.4.1 Sorption Test

Figure 2: Linear Langmuir sorption isotherm with C/C* versus C.



The isotherm data in Figure 2 were well-described by the linear form of the Langmuir equation:

$$\frac{C}{C^*} = \frac{1}{\alpha\beta} + \frac{C}{\beta} \qquad (1)$$

Where α=an absorption constant related to the binding energy(L/mg)

β=the maximum amount of solute that can be absorbed by the solid(mg/kg)

Also the coefficient K_d is known as the distribution coefficient is given by:

$$\frac{\alpha\beta}{(1+\alpha C)^2} = K_d \qquad (2)$$

From this equation, K_d values of each specimen were calculated in table 4. Table 4 shows that K_d values of mixture containing fly ash even higher than that of weathered soil and weathered soil/bentonite (95:5) mixture also, the more the ratio of fly ash increase, the more K_d value increase. From this result, it is expected that fly ash effectively attenuate contaminants transport for its high sorption capacity.

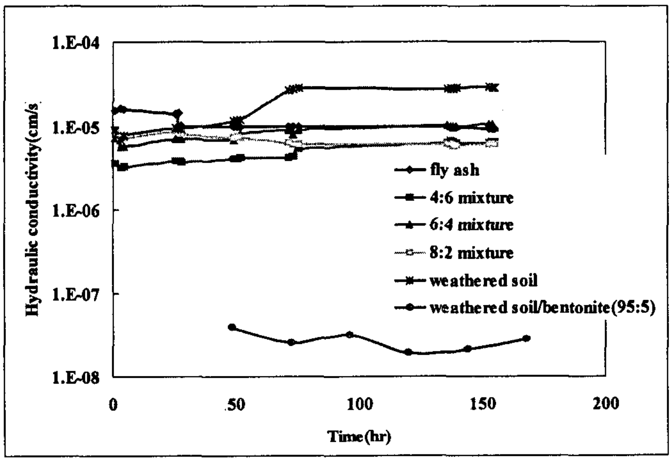
Table 4. The K_d values of each specimen

Specimen	K_d (μg/g)
Weathered soil	0.92
Weathered soil/bentonite (95:5)	1.83
Fly ash/weathered soil (40:60)	6.63
Fly ash/weathered soil (60:40)	9.08
Fly ash/weathered soil (80:20)	13.54
Fly ash	16.19

2.4.2 Hydraulic Conductivity Test

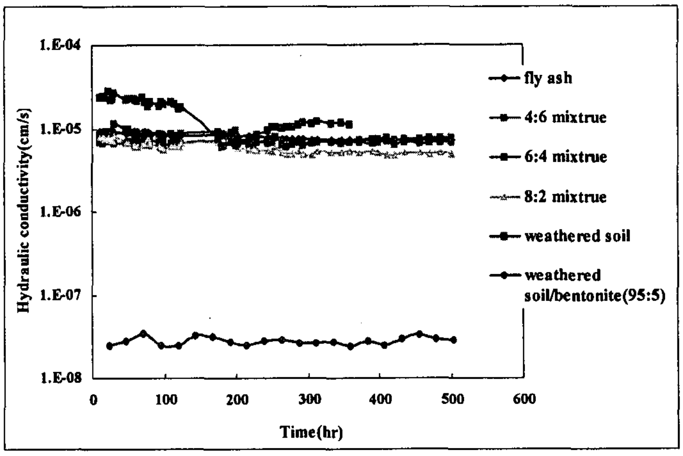
For tap water permeation, hydraulic conductivity of specimens is shown Figure 3. None of the hydraulic conductivities are less than typically required maximum for liners, $1*10^{-7}$cm/s except for weathered soil/bentonite (95:5) mixture ($2.9*10^{-8}$cm/sec). As the ratio of fly ash increase, the hydraulic conductivity shows gradually decreasingtrend due to cementation reaction. However the effect on hydraulic conductivity was not significant. And for fly ash/weathered soil mixtures, their hydraulic conductivity was very similar irrespective of the ratio of weathered soil.

Figure 3: Hydraulic conductivity for permeating tap water



As a result, it could be concluded that the addition of weathered soil doesn't affect the reducing hydraulic conductivity. When the permeant liquid was changed from water to Cd^{2+}solution, the results were shown Figure 4.

Figure 4: Hydraulic conductivity for permeating Cd^{2+}solution

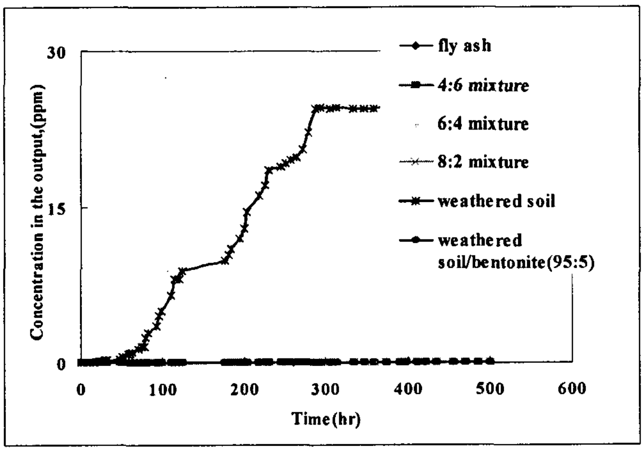


Hydraulic conductivity of all specimens except for weathered soil specimen maintained similarly like before. Especially hydraulic conductivity of weathered soil/bentonite (95:5) mixture was not increased although Cd^{2+}solution permeated. It could be considered that cation-dissolved permeant liquids had little effect on changing particle structure having relation with diffused double layer. And for weathered soil/bentonite (95:5) mixture, the result is possibly attributed to its significantly lower hydraulic conductivity that only about 1.5 pore volumes of Cd^{2+}solution passed through the specimen. Also, the concentration of Cd^{2+}solution used in this experiment is very low to replace Na^{+} in bentonite by Cd^{2+} for a short time. Therefore the bentonite probably had not fully reacted with the Cd^{2+}.

2.4.3 Leachate Effluent Analysis

The concentration versus time relation of the outflow, known as the breakthrough curve, is shown in Figure 5. For weathered soil, the breakthrough point (0.01ppm:ground water level) was observed at about 5hrs after injecting Cd^{2+}solution. While breakthrough point of mixtures containing fly ash was not observed for 500hrs. The result implied that fly ash had a sufficient retardation capacity against contaminant transport possibly by its high sorption capacity, although it showed little effect on the reduction of hydraulic conductivity. Also that of weathered soil/bentonite (95:5) mixturewas not observed like below.

Figure 5: The concentration versus time relation of the outflow



In the field, considering the seepage velocity of groundwaterand hydraulic gradient, contaminants transport will be even more retarded for a long time. However, in case of using bentonite as a barrier material, continuously permeation of contaminants through bentonite slurry wall can lead to an increased hydraulic conductivity and a piping failure[3]. In addition, the material cost for bentonite could increase the overall construction cost for the system.

In this overall perspective, fly ash could be possibly used as a suitable barrier material in containment system to attenuate the contaminant transport for its high retardation capacity and for the low cost However,to suggest the better result, it is necessary to compare the full breakthrough curve of weathered soil/bentonite (95:5) mixture and fly ash.

3. 결론

The objective of this study was to investigate the possible use of fly ash as a barrier material in containment system. The result of sorption test showed that sorption capacity of weathered soil was ignorable and that of weathered soil/bentonite (95:5) is higher than the weathered soil. While the mixtrues containing fly ash showed high sorption capacity by removing a large amount of Cd for initial concentration respectively, also the ratio of fly ash increase, the K_d value is gradually increasing.

When the specimens were permeated with tap water, hydraulic conductivity of the weathered soil/bentonite (95:5) mixture was the lowest ($2.9*10^{-8}$cm/sec). And for fly ash/weathered soil mixtures, their hydraulic conductivity was very similar irrespective of the ratio of weathered soil. Therefore, the addition of weathered soil had little effect on the reducing hydraulic conductivity.

When the permeant liquid was changed from water to Cd^{2+}solution, hydraulic conductivity of all specimens except for weathered soil maintained similarly like before. Because cation-dissolved permeant liquids didn't affect the changing particle structure having relation with diffused double layer, and for weathered soil/bentonite (95:5) mixture, hydraulic conductivity is significantly low and there is not enough Cd^{2+} to replace Na^{+} due to low permeant liquid concentration (30 ppm).

Finally, for weathered soil, breakthrough point was observed at about 5hrs after injecting Cd-solution. While that of mixtures containing fly ash was not observed for 500hrs, although hydraulic conductivity is similar with weathered soil. Also that of weathered soil/bentonite (95:5) mixture was not observed like above. To get the precise result, it is necessary to compare the full breakthrough curve of weathered soil/bentonite (95:5) mixture and fly ash. However, considering for its high retardation capacity and for the low cost fly ash could be possibly used as a suitable barrier material in containment system.

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